University of Southampton

Faculty of Social Sciences

School of Economic, Social and Political Sciences

Adolescent Childbearing and Schooling in Latin America and the Caribbean

Using population data to demystify a demographic puzzle of continuity and change

by

Ann Garbett

ORCID ID 0000-0002-0063-1529

Thesis for degree of Doctor of Philosophy

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Abstract

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Adolescent childbearing in Latin America and the Caribbean is a demographic puzzle. High rates of teenage childbearing in the region exceed global trends when compared against countries with similar development profiles. Additionally, the region's high levels of adolescent fertility have persisted over the region's dramatic schooling expansion, which usually occurs alongside postponements to entry into motherhood. This thesis examines patterns of continuity and change in adolescent childbearing in Latin America and the Caribbean through a collection of three research papers. The research begins with a broad, aggregate view and narrows progressively into smaller geographic areas and more nuanced relationships.

The first paper looks at country-level educational differentials in parity-specific adolescent fertility in six countries over the last half-century. It explores the high-level picture of long-term, parity-specific trends in a diverse set of countries from Central and South America and the Caribbean. Namely, it looks at Colombia, the Dominican Republic, Guatemala, Haiti, Mexico and Peru. The analysis offers a comprehensive demographic accounting of how the region has maintained such high levels of adolescent fertility in the face of dramatic schooling improvements.

The second paper narrows focus onto adolescent childbearing trends in Mexico over the last quarter-century. The paper estimates municipal age- and parity-specific adolescent fertility levels, and examines patterns of subnational variation, which reveal considerable and important differences that have heretofore remained unseen. Importantly, the study highlights the childbearing trends of the youngest adolescents (those 14 years and younger) for whom estimates have not been seen before.

The third paper dives deep into Mexico as a case study to look at the individual adolescent girl, and how the broader context around her shapes her risk of entering motherhood in adolescence. The analysis focuses on evidence for the changing importance of context over the adolescent age schedule. That is, after accounting for individual characteristics that are markers for adolescent fertility risk (such as school dropout), it examines whether the broader childbearing patterns of a girl's adolescent peers matter for her likelihood of having a first or second birth in adolescence—and whether the importance of context changes in magnitude at distinct adolescent ages.

The three papers shed important light on the puzzle of adolescent childbearing in Latin America and the Caribbean by unpacking trends into schooling- or parity-specific patterns and investigating trends among the youngest adolescents. Together, the studies bring needed visibility to childbearing patterns among the region's youngest and most vulnerable mothers.

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Declaration of Authorship

Name: Ann Garbett

Title of thesis: Adolescent Childbearing and Schooling in Latin America & the Caribbean: Using population data to demystify a demographic puzzle of continuity and change

I declare that this thesis and the work presented in it is my own and has been generated by me as the result of my own original research. I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

Signature: Date:

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Abbreviations

ASFR 15-19	Age-specific fertility rate for women aged 15-19 years
CONAPO	National Population Council
ENAPEA	National Strategy for the Prevention of Adolescent Pregnancies
EZLN	Zapatista National Liberation Army
MOR	Median odds ratio
NAFTA	North Atlanctic Free Trade Agreement
NCRM	National Centre for Research Methods
NEET	Not in employment, education or training
OECD	Organization for Economic Cooperation and Development
REML	Restricted maximum likelihood
UNFPA	United Nations Population Fund
VPC	Variance partition coefficient

Chapter 1

Introduction

1.1 Synthesis

This thesis examines the changing patterns of adolescent fertility and schooling in Latin America and the Caribbean through a collection of three research papers. The research begins with a broad, aggregate view and narrows progressively into smaller geographic areas and more nuanced relationships.

1.1.1 Paper 1

The first paper looks at country-level educational differentials in parity-specific adolescent fertility in six countries over the last half-century. It explores the high-level picture of long-term trends in a diverse set of countries from Central and South America and the Caribbean. Namely, it looks Colombia, the Dominican Republic, Guatemala, Haiti, Mexico and Peru. The analysis offers a comprehensive demographic accounting of how the region has maintained such high levels of adolescent fertility in the face of dramatic schooling improvements and rapid declines in total fertility. The long-term perspective and focus on parity-specific change along with a detailed separation of all possible schooling levels—including dropouts and graduates at each relevant level—make this research unique. To be clear, the aim of the analysis is to detail the evolution of schooling- and parity-specific population patterns in adolescent fertility over the course of five decades in the six countries in Latin America & the Caribbean where data make this possible. To undertake this aim, the study follows several core research objectives:

(1) Examine the details of each country's schooling expansion in terms of the eight schooling levels of interest.
(2) Explore changes in parity progression ratios for first, second and third birth in adolescence both at the population level and within each schooling level.

(3) Explore changes in cumulative adolescent childbearing at the population level and each schooling level.
(4) Explore changes in the mean age at first adolescent birth at the population level and each schooling level.
(5) And finally, explore changes in the timing of adolescent pregnancies in relation to the timing of school leaving.

The methods employed to explore these research objectives differ in their details but share the same overarching principles. As a starting point, each analysis employs regression models rather than simply producing proportions and averages directly from the data. It does so to be able to (1) smooth out the considerable statistical noise that would result from year-on-year changes in the many educational divisions examined, (2) to be able to make verifiable evaluations of whether the many educational divisions are in fact statistically distinct from each other, (3) to be able to model nonlinear change over time where it has occurred. The specific types of regression analysis include semiparametric generalized additive models, logistic binomial regressions, and Poisson regressions.

1.1.2 Paper 2

The second paper narrows focus onto subnational trends in a single country over the last two decades. In a variety of measures—including adolescent fertility, economic indicators and education rates—Mexico sits comfortably at the regional average, yet high levels of inequality (also very characteristic of Latin America and the Caribbean) mean that Mexico's subregions span a diverse continuum of development. Southern states in Mexico lag far behind the rest of the country and, in many ways, are similar to their poorer central American neighbours. Mexico City and the country's northern states, in contrast, have much higher levels of development than the rest of the country. However, these differences in socio-economic development do not correspond neatly with levels of adolescent fertility, as would be expected. As such, the paper's examination of subnational variation in adolescent fertility reveals considerable and important differences in medium-term parity-specific adolescent fertility trends, which have heretofore remained unseen. Importantly, it highlights the childbearing trends of the youngest adolescents (those 14 years and younger) for whom estimates have not been seen before. There is only a small body of literature looking at sub-national trends in adolescent fertility in any country in Latin America and the Caribbean, which adds to the value of this research chapter.

In other words, the study aims to estimate subnational parity-specific fertility at all adolescent ages as well as their trends over time. That is, it explores whether Mexico's municipal estimates follow the same pattern seen at the national level of stagnant first births and declining second births or whether the national patterns mask underlying subnational complexity. Importantly, the parity-specific estimates offered by this research include fertility of the youngest adolescents, or girls aged fourteen and younger. Again, early adolescent ages are ignored in existing municipal $ASFR_{15\text{-}19}$ measures.

To underake this aim, the study follows several core research objectives:

(1) Estimate the proportion of adolescents within each municipality with a first birth at all adolescent ages from 1990 to 2015.
(2) Estimate the proportion of adolescents within each municipality with a second birth at all adolescent ages from 1990 to 2015.
(3) Estimates adolescent progression ratios, or the proportion of girls with a first birth who have a second birth in adolescence in all municipalities from 1990 to 2015.
(4) Explore patterns of change over time and by geography in the estimates.

The study uses multilevel regression models to achieve these research objectives. Multilevel models are a powerful statistical tool used for a variety of purposes. This study exploits multilevel models not for their powerful explanatory purposes but rather for their ability to improve the reliability of estimates based on small numbers of observations. Without the models to, implausibly high and low estimates of the proportions of adolescents with births in the raw data would be common simply due to random chance. Raw estimated proportions of adolescent fertility at ages fourteen or younger, for instance, would be particularly variable and unreliable.

1.1.3 Paper 3

The third paper dives even deeper into Mexico as a case study to look at the individual adolescent girl, and how the broader context around her shapes her risk of entering motherhood in adolescence. The analysis focuses on evidence for the changing importance of context across the adolescent age schedule in teenage childbearing. That is, after accounting for individual characteristics that are markers for adolescent fertility risk (such as school dropout and poverty), it examines whether the broader childbearing patterns of a girl's adolescent peers matter for her likelihood of having a first or second birth in adolescence—and whether the importance of context changes in magnitude at distinct adolescent ages. In recent years, interest in very early adolescent fertility has grown. Evidence is emerging that the childbearing among the youngest has been particularly resistant to change , and there is unfolding qualitative recognition that early adolescent fertility arises from different contexts and causes, as well as requires distinct interventions, than does fertility among older adolescents (Álvarez Castaño 2015; Garbett, Perelli-Harris, and Neal 2021; Meneses and Ramírez 2018). To my knowledge, no other quantitative evidence exists for the phenomenon of the changing importance of context in adolescent fertility risk across the adolescent age schedule or how it differs according to a girl's position of relative deprivation. For example, if a girl is out of school in an area where most of her peers are in school, her relative position of deprivation differs from that of a girl with similar characteristics who is out of school in an area where most of her peers are also not attending school.

To be specific, the aim of this study is to explore evidence for the existence of quantifiable contextual phenomena in adolescent fertility. That is, the study explores whether girls with similar socio-economic characteristics have different probabilities of experiencing a birth in adolescence based on whether they live in one place or another, as well as whether girls with differing characteristics but living in the same area have more similar probabilities of adolescent fertility than girls living elsewhere.

The research is approached in stages, using multilevel logistic hierarchical regression analysis to explore adolescent childbearing in Mexico, an upper-middle income country with comparatively high levels of adolescent childbearing. Multilevel regressions are particularly powerful for investigating contextual effects, which manifest as patterns of clustering and variation in the data (Snijders and Bosker 2012). Several research objectives explore the research aim in stages. These objectives include:

(1) Investigate whether there is in fact clustering in the data. Specifically, clustering within Mexican municipalities, which is indicative of the existence of a possible contextual dimension to adolescent fertility.
(2) Investigate to what extent municipal-level differences in the incidence of adolescent fertility are explained by the composition of municipalities' adolescent population. That is, the clustering of adolescent fertility within areas may simply reflect the varying composition of the population in terms of their individual characteristics, with some municipalities having much higher concentrations of out-of-school youth or more households in poverty and thus higher adolescent fertility for example. It also explores how the association between individual characteristics and adolescent fertility depend on an adolescent's relative disadvantage or advantage to her peers.
(3) Explore whether the importance of contextual phenomena differ in magnitude for different groups of girls. For example, whether the influence of context is greater for younger adolescents than it is for older adolescents or greater for girls who are in school compared to girls who are out of school.
(4) Explore whether the fertility of an adolescent's peers forms a quantifiable part of the observed contextual phenomena. Additionally, examine whether the association between the fertility climate prevailing among an individual girl's peers and the girl's own individual fertility likelihood is modified according to the girl's age. That is, whether the importance of the adolescent fertility context differs across the adolescent age schedule.

1.1.4 A common thread

This introductory chapter sets the stage for this thesis' focus on schooling and adolescent fertility, or childbearing among females aged 10 to 19, in Latin America and the Caribbean. The review begins with a discussion of why high rates of adolescent fertility in Latin America and the Caribbean are so puzzling given the region's decades of impressive schooling expansion and total fertility decline. Next, a summary of Latin America and the Caribbean's patterns of adolescent sexual activity, contraceptive use and union formation provides context before taking a step back to explore what the evidence says about why adolescent fertility is problematic. After adding nuance from causal research, the discussion turns to the considerable global concern about adolescent fertility in the region and elsewhere.

The introductory chapter then turns to theoretical and empirical perspectives on the connection between schooling and fertility in demographic research. In the absence of existing theory, it draws heavily from empirical work that finds that programs that keep girls in school, or help them return to school after a birth, reduce adolescent fertility. Ultimately, this thesis frames its examination of the connection between adolescent schooling and fertility into enrolment and aspirational changes. Enrolment represents the time adolescent girls spend enrolled and present at school, and aspirations reflect the new life ambitions and plans that can arise from schooling.

This thesis' three papers use population data to examine distinct manifestations of continuity and change. The first study's long-term, high-level view adds grounding and perspective to the region's adolescent fertility puzzle. Underlying apparent stagnation in the proportion of women entering motherhood in adolescence is dramatic change in the risk at specific schooling levels. The second study's reveals that although national patterns might appear rather stagnant, they can mask considerable underlying complexity and diversity in subnational trends. Finally, the third paper dives deep into the experience of the individual girl to discover how the importance of context changes over the course of adolescence. Across all studies, a focus on parity-specific change and attention to the childbearing of the youngest (who are often otherwise excluded from other analyses and estimates) makes the research contribution and policy relevance of this thesis particularly powerful.

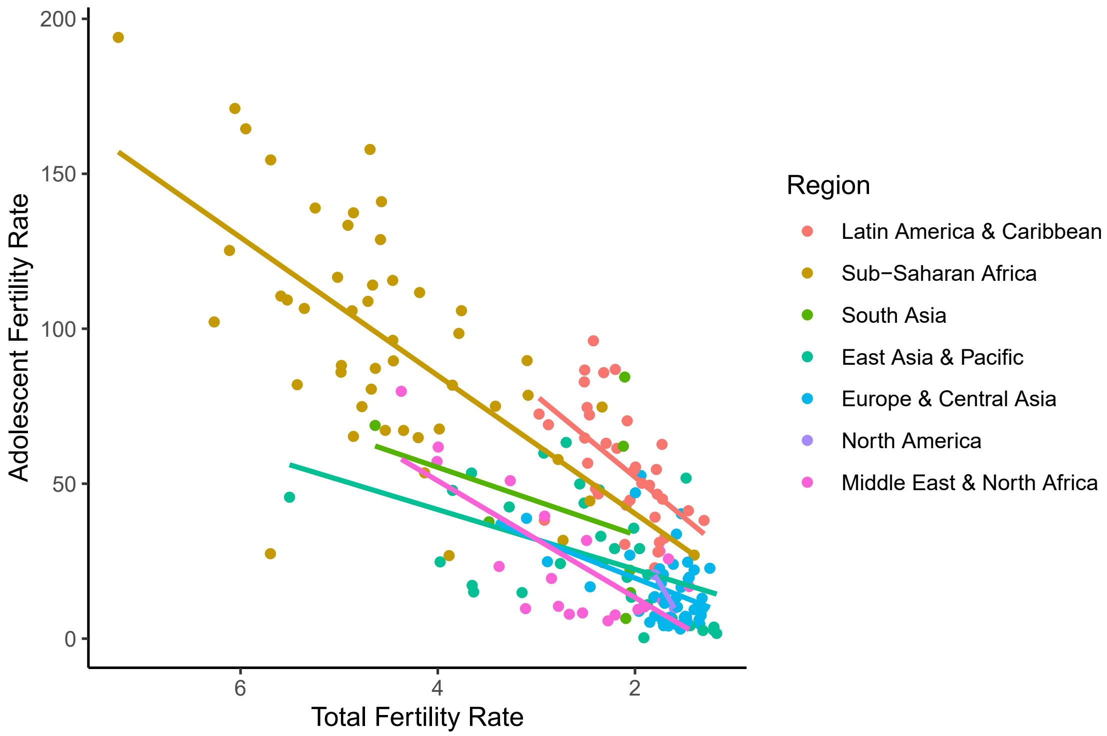
1.2 Adolescent fertility

1.2.1 The enigma of Latin America's adolescent fertility

Adolescent fertility, or childbearing among females aged 10 to 19, in Latin America and the Caribbean is a demographic puzzle. High rates of teenage childbearing in the region exceed global trends when compared against countries with similar total fertility rates. To illustrate, Figure

1.1 plots country-specific total fertility rates against age-specific fertility rates for adolescents aged 15 to 19 years with regional linear ordinary least squares regression trendlines. Latin America and the Caribbean's trendline, which sits higher than any other region, depicts how its adolescent fertility rate is much higher than that of other regions at similar levels of total fertility. Though several individual countries, particularly in parts of Africa, have higher rates of adolescent fertility, the countries also have much higher total fertility than countries in Latin America and the Caribbean. In the countries with total fertility rates of three or fewer children per woman (rates comparable to those in Latin America and the Caribbean), adolescent fertility is lower, as indicated by the lower regional trendlines. Other research finds similar anomalies when looking at the association between economic indicators and adolescent fertility as well (Azevedo et al. 2012).

Figure 1.1: Country-specific total fertility and adolescent fertility rates with regional trendlines



Source: (World Bank, 2019b)

Women in Latin America and the Caribbean today have on average two children (World Bank 2019d), and the fertility schedule follows a pattern of early starting and early stopping. This contrasts with most European and other high-income countries' fertility schedules, where low fertility is closely tied to childbearing initiation at increasingly older ages, as well as with many African schedules of high fertility characterised by early initiation and limited stopping (Alves and Cavenaghi 2009). As such, adolescent fertility accounts for a considerable share (15%) of total fertility in the region, and in some countries this share reaches 20%, or one out of every five births occurring to an adolescent mother (Benova et al. 2018). This is higher than any other region: adolescent fertility in Africa accounts for 10% of total fertility; in Europe and Asia, the shares are 5% and 7%

respectively (United Nations DESA 2015b).

That is, in Latin America and the Caribbean, fertility transitions have occurred largely without widespread childbearing postponement, having instead depended on family size limitation (Cavenaghi and Diniz Alves 2011; Esteve, Lopez-Ruiz, and Spijker 2013). Importantly, stagnant age trends in the timing of motherhood entry in the region were initially misinterpreted as no change, but more recent research discovers an ever-widening age gap, or a bimodal fertility divide, between the childbearing postponement of the most advantaged socioeconomic groups and the adolescent motherhood of their less privileged peers (Bozon, Gayet, and Barrientos 2009; Cavenaghi and Diniz Alves 2011; Esteve, Lesthaeghe, and López-Gay 2012; Esteve, Lopez-Ruiz, and Spijker 2013; Lima et al. 2018; Nathan 2015; Nathan, Pardo, and Cabella 2016; Rosero-Bixby, Castro-Martín, and Martín-García 2009).

The persistently young age schedule of fertility is particularly peculiar considering the region's impressive schooling expansion. Evidence from across the globe finds that educational expansions generally contribute substantially to childbearing postponement (Lam and Duryea 1999; Liefbroer and Corijn 1999; Monstad, Propper, and Salvanes 2008; Neels et al. 2017; Neels and De Wachter 2010). Interestingly, in the early stages of Latin America and the Caribbean's demographic transitions, education differentials in realised fertility, but not necessarily desired fertility, were among the largest in the world (Caldwell 1980; Cleland and Wilson 1987; Weinberger, Lloyd, and Blanc 1989). Today, education differentials in adolescent fertility in the region are greater than differences in total fertility (Rodríguez Vignoli 2014a). While schooling expansion seems an important component of overall fertility decline in Latin America and the Caribbean (Martin 1995), its long-term role in changes in the timing of fertility, particularly for adolescents, remains unclear.

Recent research also suggests that in the aggregate, only higher-order adolescent births have declined, not the proportion of women entering motherhood in adolescence in Latin America and the Caribbean (Berquó and Cavenaghi 2005; Cavenaghi and Diniz Alves 2011; Lima et al. 2018; Neal et al. 2018; Rodríguez Vignoli 2014a; Velarde and Zegers-Hochschild 2017). Much of the research describing the drivers of sustained adolescent childbearing in Latin America and the Caribbean indicates that increasing rates of adolescent sexual activity and union formation—in terms of higher proportions of adolescents engaging in sexual activity and forming unions, as well as initiating sexual activity and forming unions at younger ages—has not been offset by sufficient increases in adolescent contraception (Ali, Cleland, and Shah 2003; Cavenaghi and Diniz Alves 2009; Flórez and Soto 2013; Heaton, Forste, and Otterstrom 2002; Rodriguez 2013). Indeed, many adolescents do not use any contraception until after the birth of their first child (Di Cesare and Rodríguez Vignoli 2006; Esteve Palós and Florez-Paredes 2014; Rodríguez Vignoli 2014a). While access to and knowledge of contraception in in the region is regarded as near universal—with some of the highest contraception use rates in the world (Cavenaghi and Diniz Alves 2011)—adolescents still face considerable access barriers.

In essence, the structural changes and programs that have contributed to substantial declines in total fertility in Latin America and the Caribbean have not successfully translated to changes in fertility at the youngest ages (Comisión Económica para América Latina y el Caribe 2012).

1.2.2 What we know about adolescent fertility in Latin America and the Caribbean

A large body of demographic research on adolescents in Latin America and the Caribbean looks at changing patterns of adolescent sexual activity, contraceptive use and union formation. The findings suggest that increasing rates of adolescent sexual activity and union formation—in terms of higher proportions of adolescents engaging in sexual activity and forming unions, as well as initiating sexual activity and forming unions at younger ages—have not been offset by sufficient increases in adolescent contraception (Ali, Cleland, and Shah 2003; Bongaarts, Mensch, and Blanc 2017; Cavenaghi and Diniz Alves 2009; Flórez and Soto 2013; Heaton, Forste, and Otterstrom 2002). Interestingly, recent findings from the United States suggest that trends of earlier sexual debut do not always translate to increased adolescent fertility, but other socio-economic factors matter more than age in differentiated behaviours after sexual debut, such as differences in contraception use and frequency of sexual activity (Wu and Martin 2015).

Although Latin America and the Caribbean, as a region, has some of the highest use of modern contraception in the world (United Nations DESA 2015a), use rates among adolescents are manifestly low. One recent paper estimates that half of women with a birth before age 18 in a dozen countries in the region had not used any contraceptive method before the birth of their first child (Esteve Palós and Florez-Paredes 2014). In fact, the low contraceptive use rate among adolescents prior to a first birth is so pervasive that measures of contraception among adolescents often show a contradictory association of higher use rates coinciding with higher pregnancy rates (Rodríguez Vignoli 2014a). Low use rates among adolescents seem to be more often due to lack of planning, problematic social norms and misinformation than to inaccessibility. For example, adolescents often say they were not expecting to have sex so they had not planned contraception. In other cases, adolescents often say they know where, why and how to access contraception but then describe a variety of social stigmas that prevent them from acquiring it or negotiating its use with their partners (Gutiérrez et al. 2012; Instituto Nacional de Estadística y Geografía 2009). Likewise, there are mistaken but common beliefs about adolescent pregnancy risk, such as the idea that it is impossible to become pregnant at first sex (Rodríguez Vignoli 2014a). Among adolescents who use contraception, high levels of ineffective use, or contraceptive failure, only add to the prevalence of unintended adolescent pregnancies (Flórez and Soto 2007; Parada Rico 2011).

Past research often connected low rates of adolescent contraception in Latin America and the Caribbean to high levels of wantedness of adolescent pregnancies along with strong cultural expectations of early motherhood. However, the argument seems to be losing ground both because the share of adolescent pregnancies that are unintended is rapidly increasing and because there is growing recognition that it is difficult to measure the wantedness of a specific birth, particularly among women who have not yet obtained their total desired lifetime fertility (Flórez and Soto 2007; Rodríguez Vignoli 2014a; Vignoli 2017). Moreover, though abortion is illegal in the majority of Latin American and Caribbean countries (Guttmacher Institute 2017; Kulczycki 2011), estimates suggest that the region has a higher reliance on unsafe abortions among pregnant adolescents than Africa or Asia (Shah and Åhman 2004).

Having a partner dramatically heightens the risk of adolescent fertility and, conversely, becoming pregnant intensifies transitions to union formation (Grace and Sweeney 2014). Adolescent pregnancy rates are higher for those who have formed a union than those who have initiated sex but not formed a union (Covre-Sussai et al. 2015; Flórez and Soto 2013). In much of the region, the mean age of union formation has decreased, except among the most educated, with increasing rates of cohabitation more than offsetting declines in marriage (Castro Martin 2002; Castro Martín et al. 2011; Núñez and Flórez 2001). Relatively modest increases in adolescent fertility outside of a union have been found mostly among the oldest adolescents and those from the higher socio-economic strata (Flórez 2005; Flórez and Soto 2007; Núñez and Flórez 2001), who are also more likely to live in extended or composite households that provide more support for coping positively with single motherhood (Esteve, García-Román, and Lesthaeghe 2012).

For some time, research examined the early age trends in fertility in Latin America and the Caribbean at aggregate levels, which masked underlying disparities that have recently gained visibility. Stagnant aggregate-level ages in fertility timing were previously misinterpreted as no change, whereas now, a more nuanced look, finds an ever-widening gap. The increasingly disparate age schedule of fertility is now often identified as Latin America and the Caribbean's bimodal fertility regime (Alves and Cavenaghi 2009; Bozon, Gayet, and Barrientos 2009; Esteve et al. 2013; Esteve, Lesthaeghe, and López-Gay 2012; Lima et al. 2018; Nathan 2015; Nathan, Pardo, and Cabella 2016; Rosero-Bixby, Castro-Martín, and Martín-García 2009). The bimodal fertility research generally finds that all socio-economic groups but the most advantaged are initiating childbearing at ever younger ages, and women in the highest socio-economic group are progressively postponing childbearing to older ages, though with some nuance to this dichotomous simplification. For example, Neal et al. (2018) find no clear overarching pattern of change in adolescent fertility across the five Latin American and Caribbean countries in their comparison. While rural and poor women continue to have the highest incidence of adolescent fertility, rates of change can vary in surprising ways—with, as an example, the incidence increasing in urban settings and declining in rural contexts in some places.

The polarisation in the region's age schedule of fertility timing is more pronounced than other bimodal fertility schedules ever have been in Europe and North America (Chandola, Coleman, and Hiorns 1999, 2002; Lima et al. 2018; Sullivan 2005). Furthermore, the bimodality mirrors earlier findings that the region's education differentials in the quantum of fertility have consistently been the largest of any other world region (Rutstein 2002). Many authors argue the bimodal fertility schedule is a newfound manifestation of the deeply entrenched socio-economic inequalities that have long characterised the region.

Another recent discovery in Latin America and Caribbean adolescent fertility research reveals that, after the increases seen through the 1990s, the declines in rates from the 2000s are not a reflection of the declining proportion of adolescents entering motherhood, as was originally hoped, but rather a reflection of declines in higher-order births in adolescence (Alves and Cavenaghi 2009; Lima et al. 2018; Neal et al. 2018; Velarde and Zegers-Hochschild 2017). In countries with signs of declining adolescent age-specific fertility, rates among the youngest and the most vulnerable (including those from the poorest regions, lower wealth quintiles and among rural and ethnic groups) have seen increases, or at best, smaller declines than among older adolescents (Álvarez Castaño 2015; Berquó and Cavenaghi 2005; Neal et al. 2018; Rodríguez Vignoli 2014b; Rodríguez Vignoli and Cavenaghi 2014). In summary, early union formation and early sexual activity with low levels of contraceptive use perpetuate high levels of adolescent fertility among more disadvantaged adolescent women in Latin America and the Caribbean, which contrasts strikingly with the increasing postponement of fertility and union formation as well the higher rates of contraceptive use among the most advantaged women.

1.2.3 What is the problem with adolescent fertility anyway?

Given the considerable research interest in adolescent fertility around the world, how solid is the evidence that early fertility is indeed harmful? The central question may well be whether a teenage birth causes adverse life outcomes or is instead the consequence of pre-existing adverse circumstances. Put differently, because teenage mothers most often come from situations of social and economic disadvantage, it is rather difficult to determine whether preventing a birth to such an adolescent, without changing anything else about her, would improve her life chances. A birth (or its absence) cannot be assigned randomly among adolescents of similar backgrounds with the consequences then observed over time, and because adolescents who 'select' into teen births differ by characteristics that also impact later life chances, statistical methods used to describe consequences rather than just correlations must account for these fundamental differences, no matter if the differences are observed or unobservable in the data.

In the United States, where causal research on adolescent fertility is perhaps the most developed—likely because the country's high rates of teenage pregnancy have long been of public concern—three innovative, influential studies emerged in the 1990s that cast doubt on the certainty of the negatives of adolescent fertility described by research up to that point. Prior to the 1990s, research was largely correlational, giving evidence that adolescent fertility occurs most often in conjunction with poorer economic, educational and other life markers, but unable to say whether adolescent fertility actually led to the unfavourable outcomes. I summarise the three influential studies here because their clever designs helped overshadow other methodological shortcomings, so much so that they continue to be cited as evidence against concern for adolescent fertility. Hoffman (1998) provides a more technical and comprehensive review of the issues mentioned here.

The novel studies (1) compared sisters with and without teen births (Geronimus and Korenman 1992), (2) adolescents with and without miscarriages (Hotz, Mullin, and Sanders 1997), and (3) adolescents with twin births compared to singleton births (Bronars and Grogger 1994; Grogger and Bronars 1993). In concept, the studies aimed to model causal effects by approximating random selection (into miscarriage or not, or twin birth or not) or by better accounting for unobservable family effects (sister comparison). These studies estimated that the negatives caused by adolescent births were much reduced when compared to correlational studies — even those with abundant controls.

However, despite their creativity, the papers were not without flaws. The miscarriage study's sample size was exceptionally small, and many of the teens went on to have successful adolescent births after their initial miscarriage, which invalidates the comparison between the teens with miscarriages and those without. The authors did not acknowledge this. For the twin births study, its relevance to all adolescent fertility only holds if having a twin teen birth has double the costs in both time and resources as a singleton birth. The authors included evidence in their paper that economies of scale exist for twin births and as such suggest their findings are not generalizable to comparisons of the effects of a teen birth compared to no teen birth. Finally, soon after the sister comparison was published, Hoffman and others (Hoffman, Foster, and Furstenberg 1993) replicated the research in a re-analysis using additional, more extensive datasets and found significant negative effects, as opposed to the original sister study which found no effect. The difference it seems was that the original sister study was comparing teen mothers with the less successful older sisters who were still at home rather than more successful sisters who had already graduated from the parental home. The new data sets allowed comparisons with broader groups of sisters.

At the time of publication of the three studies, policy initiatives and government expenditure to reduce teenage fertility in the United States were at their height and the findings made big waves. Today, after continued advances in research, it is widely believed that while adolescent fertility does not automatically spell catastrophe, it does have negative consequences.

Many studies on the effect of adolescent fertility have followed, with ever-growing emphasis on developing methodologies to disentangle causal outcomes from selection effects. Longitudinal data has been key. The bulk of the research finds that while the economic, educational and public benefit consequences of teen fertility are more often negative than not, the intensity of the negatives can vary considerably. For the economic consequences, teen fertility will often increase the likelihood of a woman being in employment in the early years following an adolescent birth, but she misses out on returns to her work experience so that, later in life, she has lower wages than women from comparable backgrounds without teen births (Klepinger, Lundberg, and Plotnick 1999; Taniguchi 1999). Adolescent fertility limits schooling attainment, which explains some of the cause of lower wages, but not all of it (Kane et al. 2013; Klepinger, Lundberg, and Plotnick 1995; Lee 2010; Schulkind and Sandler 2019). Additionally, adolescent fertility increases the likelihood and the amount of public benefits received (Bronars and Grogger 1994; Hoffman and Maynard 2008; Lee 2010).

Research often finds variability in the intensity of the consequences when looking at specific subpopulations, for example there are differences by racial and ethnic identity in the United States. There seem to be greater and more persistent negative consequences to the groups of women who are most disadvantaged from the outset, and the magnitude of the consequences can be masked when, consequences to blacks for example, are not separated from the often less negative consequences to whites, who generally have more resources with which to cope positively with the challenges of adolescent births (Bronars and Grogger 1994; Klepinger, Lundberg, and Plotnick 1995; Klepinger, Lundberg, and Plotnick 1999).

The adverse consequences can also vary by timing of the adolescent birth, and the negatives can carry on to the next generation. The difficulties for adolescents who become mothers at the youngest ages are greater in magnitude and likelihood than to women who become mothers in later adolescence (Boden, Fergusson, and Horwood 2008; Olausson et al. 2001). Consequences for the children of teen mothers include lower school achievement, poorer cognitive performance, more behavioural problems, and more time in the criminal justice system (Augustine and Negraia 2018; Duncan et al. 2018; Duncan, Kalil, and Ziol-Guest 2017; Hoffman and Maynard 2008; Miller 2009; Mollborn et al. 2014). A few studies, in an effort to test the hypothesis that there are biological trade-offs between early fertility and later longevity, have also found higher mortality in later life among women who gave birth in adolescence, but this could be because adolescent fertility often coincides with other risky and unhealthy life situations that are more directly related to lower longevity than adolescent fertility in and of itself (Doblhammer 2000; Grundy 2009; Olausson et al. 2004).

Particularly in developing contexts, but also in high-income countries, higher rates of maternal and infant mortality and morbidity among adolescent mothers make health concerns of adolescent fertility a priority. The heightened maternal mortality risks mean that it is one of the leading causes of death for this otherwise low-mortality age group (Laski 2015). While some of the mortality risk is a result of higher prevalence of low socio-economic status and first births among adolescent mothers, other factors independent of socio-economic status contribute to the increased risk (Conde-Agudelo, Belizán, and Lammers 2005; Nove et al. 2014; Prentice et al. 2013). For example, there is evidence that adolescents have poorer maternal health (such as inadequate antenatal care and deliveries without professional medical care) than older women with similar background characteristics (Magadi 2006a). Biological immaturity may also be at play. Adolescence is an important phase of height recovery in under-nourished populations and maternal stature, specifically, a mother's height, weight, and pelvic size relate strongly to child and maternal outcomes. Because low nutritional status delays puberty, in the poorest contexts, the interval between menarche and fertility can be quite short, leaving a greater likelihood of resource competition between the pregnancy and the mother's own continued development (Prentice et al. 2013). The youngest adolescent mothers have been found to have particularly high rates of pre-term births, infant mortality and low birth weights (Magadi 2006b).

A recent publication by Diaz and Fiel (2016) may well prove as pivotal as the novel studies of the 1990s for reshaping the direction of the field's research on adolescent fertility. The authors expertly and insightfully reconcile how the vast diversity in effects in research on adolescent fertility is not in fact a contradiction. As researchers have prioritised methodologies that reduce selection bias in their pursuit of isolating causal effect, they have ignored effect heterogeneity. In reality, the consequences of adolescent fertility follow a broad continuum that vary substantially among different subpopulations of women based on their probabilities of entering motherhood in adolescence. That is, each of the various statistical methods used in adolescent fertility research measure effects specific to one subpopulation, offering a single snapshot instead of mapping the bigger picture. With an impressively clear technical explanation, the authors account for where each of the main statistical methods sit along a theoretical continuum and why each method estimates the greater or lesser effect intensities seen in the research.

Ultimately, the balance of the evidence indicates that adolescent fertility does indeed cause negative outcomes for most teenage mothers and their children, even over and above the large influence of pre-existing difficult circumstances. In other words, when faced with similarly adverse circumstances, women who postpone motherhood beyond adolescence generally fare better than women who do not. Their children fare better too. Dramatic changes in the returns to education, in the partnership status of teen mothers, in the availability of public support, and the ever-increasing postponement of births among other women, likely means that the effects of teen births change as well (Hoffman 1998; Mollborn 2017). The issue merits continued analysis; particularly in looking at adolescent fertility in different contexts, in different time periods, and in different ways.

1.2.4 Consequences of adolescent fertility in Latin America and the Caribbean

There is only a sparse body of causal evidence of the consequences of adolescent fertility in Latin America and the Caribbean, largely because of limited data. Consequences could be less dire than they are in high-income countries because adolescent fertility is more common, meaning it is less a marker of extreme disadvantage. Additionally, in contexts where there are fewer formal job opportunities and gender norms restrict women's workforce participation, adolescent fertility may have less impact on economic pursuits (McQueston, Silverman, and Glassman 2012). Indeed, one study in Mexico using the miscarriage method found that adolescent mothers were more likely to be employed and did not have lower schooling attainment than their peers who miscarried, though they did have greater dependence on social assistance and welfare receipts (Azevedo et al. 2012). However, a study in Colombia, clarifies that although adolescent mothers had higher employment rates, they were performing lower-class jobs (Urdinola and Ospino 2015), which echoes evidence from the United States about adolescent mothers experiencing lower returns to their employment (Klepinger, Lundberg, and Plotnick 1999; Taniguchi 1999).

Alternatively, adolescent fertility in Latin America and the Caribbean may have more negative consequences than what is seen in high-income settings. Because of the region's rapidly changing educational and economic context, and more limited public support to adolescent mothers, women who initiate childbearing early may increasingly be left behind their peers. The context of adolescence has changed drastically over the last half century and, increasingly, those who are able to spend more adolescent years on human capital accumulation are better positioned to take advantage of changing economic contexts for themselves and for their children (Patton et al. 2018). Indeed, there are several studies in the region that try to disentangle selection and causality, and they find effects that both mirror and intensify the negative consequences seen in other contexts.

One study in Brazil finds the effects of teenage pregnancy, when controlling for endogeneity, are surprisingly greater than those estimated in correlational evidence on adolescent mothers' earnings, educational achievement and the education of their children (Rios Neto 2009). Issues of endogeneity are important because, for example, adolescent fertility might cause poverty but poverty might also cause adolescent fertility, or another unobserved variable related to both might drive the results. Though not in Latin America or the Caribbean, albeit another developing context, one study in Madagascar, rare for its use of longitudinal data, also finds that the reductions in schooling caused by adolescent fertility are greater than the reductions suggested by correlational evidence (Herrera Almanza and Sahn 2018). This differs from estimates in high-income settings where the negatives from causal evidence are usually less than those from correlational evidence. Longitudinal evidence from Mexico also finds adolescent fertility reduces schooling (Arceo-Gomez and Campos-Vazquez 2014) in contrast to the previously mentioned and perhaps less generalizable miscarriage study (Azevedo et al. 2012) that did not find schooling reductions.

It also seems that adolescent motherhood in Latin America and the Caribbean leads to more intense intimate partner violence and child mortality, particularly for those who enter motherhood before age 17—both themes not often explored in high-income settings (Urdinola and Ospino 2015). The study is important because its findings suggest that early fertility has disadvantages independent of those related to early union formation, which are otherwise often difficult to disentangle. The connection between the acute vulnerability of the youngest wives and mothers and intimate partner violence has also been found in longitudinal evidence in Bangladesh, another developing context (Yount et al. 2016). Other evidence in Latin America and the Caribbean finds that heightened maternal and neonatal mortality and morbidity risks are most pronounced among adolescent mothers aged 15 and younger (Conde-Agudelo, Belizán, and Lammers 2005; Neal, Channon, and Chintsanya 2018; Nove et al. 2014). This contrasts with sub-Saharan Africa where generally all adolescents, not just the youngest, have heightened risks. This is possibly a reflection in part of the better health systems in much of Latin America and the Caribbean than in sub-Saharan Africa. Additionally, Latin America and the Caribbean adolescents have shorter inter-pregnancy intervals compared to non-adolescent women (Conde-Agudelo, Belizán, and Lammers 2005), and the increased mortality and morbidity risks of short inter-pregnancy intervals to both mother and baby can be alarmingly high (Fotso et al. 2013; Kalamar, Lee-Rife, and Hindin 2016; Norton, Chandra-Mouli, and Lane 2017).

1.2.5 What qualitative and correlational evidence add

Non-causal research adds important depth to the understanding of adolescent fertility in Latin America and the Caribbean. Women with adolescent births acknowledge difficulties that arise from economic hardship and feelings of isolation or loss of freedom, but they do not usually attribute their problems to the adolescent birth. Instead, their perceptions of motherhood are overwhelmingly positive—across countries and contexts (Carvalho 2007; De Rosa, Doyenart, and Lara 2016; Neuhouser 1998; Steele 2011). Adolescents see their motherhood as a source of life purpose and impetus of strength. Even when a pregnancy is not initially planned or wanted, adolescents describe how it brings meaning, emotional security, maturation and improved social standing. Motherhood in Latin America and the Caribbean, even adolescent motherhood, is reverenced. Likewise, motherhood is generally represented as the most valuable status a woman can achieve, and, particularly in situations of deprivation, it is often the only positive adult identity open to females (Lenkiewicz 2013; Steele 2011).

Interestingly, in one study, adolescents in Mexico describe age 20 as an important threshold for motherhood (Lenkiewicz 2013). Although the adolescent mothers in the study are positive about their pregnancies and describe them as intended, they acknowledge that pregnancies to women aged 20 and above are not subject to the tacit cultural criticisms that their own young motherhood carries. One rare study (Flórez 2005) compares conceptualisations of motherhood among adolescents of higher and lower socio-economic strata — rather than conceptualisations exclusively from those who experience adolescent motherhood — and finds that only youth from higher strata talk about how motherhood should be postponed until after attaining economic security and emotional maturation. Adolescents from lower strata do not talk of delaying motherhood and instead, in direct opposition to higher-strata adolescents, describe children as sources of emotional security and social maturation.

Notwithstanding the positive themes, the keen veneration of motherhood sits in strong dissonance with two other salient cultural themes: an acute taboo against female sexual activity among young, unmarried women; and an indulgent acceptance of an impatient sex drive among young men (Carvalho 2007; Steele 2011). Young women must safeguard their virginity while young men must prove their masculinity and virility with early and, ideally, ubiquitous sexual activity. These mismatched cultural themes are pervasive in how young people speak of their sexual experiences, and can manifest themselves in problematic ways. For example, particularly in the most traditional settings, large proportions of young men experience their sexual debut with commercial sex workers, and many young women feel pressured into unprotected sex to prove they love and trust their partner (Evangelista and Kauffer 2009). Navigating or negotiating contraception in this context can be difficult for young women. Strong gender stereotypes dictate that women should be asexual or sexually inexperienced and passively accept their male partners' sexual demands (Azevedo et al. 2012). Use of contraceptives are seen to imply previous promiscuity and a lack of trust in each other's fidelity and commitment (Lenkiewicz 2013). As a result, though motherhood is uniformly reverenced, adolescent motherhood is also censured. While teenage pregnancy often means that a young woman has failed certain cultural sexual expectations, it is also an accepted, prevalent, often celebrated, fact of life (Lenkiewicz 2013).

Issues of restricted agency along a variety of dimensions permeate the research as well, and agency, whether it is rational and deliberative or emotional and subconscious, is fundamental to reproductive behaviour and fertility decisions (Guzzo et al. 2019). On the one hand, many adolescent mothers in Latin America and the Caribbean lack other life plans and aspirations (such as further education) that would conflict with motherhood, and as such, they do not feel their fertility interrupts anything (Azevedo et al. 2012). On the other hand, as touched on previously, contradictory standards for sexual activity and use of contraception make it difficult for adolescent females to control their own risk exposure. Additionally, though adolescents affirm they know about contraception, they will express uncertainty or passivity about how they became pregnant — it was something that happened to them, not something that was the result of their (lack of) decision-making (De Rosa, Doyenart, and Lara 2016; Lenkiewicz 2013). Similarly, large numbers of adolescents report not using contraception simply because they had not planned on having sex (Rodríguez Vignoli 2014a). Low self-esteem, fear of rejection, and a dependence on snap decisions arising from emotions of the moment also characterise adolescent discussions of sexual agency in Latin America and the Caribbean (Flórez 2005; Lipovsek et al. 2002). Research from United States affirms that ambivalence about adolescent pregnancy increases its probability of occurring while strong desires to explicitly avoid pregnancy consistently predict lower risk (Miller, Barber, and Gatny 2013).

The dynamics of extended families are also important themes in adolescent fertility in Latin America and the Caribbean. Adolescent fertility is more common in female-headed households, households with high densities (e.g. many family members sharing a smaller home), and households with less parent-adolescent affection and more conflict, though the presence of grandparents is correlated with less adolescent fertility (Kruger and Berthelon 2009; Lipovsek et al. 2002; Ngom, Magadi, and Owuor 2003). Family networks are also important for determining whether an adolescent mother returns to school. Unmarried adolescent mothers, who are more likely to be from households with higher socio-economic status, return to school more frequently than adolescents who are married or in a union and have moved either into their partner's household or formed their own household (Flórez and Soto 2007). Because early union formation and early fertility are correlated with greater relationship instability (Azevedo et al. 2012), partnership dissolution may strain the limited resources of extended families in addition to challenging the mother and baby's well-being (Comisión Económica para América Latina y el Caribe and United Nations Children's Fund 2007). In fact, union instability is related to higher child mortality risk in the region (DeRose et al. 2017). Finally, only among the poor is adolescent fertility associated with reductions in a mothers' monthly wages and children's nutritional status, and it is only among the poor that a mother's contribution to household income is associated with improvements in children's well-being (Buvinic 1998).

1.2.6 Human rights and demographic scope

There is considerable international concern about adolescent fertility. Perhaps most prominent is its inclusion in the United Nations Sustainable Development Goals as one of two indicators for tracking progress toward the pursuit of universal access to sexual and reproductive health-care services (United Nations 2016). The Every Woman Every Child, Global Strategy for Women's, Children's, and Adolescents' Health 2016-2030 is designed to bolster the aims of the health-related Sustainable Development Goals as well as consolidate funding and action. Importantly, the Strategy added adolescents, as well as the key issue of adolescent fertility, to its focus, in recognition that adolescents often miss out in programs aimed exclusively at children or women (Organization 2018). Many other leading global actors, such as the World Health Organization and United Nations Population Fund periodically publish reports, recommendations and toolkits advocating for the reduction of adolescent fertility (Plan International 2016; World Health Organization 2011). Mexico's recent national initiative to eliminate fertility among girls aged 10-14 years and cut rates in half among girls aged 15-19 years by 2030 (Gobierno de la República 2015) mirrors similar initiatives in many other countries in the region (Pan American Health Organization 2014; United Nations Children's Fund 2016).

On the global stage, concern about adolescent fertility is often framed within a broader context of human rights and demographic scope. Most fundamentally, reproductive health, sexuality and fertility is a basic human right (Nations 1994). A human rights approach to development insists that every individual should be empowered to expand and develop the capabilities and opportunities (i.e. substantive freedoms) that allow her to lead the kind of life she values (Sen 1999). From this perspective, adolescence, and the schooling that occurs in adolescence, becomes one of most critical phases for determining lifelong freedom (World Bank 2006).

All women, including adolescent girls, should be empowered to make informed choices about their reproductive health, their sexuality and their fertility. Empowerment, at its most basic level, means the ability to make choices. One powerful but pragmatic conceptualisation of empowerment describes how it is the interaction of three fundamental dimensions: (1) resources, or access to material and social resources; (2) agency, or the process of decision-making; and (3) achievements, or whether improvements in agency and resources produce positive well-being outcomes (Kabeer 1999). Early fertility is often closely accompanied by markers of disquieting disempowerment. Limited agency, as discussed previously, is a salient theme in adolescents' accounts of their sexual activity and fertility in Latin America and the Caribbean. Early fertility is also associated with less control over household resources, and greater acceptance that gender-based violence (Klugman et al. 2014). In Latin America and the Caribbean, intimate partner violence, gender-based emotional abuse and controlling behaviours are widespread (with one fourth to one half of women ever married or in a union in the region reporting having ever experienced it), and the prevalence is markedly higher among women with a first birth in adolescence as well as among women with lower schooling levels (Bott et al. 2012). Even as the women who married or had children early mature and acquire greater resources, their higher likelihood of experiencing violence persists (Kidman 2017).

In considering the demographic scope of adolescent fertility, never has Latin America and the Caribbean had a larger body of youth. The region's unique early fertility pattern may well have implications for its macro-level socio-economic profile and the realisation of its demographic dividend. Though it is hardly explored in the literature, pervasive early fertility could be a key development obstacle for the region. Many adolescents, particularly young girls, have a bleak outlook on their labour market prospects and schooling's ability to translate into employment opportunities (both in terms of finding employment as well as in improving the type of employment and level of earnings) (Azevedo et al. 2012). However, not only do women who stay in school longer have better job opportunities, higher earnings and fewer dependants (Alves and Cavenaghi 2009; Wodon et al. 2017), but early childbearing in Latin America and the Caribbean seems to decrease female employment rates and earnings, even after controlling for low levels of economic opportunity at the outset (Azevedo et al. 2012). In contrast to many of the lowest-income countries where female labour force participation and productivity is relatively unaffected by early fertility, in the middle income countries of much of Latin America and the Caribbean, early fertility matters for a woman's lifetime labour and earning prospects (Wodon et al. 2017). Disadvantages from early fertility compound the region's persistently low female labour force participation, as well as the pattern that female employment is concentrated in gendered, low-productivity sectors (such as domestic and food services, for example) (Economic Commission for Latin America and the Caribbean 2014, 2018). Additionally, economic dependence heightens vulnerability to intimate-partner violence (Bott et al. 2012). Of acute relevance is the World Bank (2016) report that warns that the region's slowed population growth and favourable dependency ratios will only translate fully into the macroeconomic benefits of an impressive demographic dividend if there are serious improvements in human capital investment (more schooling and training), accelerated job creation, and large reductions in barriers to female labour force participation in the region.

Schooling offers an almost inexhaustible list of benefits that counter the risks that accompany adolescent fertility. School enhances autonomy, stimulates greater cognitive capacity, encourages more egalitarian conjugal relationships, increases control over household economic resources, brings better health and lower mortality to children, and spurs greater longevity and productivity among adults (LeVine et al. 1991; Patton et al. 2016). It is perhaps no coincidence that the protraction of schooling throughout adolescence corresponds to the impressive neural development that happens at that life stage, second only to that in infancy (Patton et al. 2016). Increasingly, there is a modern mismatch between biological maturity and social immaturity in adolescence; the need for extended education conflicts with puberty's profound biological changes that allow for such early family transitions (Patton and Viner 2007). With this background, the discussion now turns to review the connections between education and fertility in demographic research.

1.3 Schooling and fertility

1.3.1 Classic perspectives on the relationship between schooling and fertility

Why a woman's schooling is one of the strongest predictors of how many children she will have is one of demography's most interrogated questions. From the large body of empirical and theoretical work that explores the relationship between education and fertility in a vast array of contexts, two consistent and concurrent themes arise: (1) education and fertility have a negative relationship, or, on average, as a woman's years of schooling increase, the number of children she has decreases (Ainsworth, Beegle, and Nyamete 1996; Behrman 2015; Brand and Davis 2011; Diamond, Newby, and Varle 1999; Nisén et al. 2014; Sohn and Lee 2019); and (2) women at all education levels experience substantial declines in their total fertility over time, particularly over demographic transitions (Abbasi-Shavazi et al. 2008; Bongaarts 2003; Choe and Retherford 2009; Kravdal and Rindfuss 2008; Shapiro 2012; Yoo 2014). In fact, in looking at explanations for demographic transitions worldwide (or the transitions from high to low fertility regimes), the spread of mass education has long been seen as one of the strongest candidates (Caldwell 1980; Drèze and Murthi 2001; Ní Bhrolcháin and Dyson 2007).

The negative fertility and education relationship is not without its caveats. For example, it is not always strictly monotonic. In some cases, women in low-income countries with a few years of schooling can have more children on average than their counterparts without any schooling (Ainsworth, Beegle, and Nyamete 1996; Diamond, Newby, and Varle 1999). In high-income countries, the most educated women can have higher propensities and desires for larger families than their less educated peers (De Wachter and Neels 2011; Dribe and Stanfors 2010; Heiland, Prskawetz, and Sanderson 2005; Kravdal 1992; Kreyenfeld 2002). Though education is often used as proxy for socio-economic status, the two are not necessarily the same. In the sparse evidence that exists from before the 1800s, higher wealth and social status were associated with higher fertility, but the relationship has long since reversed. Education's relationship, in contrast, has been consistently negative (Skirbekk 2008).

Declines over time are not without their qualifications either. Post-war baby booms saw fertility increases across the board, even for the most educated women (Davalos and Morales 2017; Gustafsson 2001; Hirschman 1994; Sánchez-Barricarte 2018; Van Bavel 2014). Additionally, declines, differentiated by socio-economic groups, do not appear to be completely converging. That is, fertility differentials persist even for countries with deeply established two-child norms (Abbasi-Shavazi et al. 2008; Bongaarts 2003; Choe and Retherford 2009; Kravdal and Rindfuss 2008; Shapiro 2012; Skirbekk 2008; Yoo 2014). Interestingly, while Latin America and the Caribbean has seen the world's largest education differentials in realised fertility since data have been available, its differentials in desired fertility have never been as pronounced, suggesting that only the more educated have been able to match their realised fertility to their desired fertility while the less educated far exceeded their desired fertility (Martin 1995; Skirbekk 2008; Weinberger 1987; Weinberger, Lloyd, and Blanc 1989).

Classical theories on the explanations for why schooling reduces fertility emphasise changing cost-benefit, quality-quantity trade-offs to the mother, often in economic or social and psychological terms that make child rearing seem a more demanding, high-cognitive, resource-intensive task fraught with opportunity costs (LeVine et al. 1991). In empirical work at the individual level, the economic connections are changeable and sometimes quite thin (Cleland 2002), particularly in lower-income countries where just a few years of education can make a large fertility difference but little difference in formal female employment (Chowhudry and Trovato 1994; Cleland and Wilson 1987). Theories about sociocultural influences are often complicated by the changing context of schooling over time. For example, a changing social milieu brought by rapid schooling expansions in Nepal meant that growing up close to a school, independent of whether a woman attended or not, dampened a woman's later fertility (Axinn and Barber 2001). While research in low- and middle-income countries continues to find that the quantity-quality trade-off in family size and schooling persists (Duncan, Kalil, and Ziol-Guest 2017), there are two proximate determinants of fertility that education seems to consistently influence. First, schooling increases contraception use, resulting in fewer unwanted births; second, schooling delays the initiation of childbearing, also resulting in lower lifetime fertility (Cleland 2002). The robust positive relationship between schooling and contraception has been found worldwide, and higher levels of education are associated not only with higher levels of contraceptive use, but also with more effective use (Bongaarts 2003, 2010; Martin and Juarez 1995; Musick et al. 2009).

In contrast to schooling's negative association with the quantum, or quantity, of fertility, as discussed above, there is a positive association between schooling and the tempo, or timing, of fertility (Cleland 2002). The more schooling a woman has, the later she begins childbearing. While theoretical work on the relationship between education and the timing of fertility has been given comparatively less attention than the connection between education and the quantum of fertility, empirical work is widespread. A number of important nuances qualify the positive relationship between education and the tempo of fertility. Most fundamentally, education and fertility are jointly determined — and both are influenced by family background and other contextual factors (Tropf and Mandemakers 2017). For instance, women who are more likely to initiate childbearing are also more likely to leave school earlier, and conversely, women who are less likely to enter motherhood early, are more likely to leave school later (Cohen, Kravdal, and Keilman 2011; Martín-García and Baizán 2006; Stange 2011). Also, women seem to adapt their educational choices to suit their future family formation intentions and vice versa. Those who study more traditionally 'female' subjects, or subjects more amenable to careers with interruptions for family formation, also have a higher likelihood of first births for a given enrolment and attainment status (Lappegård and Rønsen 2005; Martín-García and Baizán 2006). While current enrolment reduces fertility (Blossfeld and De Rose 1992), highly educated women often experience a catching-up phase of higher fertility propensities after schooling (Lappegård and Rønsen 2005).In both high-income countries (Mooyaart and Liefbroer 2016) and low-income countries (Glick, Handy, and Sahn 2015), education's influence on the timing of fertility is multigenerational in that parental educational is related to the timing of children's fertility, independent of the child's own education, and the influence is strongest in adolescence.

Education-differentiated postponement patterns are not uniform. The timing of first births can follow increasingly divergent patterns — even in many European countries where differences in the total number of children born to women with different levels of schooling are small. Trends among the least schooled are seeing either no change or moving to younger average ages in timing of first births, while groups of more schooled women are progressively delaying motherhood. Often, the average age at first birth at the population level can change little, masking an underlying variance of increasingly different fertility timing regimes. This first birth age dispersion has been seen in many high-income countries in variety of time periods (Andersson et al. 2009; Berrington, Stone, and Beaujouan 2015; Bloom and Trussell 1984; Lappegård and Rønsen 2005; Rendall et al. 2010; Rindfuss, Morgan, and Offutt 1996; Spéder 2006). More homogeneous shifts to later ages among all education profiles in countries like Norway and France contrast with the United Kingdom's increasing age polarisation (Raymo et al. 2015; Rendall et al. 2005, 2010; Rendall et al. 2009). Often, childbearing postponement is more strongly related to time since leaving school than to calendar age; the increased time women spend in education can account for much of the postponement of first births. Where researched, the length of the interval between leaving school and first birth has changed little, despite dramatic increases in average age at first birth (Neels et al. 2017; Ní Bhrolcháin and Beaujouan 2012). Nevertheless, data limitations make this interval analysis challenging to study elsewhere because a woman's age at leaving full-time education, rather than her highest attained schooling level, is not often available.

Ultimately, almost all of these findings are from high-income countries for women at advanced levels of education, which makes their translation to a theoretical understanding of adolescent fertility and schooling in Latin America and the Caribbean more difficult. The relationship between schooling and the tempo of adolescent fertility is much more immediate than the relationship between schooling and general fertility. Adolescent fertility and pre-tertiary schooling, by definition, both happen in adolescence. Furthermore, the patterns of education-differentiated age polarisation in fertility in Latin America and the Caribbean have occurred alongside steep declines in overall fertility, while age dispersion in high-income countries has occurred within the context of little change in overall fertility (Alves and Cavenaghi 2009; Esteve, Lopez-Ruiz, and Spijker 2013; Miranda-Ribeiro and Garcia 2013).

1.3.2 Adolescent fertility and schooling: evidence

In the absence of satisfactory theoretical work heretofore on the relationship between schooling and the timing of adolescent fertility, empirical work on the subject offers an illuminating point of departure. The strongest evidence for a causal relationship between school and adolescent fertility comes from randomised control trial evaluations. Programs that encourage girls to stay in school, or to return to school after they have dropped out, significantly reduce adolescent marriage, fertility and sexual activity rates. This been found in trials in Latin America and the Caribbean, Africa and Asia (Baird et al. 2010; Duflo, Dupas, and Kremer 2015; Kalamar, Lee-Rife, and Hindin 2016). For example, evaluations of Mexico's cash transfer program *Oportunidades*, which conditions benefit payments to poor mothers on the school attendance of their children, find that the program also delays sexual activity, fertility and marriage among adolescent girls who are beneficiaries — and the effects are greater for girls who are beneficiaries for longer periods of time (Gulemetova-Swan 2009; Kalamar, Lee-Rife, and Hindin 2016). In Colombia, a lottery for private school tuition vouchers for poor adolescents decreased rates of adolescent marriage and cohabitation (Angrist et al. 2002). In Chile, lengthening the school day, or the number of hours adolescent girls spent at school each day, reduced adolescent pregnancy rates (Kruger and Berthelon 2009). Finally, in the Dominican Republic, a program that provided training on life skills and employability to youth who had dropped out of school notably decreased adolescent fertility rates despite having no discernible impact on the adolescent females' employment rates (Ibarraran et al. 2014; Novella and Ripani 2016).

Although the evidence base is small, when compared against each another, randomised control trials report that stay-in-school programs consistently fare better than sex education programs in reducing adolescent fertility and marriage (Duflo, Dupas, and Kremer 2015; Jones et al. 1999; Kalamar, Lee-Rife, and Hindin 2016; Mason-Jones et al. 2016; McQueston, Silverman, and Glassman 2012). To clarify, not many sex education programs measure biological outcomes rather than changes in knowledge or self-reported behaviour, but when they do, the stay-in-school programs have more consistently positive results, particularly in the longer term. One prime example is a trial in Kenya (Duflo, Dupas, and Kremer 2015) that compared the provision of a government sex education curriculum against the provision of an education subsidy in the form of two free uniforms over an 18-month period (in schools with no sex education curriculum). Only the free uniform program led to a reduction in pregnancy rates, largely through reductions in school dropouts and early marriage. In a third test, when the free uniforms and sex education curriculum were combined together in some schools, the pregnancy reduction effect was erased. The authors hypothesised that this happened because of the way the curriculum discussed risks of sexually transmitted infections, which ultimately encouraged girls to settle into committed relationships and drop out of school rather than engage in more casual relationships. In a systematic review of all randomised control trials of school-based interventions aimed at improving adolescent sexual and reproductive health, only eight trials from 1990 to 2016 were found to have measured outcomes in terms of biological effects (Mason-Jones et al. 2016). Tellingly, the six identified sex education programs had no observable effect on pregnancy whereas the two identified programs that gave incentives to stay in school (the Kenya study was one of these), reduced pregnancies. Only one trial from Latin America, an abstinence-focused program in Chile, qualified for inclusion in the review. Interestingly, the original study of the Chilean program reported a reduction in pregnancies, but the review found these results were more likely to reflect bias in the evaluation design than a true effect.

The previous discussion is not meant to discount the importance of quality, school-based comprehensive sexuality education. Adolescents need access to reliable information on sexual health, relationships and their rights and choices. Sex education in Latin America and the Caribbean generally has favourable policy frameworks that, on paper at least, closely align with international best practice recommendations (Panchaud et al. 2019; United Nations Educational, Scientific and Cultural Organization 2009). What plagues school-based sex education in the region is weak implementation. The quality of sex education in the region is ultimately crippled by little teacher training, overcrowded curricula, and a scarcity of culturally relevant teaching materials combined with limited budgets, minimal monitoring and insufficient government commitment (Azevedo et al. 2012; Panchaud et al. 2019). As such, it is unsurprising perhaps that reviews of rigorously-evaluated programs find that, while sex education programs are more likely to have positive results for behavioural outcomes than they are to have negative results, the most likely outcome is actually no effect, particularly for adolescent pregnancy (Kirby, Laris, and Rolleri 2007). Additionally, large portions of adolescents in Latin America and the Caribbean are out of school at ages when the information could perhaps have more immediate influence on sexual practice.

In most cases it seems that girls leave school prior to becoming pregnant rather than leave school because of a pregnancy. Data from Latin America and the Caribbean finds that around two thirds of girls leave school before becoming pregnant (Sanchez et al. 2006). Likewise, in Africa, closer to four fifths of girls leave school before marriage or pregnancy (Grant and Hallman 2008a; Lloyd and Mensch 2008; Mensch et al. 2001). In both contexts, adolescents cite financial constraints as the primary cause for leaving, which illuminates why programs that use scholarships and cash transfers to keep adolescents in school have found such ready impact. Even so, an adolescent's interest and performance in school also matter for her fertility risk (Harden et al. 2009). One European study found that it was the adolescents whose performance had deteriorated the most over time that were most at risk of fertility, not those who were consistently the poorest performers (Kiernan 1997). Indeed, disenchantment with education is a ubiquitous theme in qualitative work on adolescent fertility in the region (Lenkiewicz 2013; Näslund-Hadley and Binstock 2011). Finally, pregnancy for adolescents does not always mean automatic school abandonment. There is evidence that adolescents will return to school if they are more invested in school to start with, remain unmarried, and have a family member at home to help with childcare (Grant and Hallman 2008a; Madhavan and Thomas 2005). Nevertheless, reducing adolescent fertility can be important for improving national schooling targets. Research that estimates whether addressing adolescent fertility can help reduce the gender gap in education finds the payoffs are highest, not in places like Africa with the highest adolescent fertility, but in places like Latin America and the Caribbean where there is more advancement to higher grades (Eloundou-Enyegue and Stokes 2004). In summary, in low- and middle-income countries, the causal evidence strongly suggests that schooling limits adolescent fertility much more than adolescent fertility limits schooling. Additionally, when comparing school with sex education, schooling stands as the best contraception.

1.3.3 Adolescent fertility and schooling: theory

In cataloguing the empirical evidence on the relationship between education and the timing of adolescent fertility, two overarching themes emerge. These are: (1) an incarceration effect, or being enrolled and present at school reduces adolescent fertility while the girl remains in school; and (2) an aspirational effect, or schooling inspires changes in a girl's life goals and expectations and reduces adolescent fertility after she leaves school. While theories of adult fertility postponement emphasise education's aspirational and incarceration effects, their interpretation is slightly different. They usually frame aspirational changes in terms of changing economic expectations and trade-offs as well as the influence of changing social norms for life course event timing (Gustafsson 2001; Kohler, Billari, and Ortega 2002). An incarceration effect is also broadly discussed but it is usually called enrolment effect because the schooling levels studied in adult fertility research are generally not compulsory.

In adolescent fertility research, what is called the incarceration effect describes how time spent in school directly reduces adolescent fertility from what would otherwise happen if the adolescents were not in school. Evidence of this effect in demographic research is supported strongly by studies on the impact of school reforms on adolescent fertility. The research finds that changes in compulsory schooling requirements, which increase the age of school leaving, causally reduce adolescent fertility (Grönqvist and Hall 2013; Monstad, Propper, and Salvanes 2008; Silles 2011). Pure incarceration effects reduce adolescent fertility only at the ages affected by the school reforms, as was found by Geruso and Royer (2018) in the United Kingdom where the extra time spent in school seemed to prevent adolescents from meeting older males.

In contrast, an aspirational effects find that adolescent fertility reductions extend years beyond the ages at which school attendance occurs. Changes in compulsory schooling usually show effects that continue at ages beyond those affected by the reforms (Black, Devereux, and Salvanes 2008; Cygan-Rehm and Maeder 2013; Monstad, Propper, and Salvanes 2008). Likewise, the free uniform program in Kenya found that the adolescent fertility effects extended far beyond the program's duration (Duflo, Dupas, and Kremer 2015). The aspiration effect hypothesises that the additional time in school can change adolescents' life plans and ambitions — whether by moving the girls to accumulate even more schooling (and thus prolonging the incarceration effect), or encouraging later transitions to motherhood because of changed social and economic aspirations even if they are no longer in school. Ultimately, framing the relationship into aspirational and incarceration effects must recognise that there is no invariable, universal schooling effect even if the general pattern is consistent. The impact of education on the timing of childbearing is mediated by many other factors, including culture, ethnicity, quality of schooling, employment opportunities, place of residence and more.

The ecological model, a prevailing theoretical framework for adolescent fertility, recognises that schooling is not the only point of influence. The model organises the structural and behavioural interactions that lead to adolescent pregnancy into progressively expanding spheres of influence, starting with the individual then broadening to the family, community, and beyond (Corcoran 1999; Svanemyr et al. 2015). The influence of the broader context is apparent in a great deal of research. For example, adolescent fertility timing patterns differed among Belgian Flemish-speaking and Belgian French-speaking populations, two distinct cultures within the same country, as well as between Netherlands Dutch and Belgian Flemish, who share similar cultural elements but live in neighbouring countries (Steenhof and Liefbroer 2008). In several studies in sub-Saharan Africa, community educational levels and community adolescent fertility levels can amplify or diminish a girl's risk of adolescent fertility beyond what is predicted by her individual schooling attainment or socio-economic status (Benefo 2006; Brewster 1994; Derose and Kravdal 2007; Kravdal 2002, 2012). In the United Sates, patterns of sexual activity at an adolescent's school can speed up individuals' sexual debut (Fletcher 2007). In Sweden, the consistent influence of social age on the timing of first births, as determined by one's year in school rather than one's calendar age, emerges from a comparison of adolescents with one month difference in calendar age but one year difference in school age (Skirbekk, Kohler, and Prskawetz 2004). The same is found in adolescent fertility research in Mexico where if a woman progresses through school at a younger age than her peers in the same schooling trajectory, she has a heightened risk of early sexual debut and adolescent fertility (Caudillo 2019).

Family context is also important for adolescent fertility. A great deal of longitudinal research finds that intergenerational transmission is manifest in both education and adolescent fertility outcomes (Glick, Handy, and Sahn 2015; Mooyaart and Liefbroer 2016). Additionally, the influence of a mother's preference for her daughter's family size, a mother's preference for the timing of her daughter's entry into motherhood, or alternatively, a mother's perception of the importance of interests that compete with childbearing (such as education and career), as well the size of an origin family are connected to the likelihood of adolescent fertility (Barber 2000, 2001). It has long been observed that women who were themselves teen mothers often have daughters who become teen mothers (Kahn and Anderson 1992; Kiernan 1997). The higher mortality of families with low socio-economic status in Finland was recently found to have an independent and significant association with early fertility (Berg, Lawson, and Rotkirch 2020), possibly hinting that early mortality patterns in Latin America and the Caribbean could also be a contributor to adolescent fertility. Additionally, the influence of family context on fertility preferences seems to be strongest in adolescence (Heiland, Prskawetz, and Sanderson 2008; Steenhof and Liefbroer 2008). Some evidence finds the strength of intergenerational transmissions is increasing over time — with the associations being more pronounced in more recent decades compared to the past (Murphy and Wang 2001), while other research finds more stability over time (Mooyaart and Liefbroer 2016).

Nevertheless, and this is encouraging, the connection between parental expectation of educational attainment and adolescent fertility risk seems to be independent of the adolescents' ability or socio-economic advantage. The higher the parental expectations for a daughter's schooling attainment, the lower her risk of adolescent pregnancy, no matter the family circumstances (Kneale 2010). Similarly, academic performance, ability and interest is more important for adolescent fertility outcomes than intergenerational transmission of fertility preferences and original family socio-economic status (Berrington and Pattaro 2014; Jones et al. 1999; Ribar 1994). In summary, at least in the high-income countries where it has been studied, schooling aspirations matter more than intergenerational transmission and socio-economic status for adolescent fertility. However, a multitude of other factors may well interact to change how schooling impacts adolescent fertility over time.

Ultimately, the aim of the present research is not to examine individual-level, causal evidence of the effect of schooling on adolescent fertility, but instead, to use the micro-level evidence as the theoretical foundation for an aggregate view of the changing relationship between schooling and adolescent fertility in Latin America and the Caribbean. Documenting schooling's changing relationship to adolescent fertility will help uncover the changing nature of schooling's association with adolescent fertility, particularly in light of the region's puzzlingly high rates of adolescent fertility. Indeed, little is known about education differentials in adolescent fertility in the region, though we know considerably more about other aspects such as changing patterns of sexual activity and union formation.

Population-level changes in demographic phenomena lie at the heart of demography even though firm conclusions of causation are more elusive (Ní Bhrolcháin and Dyson 2007). No longer called an effect, because of the ambiguity of causality at the macro-level, school-based incarceration is related to changes in the protectiveness of school-going against adolescent fertility. Changes in population patterns can be associated with changes in the time spent in adolescence enrolled and present at school as well as changes in fertility rates among current school-goers. School-inspired aspirational changes operate beyond school enrolment in the adolescent years spent out of school. They are associated with changes in the life aspirations of adolescents, which influence the timing of fertility by either conflicting with or encouraging early childbearing. Changes can occur in the length of the interval between school leaving and giving birth as well as in the fertility intensity of out-of-school adolescents. School-based incarceration and school-inspired aspirations can work together simultaneously to produce complex population-level changes in education differentials in adolescent fertility. Ultimately, even stagnant aggregate adolescent fertility may well involve changes in underlying education differentials as the schooling composition of the adolescent population changes.

These population patterns in fertility and schooling are not independent of broader individual and societal factors, only some of which will be explored in this research. The rather undivided focus on the dynamics of schooling and adolescent fertility is intentional. In deepening our understanding of the schooling patterns of adolescent childbearing, we strengthen our ability to reduce it. While it is impossible to change ethnic identities and difficult to directly influence wealth, policy interventions can dramatically impact education. In this sense, education is not simply a means to quantify socio-economic inequalities in fertility outcomes, but a malleable instrument through which to expand opportunities and promote human rights.

Chapter 2

Only University is Enough?

The puzzle of sixty years of adolescent fertility and schooling expansion in Latin America and the Caribbean

It is a demographic puzzle that Latin America and the Caribbean's high levels of adolescent fertility have persisted over the region's rapid fertility transition and dramatic schooling expansion. Demographic transitions and schooling improvements usually occur alongside postponements to entry into motherhood. The small handful of studies that have examined this puzzle have given mixed results: in some cases, women in all educational strata have seen increasing levels of adolescent fertility in the region while in other cases, university-educated women have been immune to increasing adolescent childbearing. However, what is missing is an analysis that can reconcile the mixed messages and place them within the bigger picture. That is, what is missing is an analysis of what adolescent fertility patterns have been over the long term; what they have been for first as well as higher-order adolescent births; and what they have been for education divisions that distinguish between all relevant schooling levels, particularly upper- and lower-secondary education, as well as dropouts and graduates at each level.

This study looks at six Latin American and Caribbean countries using 38 nationally representative demographic surveys to create a comprehensive demographic accounting of adolescent fertility for women born from 1936-1996. Cohort-based measures of parity-specific teenage childbearing examine how patterns of adolescent fertility have evolved within each major schooling milestone: no school, primary, lower-secondary, upper-secondary and tertiary. The study further disaggregates trends among graduates and dropouts at all appropriate levels (all levels except no school and tertiary). The analysis reveals that in most, but not all, of the six countries analysed, only women who reach university have not seen long-term increases in adolescent first births. In con-

trast, schooling-specific rates of second and higher-order adolescent births have generally, but not universally, fallen. The findings also emphasize lower-secondary's diminishing returns and upper-secondary's distinctiveness in adolescent fertility patterns. In essence, the results underscore the importance of expanding girls' access to upper-secondary and tertiary schooling. Ultimately, the findings in the six countries analysed are relevant not just for Latin America and the Caribbean, but for all the world's lower- and middle-income countries where adolescent childbearing remains widespread despite dramatic fertility transitions and schooling expansions over the last half century.

2.1 Introduction

Over the last sixty years, Latin America and the Caribbean's adolescent birth rate has nearly halved, falling from 106 to 61 births per thousand adolescents aged 15-19. Nevertheless, declines in many other world regions have been greater. Today, Latin America and the Caribbean's adolescent birth rate is among the highest in the world, second only to Sub-Saharan Africa, whereas six decades ago Latin America and the Caribbean's rate sat squarely in the middle of the globe's regional averages (United Nations Population Division 2019a).

Meanwhile, the last six decades in the region have seen dramatic fertility transitions and schooling expansions. Latin America and the Caribbean's total fertility rate was six children per woman in 1960 and today it is just below replacement level at two children per woman (World Bank 2019b). Country-specific total fertility rates in the region today cluster quite closely together. Although three countries still see fertility above 2.5 (Bolivia at 2.7, Guatemala at 2.8 and Haiti at 2.9), they represent only 8% of the region's population (World Bank, 2019b). Impressive schooling expansions match the rapidity of the region's fertility declines. An increasing proportion of the population has been progressively attending a greater number of school years. To be specific, one out of every four women aged 20-24 years had no formal schooling in 1970, but by 2010, less than 2% of that age group had never gone to school (World Bank 2019a). Likewise, women aged 20-24 had an average of only four years of schooling in 1970, and by 2010, that figure had more than doubled to an average of ten years. In essence, adolescent fertility has been more resistant to decline than has total fertility in the face of the region's sweeping educational transformation.

Four studies have queried the conundrum, but uncertainty remains given that each of the previous studies had distinct educational divisions, covered different time periods, accounted for adolescent fertility differently, and did not always come to the same conclusion. The first study looked at, among other things, changes in age-specific fertility rates among Brazilian women with 0-8 years of schooling compared to 9 or more years of schooling in surveys from 1996 and 2006 (Cavenaghi and Diniz Alves 2011). The study found that fertility rates increased for all adolescents—both for those with 8 or fewer years of schooling as well as those with 9 years or more years of schooling—

but declined for all educational groups of older women. A few years later, another study looked at changes in adolescent fertility by individual schooling years (from 0 to 13+ years of schooling) in data from around 1990 and 2010 in six countries (Rodríguez Vignoli and Cavenaghi 2014). Importantly, instead of examining the adolescent fertility rate, the study looked at the proportion of 19-year-olds who were mothers. Other concurrent research had also begun to explore changes in the proportion of women entering motherhood in adolescence to better understand why many countries' adolescent fertility rates in the region had stagnated or increased over the 1990s. Roriguéz Vignoli and Cavenaghi's (2014) analysis indicated that the only educational group that had not seen an increasing proportion of adolescent motherhood across all countries was the group without any formal schooling. Also in 2014, Esteve and Florez-Paredes (2014) looked at the question but in more countries and over a longer period of time. Their study examined changes in the proportion of women entering motherhood in adolescence in 12 countries, with estimates for each decade of women born from 1940 to 1980. The study divided each country's population into four education groups: women with 0-5 years, 6-8 years, 9-12 years and 13 or more years of school. This time, the findings indicated that all education groups had seen increases, and that the growth was especially concentrated in the groups with less than 13 years of school. That is, those with secondary schooling and lower. The final study, Batyra (2020), looked at first births in adolescence among women born from 1945-1980 in Ecuador, Colombia and Peru. Batyra's (2020) educational divisions distinguished between those who had completed tertiary schooling, those who had or had not completed secondary schooling, and those with up to completed primary. In this case, women with completed tertiary did not see increases in first births in adolescence while women with incomplete secondary had seen the most dramatic increases.

Given these differences in categorisations and conclusions, the picture remains unclear. What is missing is an analysis that can reconcile the mixed messages by bringing together an accounting of what adolescent fertility patterns have been over the long term; what they have been for first as well as higher-order adolescent births; and what they have been for education divisions that distinguish between all relevant schooling levels, particularly upper- and lower-secondary education, as well as dropouts and graduates at each level. Accordingly, this study looks at all Latin American and Caribbean countries with more than fifty years of nationally-representative, parity- and education-specific fertility data. These countries are Colombia, the Dominican Republic, Guatemala, Haiti, Mexico and Peru and represent 38% of the region's population (United Nations Population Division 2019b). Conveniently, the countries' contrasting adolescent fertility levels and schooling patterns span the region's trends. Guatemala and Haiti have some of the lowest schooling indicators, and while Guatemala's adolescent fertility rates are among the region's highest, Haiti's are among the lowest. Meanwhile, Colombia and Peru have some of the highest schooling indicators alongside average adolescent fertility rates. Mexico and the Dominican Republic's schooling indicators are fairly average, and while Mexico's adolescent fertility is also fairly average, the Dominican Republic sees some of the region's highest adolescent fertility rates (Kattan and Székely 2015; United

Nations Population Division 2019a).

The findings suggest that though this study's selected countries cover a variety of disparate fertility patterns, they share many similarities in regards to their changes in trends of adolescent fertility and schooling. However, these countries should not be taken to be specifically representative of the region as a whole. Nevertheless, initial data explorations of most of the region's countries (over shorter time periods) found considerable similarities in the overarching patterns explored in this study. Additionally, the four previously mentioned studies, which probed many countries not included in this study saw considerable similarities in increasing adolescent fertility in spite of sweeping educational expansions.

Again, the aim of this analysis is to detail the evolution of schooling- and parity-specific population patterns in adolescent fertility over the course of five decades of two demographically transformative phenomena—the fertility transition and schooling expansion—in the six countries in Latin America & the Caribbean where data make this possible. To undertake this aim, the study follows several core research objectives:

(1) Examine the details of each country's schooling expansion in terms of the eight schooling levels of interest.
(2) Explore changes in parity progression ratios for first, second and third birth in adolescence both at the population level and within each schooling level.
(3) Explore changes in cumulative adolescent childbearing at the population level and each schooling level.
(4) Explore changes in the mean age at first adolescent birth at the population level and each schooling level.
(5) And finally, explore changes in the timing of adolescent pregnancies in relation to the timing of school leaving.

2.2 Background

It is not simply because of the mixed picture provided by previous studies that this paper's consolidation of the three critical aspects of the (1) long term, (2) parity-specific, and (3) educationally nuanced accounting of adolescent fertility is relevant. The persistence of Latin America and the Caribbean's high levels of adolescent childbearing speak to a larger underlying theoretical question about the connection between fertility and education. However, before exploring the theoretical underpinnings, it is important to first give flesh to this study's interest in long term, parity-specific and educationally-nuanced adolescent fertility patterns.

As a starting point, the study focuses on adolescent fertility, defined as childbearing among women aged 10 to 19 years (World Health Organization 2007) for two reasons. First, the bulk of causal evidence confirms that adolescent fertility has negative consequences for both mother and child (Diaz and Fiel 2016; Duncan et al. 2018; Kane et al. 2013). In Latin America and the Caribbean specifically, research that goes beyond associative evidence to approach causal impact finds negative effects on women's earnings, their educational achievement as well as that of their children, and brings particularly intense vulnerabilities to intimate partner violence (Arceo-Gomez and Campos-Vazquez 2014; Azevedo et al. 2012; Rios Neto 2009; Urdinola and Ospino 2015). Second, not only is adolescent fertility exceptionally pronounced in Latin America and the Caribbean, but it accounts for a large and growing share of the region's fertility. On average, 15% of all births in the region are to adolescents (with as many as 25% in some countries) (Álvarez Castaño 2015; Benova et al. 2018), which is higher than any other world region (from 5% in Europe, 7% in Asia and 10% in Africa) (United Nations DESA 2015b). Indeed, teenage childbearing and its multifarious occurrence in populations and over time merits continued study (Mollborn 2017).

2.2.1 Long-term perspective

The importance of a long term perspective takes root in the fascinating story of the region's fertility transition. In Latin America and the Caribbean, fertility transitions have occurred largely without widespread childbearing postponement, having instead depended on family size limitation (Cavenaghi and Diniz Alves 2011; Esteve, Lopez-Ruiz, and Spijker 2013). That is, childbearing patterns defined by early starting and early stopping. In parts of Europe and Asia, in contrast, the progressive postponement of entry into motherhood continues to be an important component of long-term fertility decline (Hirschman 1994; Kohler, Billari, and Ortega 2002; Sobotka 2004; see Perelli-Harris 2005 for an Eastern European exception). Initially, stagnant age trends in motherhood entry in Latin America and the Caribbean were misinterpreted as no change, but more recent disaggregation unmasks underlying disparities. Research discovers an ever-widening age gap, or a bimodal fertility divide, between the childbearing postponement of the most advantaged groups and the early motherhood of their less privileged peers (Bozon, Gayet, and Barrientos 2009; Cavenaghi and Diniz Alves 2011; Esteve, Lesthaeghe, and López-Gay 2012; Esteve, Lopez-Ruiz, and Spijker 2013; Lima et al. 2018; Nathan 2015; Nathan, Pardo, and Cabella 2016; Rosero-Bixby, Castro-Martín, and Martín-García 2009).

The persistently young age schedule of fertility is peculiar considering the region's impressive schooling expansion that has occurred alongside strong total fertility decline. As a broad rule, education is widely seen as the single most important driver of fertility decline and postponement (Abel et al. 2016; Lutz 2014). Evidence from across the globe not only finds that women at all education levels experience substantial declines in fertility over demographic transitions (Abbasi-Shavazi et al. 2008; Bongaarts 2003; Choe and Retherford 2009; Kravdal and Rindfuss 2008; Shapiro 2012; Yoo 2014), but that educational expansions contribute substantially to childbearing postponement (Lam and Duryea 1999; Liefbroer and Corijn 1999; Monstad, Propper, and Salvanes 2008; Neels et al. 2017; Neels and De Wachter 2010).

Nevertheless, research finds that changes in the timing of motherhood entry are not always consistent across educational strata. Even in many high-income countries, where differences in the total number of children born to women with different levels of schooling are small, the timing of first births can follow increasingly disparate patterns. Trends in age at first birth among the least schooled may see no change or move to younger average ages, while groups of more schooled women progressively delay motherhood (Andersson et al. 2009; Berrington, Stone, and Beaujouan 2015; Bloom and Trussell 1984; Lappegård and Rønsen 2005; Raymo et al. 2015; Rendall et al. 2010; Rindfuss, Morgan, and Offutt 1996). In contexts where all education groups see progressive delays, postponement among the least schooled is often smaller than that of the most schooled (Lappegård 2000; Ní Bhrolcháin and Beaujouan 2012).

In the early stages of Latin America and the Caribbean's demographic transitions, education differentials in realised fertility, but not necessarily desired fertility, were considerable (Caldwell 1980; Cleland and Wilson 1987; Weinberger, Lloyd, and Blanc 1989). Today, education differentials in adolescent fertility in the region are greater than differences in total fertility (Rodríguez Vignoli 2014a). While schooling expansion seems an important component of overall fertility decline in Latin America and the Caribbean (Martin 1995), its long-term role in changes in the timing of fertility, particularly for adolescents, remains unclear. This is particularly the case because recent declines from the adolescent fertility peaks of the 1990s (Berquó and Cavenaghi 2005; Cavenaghi and Diniz Alves 2011; Lima et al. 2018; Neal et al. 2018; Rodríguez Vignoli 2014a; Velarde and Zegers-Hochschild 2017) may not necessarily translate to declines relative to earlier decades, and most adolescent fertility research in Latin America and the Caribbean focuses on these more recent fluctuations, leaving the long-term picture relatively unexplored.

2.2.2 Parity-specific change

Now that the value of looking at adolescent fertility over the long term is established, it is important to speak to parity-specific analysis. Attention to parity-specific change is critical given that the most common measures of adolescent fertility are not parity-specific and recent research suggests that in the aggregate, only higher-order adolescent births have declined, not the proportion of women entering motherhood in adolescence in Latin America and the Caribbean (Berquó and Cavenaghi 2005; Cavenaghi and Diniz Alves 2011; Lima et al. 2018; Neal et al. 2018; Rodríguez Vignoli 2014a; Velarde and Zegers-Hochschild 2017). Most existing research relates this to patterns of contraceptive access.

While access to and knowledge of contraception in in the region is regarded as near universal—with some of the highest contraception use rates in the world (Cavenaghi and Diniz Alves 2011)—adolescents still face considerable access barriers. Much of the research describing the drivers of sustained adolescent childbearing in Latin America and the Caribbean indicates that increasing rates of adolescent sexual activity and union formation—in terms of higher proportions of adolescents engaging in sexual activity and forming unions, as well as initiating sexual activity and forming unions at younger ages—has not been offset by sufficient increases in adolescent contraception (Ali, Cleland, and Shah 2003; Cavenaghi and Diniz Alves 2009; Flórez and Soto 2013; Heaton, Forste, and Otterstrom 2002; Rodriguez 2013). Indeed, many adolescents do not use any contraception until after the birth of their first child (Di Cesare and Rodríguez Vignoli 2006; Esteve Palós and Florez-Paredes 2014; Rodríguez Vignoli 2014a).

In other words, once an adolescent experiences a first birth, barriers to accessing contraception appear to diminish considerably. While some research suggests that access is not equal across all education strata for adolescents who have already had a birth (Velarde and Zegers-Hochschild 2017), other research finds that access is more universal, in the sense that second birth intervals have substantially lengthened for women of all education strata (Batyra 2016; Casterline and Odden 2016). An analysis of the long-term declines in second births over detailed educational divisions is completely missing. In essence, trends for first and higher-order births among adolescents have been completely distinct, but almost no research has examined long-term trends in higher-order births among adolescents.

2.2.3 Educational nuance

Today, secondary schooling remains considerably understudied in demography (Patton et al. 2016) even though nearly two thirds of women in Latin America and the Caribbean (63%) finish their schooling sometime during secondary education, with considerable cross-country variation in patterns of lower- and upper-secondary school attainment (Kattan and Székely 2015).

In education research in contrast, now that the region has largely achieved universal primary schooling, attention has turned to secondary schooling, with particular emphasis on the differences in lower- and upper-secondary attainment for positive lifetime outcomes (Kattan and Székely 2015). Demographic research lags behind this development; I find no fertility research in the region examining this schooling distinction explicitly. Nevertheless, a handful of studies find that schooling certificate years (that is, the final year of primary or secondary schooling levels) have distinctive fertility outcomes than non-certificate years (Ainsworth, Beegle, and Nyamete 1996; Batyra 2020; Lam, Sedlacek, and Duryea 1993). These findings support this study's intention to differentiate by formal levels, rather than individual years of schooling. Indeed, a growing proportion of students from poorer socio-economic backgrounds are reaching upper-secondary schooling but they are not always able to graduate at the rates of their better-off peers, and an increasing share of dropouts in the region are occurring at upper-secondary rather than lower-secondary schooling (Batyra 2020; Kattan and Székely 2015). Additionally, for overall fertility decline, at least in Brazil, differences between incomplete and complete level-specific schooling careers are important at lower schooling levels in the early decades, and differences at secondary and higher levels only emerge in the 1990s (Lam, Sedlacek, and Duryea 1993; Miranda-Ribeiro and Garcia 2013). In Ecuador and Colombia in recent years, increases in adolescent childbearing are most intense among secondary dropouts (Batyra 2020), but this research does not distinguish between upper- and lower-secondary schooling.

While previous paragraphs in this paper already looked at the relationship between education and fertility over the demographic transition, it is worth taking a second look, this time paying attention to specific schooling levels. At low levels of education, the relationship between schooling and fertility is not always systematic. Mainly in certain sub-Saharan contexts in past decades, women with just a few years of schooling have more children on average than their counterparts without any schooling (Ainsworth, Beegle, and Nyamete 1996; Bongaarts 2010; Jejeebhoy 1995; Martin 1995). In Latin America, a few years of primary schooling has made a more consistent difference for overall fertility (Diamond, Newby, and Varle 1999; Lam and Duryea 1999). In contrast to primary schooling, secondary and tertiary schooling is universally related to smaller family size in lower- and middle-income countries (Ainsworth, Beegle, and Nyamete 1996; Jejeebhoy 1995). While tertiary is related to even stronger family size limitation than secondary, over time, both in sub-Saharan Africa and Latin America, fertility differences between women with tertiary and those with no school have narrowed while differences between women with primary and secondary schooling have widened (Shapiro 2012). In the past, the greatest education-related fertility change in lower-income countries was often seen between women with no school and varying years of primary education (Axinn and Barber 2001; Cleland and Ginneken 1988; Jain 1981), but more recently, the greatest fertility change occurs in the middle education groups, not the highest or lowest (Esteve, Lopez-Ruiz, and Spijker 2013; Heaton and Forste 1998; Shapiro 2012). Essentially, after greater educational expansion, it seems that higher levels of education (that is, lower and upper secondary as well as tertiary) matter more than primary years for lifetime fertility outcomes (Patton et al. 2016).

Existing research on educational differences in adolescent fertility largely reveal the same themes as those just mentioned above for lifetime fertility. In recent years, women in Latin America and the Caribbean with no school are found to have a lower incidence of adolescent fertility than those with only a few years of school (Rodríguez Vignoli and Cavenaghi 2014). Additionally, the threshold point in school years—the point at which the high incidence of adolescent fertility in the region begins to diminish—has increased over time from a few years of primary to a few years of secondary (Gómez-Inclán and Durán-Arenas 2017; Gupta and Iuri da Costa 1999; Rodríguez Vignoli and Cavenaghi 2014). The pattern in Africa is similar: in most research, girls' education from secondary and above is related to reductions in adolescent births while lower levels of schooling, over the long term, are not (Gupta and Mahy 2003; Towriss and Timæus 2018). It seems the greatest change and variability for both early fertility and marriage postponement in Africa and Latin America and the Caribbean are at the middle education levels, not the lowest schooling years (Esteve Palós and Florez-Paredes 2014; Vavrus and Larsen 2003; Weinberger 1987). Even in high-income settings, schooling expansions in upper-secondary completion have been an important marker for teen birth reductions and fertility postponement (Grönqvist and Hall 2013; Lappegård 2000; Rendall et al. 2005).

In summary, adolescent fertility in Latin America and the Caribbean has remained perplexingly high. To unravel the puzzle, this study will look at changes over the last half century in adolescent first, second and third births for groups of women who attain the following eight schooling divisions: no school, primary incomplete, primary complete, lower secondary incomplete, lower secondary complete, upper secondary incomplete, upper secondary complete, some tertiary. The analysis does not distinguish tertiary dropouts from graduates because although tertiary starts in adolescence, its completion extends beyond the teenage years.

2.3 Theoretical implications

With a better understanding of why a long-term, parity-specific and educationally nuanced accounting of adolescent fertility is needed, it is worth turning to the theoretical underpinnings of fertility and education to give this study even more relevance. The relationship between education and fertility is one of demography's most interrogated questions. Classical theories on the explanations for why schooling reduces fertility emphasize changing cost-benefit, quality-quantity trade-offs to the mother, often in economic or social and psychological terms that transform conceptualisations of child rearing into a more demanding, high-cognitive, resource-intensive task fraught with opportunity costs (LeVine et al. 1991). This means that, as a general rule, when a woman's years of schooling increase, the number of children she has decreases (Ainsworth, Beegle, and Nyamete 1996; Behrman 2015; Brand and Davis 2011; Diamond, Newby, and Varle 1999; Nisén et al. 2014; Sohn and Lee 2019). However, adolescent fertility is less about the quantity of fertility than it is about the timing of fertility. Theoretical work on the relationship between education and the timing of fertility has been given comparatively less attention than the connection between education and the quantum of fertility, but empirical work on the connection is widespread. In cataloguing the empirical evidence on the relationship between education and the timing of fertility, two overarching themes emerge. These are: (1) there is an enrolment effect, or being enrolled and present at school reduces fertility while the woman remains in school; and (2) an aspirational effect, or schooling inspires changes in a woman's life goals and expectations and reduces fertility even after she leaves school.

The enrolment effect finds considerable support in empirical work on adolescent fertility. The strongest evidence for a causal link between schooling and adolescent fertility comes from randomised control trial evidence. Programs that encourage girls to stay in school, or to return to school after they have dropped out, have proven to reduce adolescent marriage, fertility and sexual activity rates. This is found in trials in Latin America and the Caribbean, Africa and Asia (Angrist et al. 2002; Baird et al. 2010; Duflo, Dupas, and Kremer 2015; Gulemetova-Swan 2009; Ibarraran et al. 2014; Kalamar, Lee-Rife, and Hindin 2016; Kruger and Berthelon 2009; Novella and Ripani 2016). Other rigorous demographic work also supports the causal relationship. Often, the enrolment effect is called an incarceration effect when the research exploits changes in compulsory schooling laws. Time adolescent girls spend enrolled and present at school directly reduces teenage fertility levels (Geruso and Royer 2018; Grönqvist and Hall 2013; Kruger and Berthelon 2009; Monstad, Propper, and Salvanes 2008; Silles 2011).

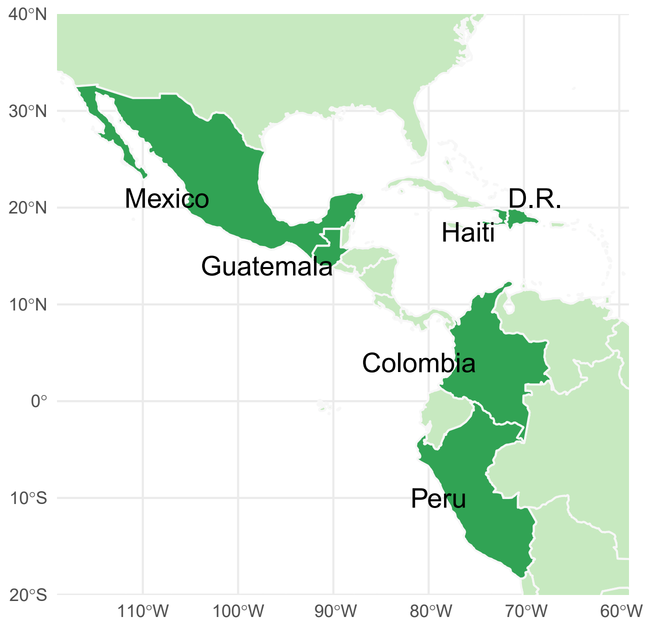
An aspirational effect has more relevance to the adolescent context than an opportunity cost effect because for adolescents, economic questions are more about future prospects than present engagement, and adolescents' decision-making, both in fertility and other processes, is markedly different than that of adults (Kearney and Levine 2012; Kearney and LeVine 2014; Levine 2001; Oreopoulos 2007). Indeed, adolescent decision-making differs from that of adults because adolescents are still developing their self-control, sense of agency and auto-determination; they are more markedly influenced by peer pressure and emotions of the moment and, perhaps most importantly, they heavily discount the future (Azevedo et al. 2012; Flórez 2005; Lipovsek et al. 2002; Patton et al. 2016). An aspirational conceptualisation recognizes the future-orienting power of schooling for adolescents. Indeed, much of the causal enrolment effect research also finds that adolescent fertility reductions can extend years beyond the ages at which school attendance occurs—the studies attribute these reductions to school-inspired changes in adolescent's life aspirations (Baird et al. 2010; Black, Devereux, and Salvanes 2008; Cygan-Rehm and Maeder 2013; Duflo, Dupas, and Kremer 2015; Kalamar, Lee-Rife, and Hindin 2016; Mason-Jones et al. 2016; Monstad, Propper, and Salvanes 2008). More broadly, education is an important means through which individuals gain a greater sense of control over their life course (Lutz 2017; Musick et al. 2009) and in Latin America and the Caribbean research, a lack of a sense of agency or control is a dominant theme in adolescent mothers' descriptions of their fertility (Azevedo et al. 2012; De Rosa, Doyenart, and Lara 2016; Lenkiewicz 2013).

Ultimately, in translating the enrolment and aspiration themes to the macro-level population patterns, they can no longer be described as effects. Nevertheless, uncovering the population patterns can still contribute to our theoretical understanding of the relationship between education and adolescent fertility. Importantly, the recent causal work does not examine long-term trends but instead offers single snapshots in time. Given the evolution of the long-term associative evidence described earlier—where specific schooling levels increase or diminish in importance for fertility outcomes—it seems reasonable that schooling's relationship with adolescent fertility varies by context and changes over time. Documenting the changing population patterns is a first step. As such, this study aims to uncover the changes inherent in a long-standing fertility and schooling puzzle: the population patterns of Latin America and the Caribbean's sustained adolescent fertility over the course of its schooling expansion and fertility transition.

2.4 Data

This study takes the only Latin American and Caribbean countries for which more than fifty years of nationally-representative, parity-specific adolescent fertility and school attainment data are available. The countries—Colombia, Peru, the Dominican Republic, Haiti, Guatemala and Mexico—form three pairs of contiguous countries (see Figure 2.1) and represent 38% of the region's population (United Nations Population Division 2019b).

Figure 2.1: Study countries



Data come from nationally-representative repeated cross-sectional household surveys from 32 standard Demographic and Health Surveys (DHS), and, in the case of Mexico, from six National Demographic Dynamics Surveys (or ENADID for its name in Spanish, Encuesta Nacional de la Dinámica Demográfica). Surveys within each country are pooled together. The number of surveys pooled for each country's analysis ranges from three in Guatemala to ten in Peru. In the DHS surveys, the data come from the Individual Women's Data, also known as the Individual Recode files, from the women's questionnaire conducted with every woman aged 15 to 49 years in each surveyed household. Mexico's data come from the women's questionnaire, women's birth history questionnaire and individual household member survey results. The women's questionnaire was conducted with every woman aged 15 to 54 in each surveyed household.

Sample selection includes all women aged 20 years or older in the year before each survey. Because this study is interested in adolescent fertility measures that capture the lived experience of women throughout their entire adolescence, it selects only women who have completed their adolescence to avoid censoring and truncation. This selection also potentially improves the accuracy of the estimates as adolescents seem to underreport their current fertility (or overreport their age) compared to non-adolescent women's reports of their adolescent fertility (Neal and Hosegood

2015).

Selected cases cover women born as early as 1936-1944 (depending on the country), representing women who completed their adolescence, or reached their twentieth birthday, in 1956-1964. The most recent estimates cover women born from 1991-1996, representing women who completed their adolescence in 2011-2016. Table 2.1 details the total number of selected cases in each country, detailed by survey and woman's birth year. Note that the analysis is conducted by individual years, but the table consolidates cases into ten-year groupings for brevity. Total cases range from 32,445 in Guatemala to 405,499 in Mexico.

2.4.1 Variables

The variables of interest in this study's estimation of parity- and schooling-specific adolescent fertility levels come from retrospective questions detailing a woman's reported date of birth, her highest reported level of schooling attained, and the reported dates of birth of all her children born up to the time of the survey. Adolescent births are identified as all births occurring to a woman before the month in which she turned twenty.

Schooling levels are coded by aligning survey schooling variables to the International Standard Classification of Education's (ISCED) current categorisations for each country's specific system of primary, lower secondary, upper secondary and tertiary schooling (UNESCO Institute for Statistics 2012). Graduates are those who attain the terminal year of schooling at a given level, as identified in the ISCED classification and dropouts are those who attain any non-terminal year in a given schooling level. The analysis does not distinguish tertiary dropouts from graduates because although tertiary starts in adolescence, its completion extends beyond the teenage years. Table 2.2 lists the theoretical entry age and duration of each schooling level in each country. No two countries share the exact same schooling progression but primary schooling generally begins at age six and lasts for six years, lower secondary beings at age 12 and lasts for three years, upper secondary begins at age 15 and lasts for two to three years, and tertiary begins at age 17 or 18 years. In essence, in every country, a complete (though not necessarily compulsory) schooling trajectory requires a woman remain in school throughout her entire adolescence. It is possible that these schooling classifications have changed over time, but because reliably documenting six decades of schooling classification for every country is not possible, the current classifications offer the clearest and most relevant comparison.

The DHS imputes birth dates when a woman is unable to provide year and/or month of birth for herself and/or her children. Between 0.1% (Colombia) and 4.1% (Haiti) of women's birth dates and 1% (Haiti) to 3.7% (Dominican Republic) of children's birth dates were imputed. The ENADID surveys in Mexico do not impute dates and 0.3% of cases with missing women's birth dates and 2.3% of cases with missing child birth dates are dropped from Mexico's analysis while the cases

		Cases by ten-year birth cohort								Unused cases	
Survey type	Survey year	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	Total cases	Too young	Incomplete data
Colombia											
DHS	1986	237	930	1,507	1,233				3,907	1,418	4
DHS	1990		1,225	2,181	3,245				6,651	1,989	4
DHS	1995		863	2,575	3,446	1,943			8,827	2,313	0
DHS	2000			2,288	3,190	3,688			9,166	2,419	0
DHS	2004-05			3,949	9,638	10,799	6,045		30,431	10,890	23
DHS	2009-10			2	11,453	12,892	14,927		39,274	14,247	0
DHS	2015-16				3,763	8,804	10,290	5,955	28,812	9,906	0
		237	**3,018**	**12,502**	**35,968**	**38,126**	**31,262**	**5,955**	**127,068**	**43,182**	**31**
Dominican Republic											
DHS	1986	299	1,315	1,964	1,769				5,347	2,298	0
DHS	1991		887	1,651	2,510	301			5,349	1,946	23
DHS	1996		369	1,738	2,409	1,813			6,329	2,089	4
DHS	1999		6	245	346	376			973	312	1
DHS	2002			3,245	5,953	7,116	1,601		17,915	5,461	8
DHS	2007			1,271	6,333	7,444	5,899		20,947	6,214	34
DHS	2013				1,265	2,285	2,706	1,012	7,268	2,104	0
		299	**2,577**	**10,114**	**20,585**	**19,335**	**10,206**	**1,012**	**64,128**	**20,424**	**70**
Guatemala											
DHS	1987		776	1,577	1,408				3,761	1,399	0
DHS	1995		818	2,632	3,379	2,205			9,034	3,369	0
DHS	2014-15				2,064	5,576	7,565	4,445	19,650	6,264	0
			1,594	**4,209**	**6,851**	**7,781**	**7,565**	**4,445**	**32,445**	**11,032**	**0**
Haiti											
DHS	1994-95		400	1,107	1,517	839			3,863	1,485	8
DHS	2000			1,799	2,381	3,341			7,521	2,621	17
DHS	2005-06			675	2,057	2,860	2,188		7,780	2,970	7
DHS	2012				1,803	3,029	4,637	1,088	10,557	3,727	3
DHS	2016-17			516	1,288	2,750	3,899	3,528	11,981	3,532	0
			400	**4,097**	**9,046**	**12,819**	**10,724**	**4,616**	**41,702**	**14,335**	**35**
Mexico											
ENADID	1992	1,432	9,921	14,958	21,160	4,657			52,128	17,356	54
ENADID	1997		7,493	16,618	23,676	20,595			68,382	19,453	187
ENADID	2006			5,175	9,120	10,476	6,660		31,431	7,335	147
ENADID	2009			9,003	22,353	25,454	25,178		81,988	18,314	213
ENADID	2014			367	19,576	24,953	25,449	11,193	81,538	17,087	86
ENADID	2018				13,648	26,410	27,034	22,940	90,032	18,394	13
		1,432	**17,414**	**46,121**	**109,533**	**112,545**	**84,321**	**34,133**	**405,499**	**97,939**	**700**
Peru											
DHS	1986	217	1,016	1,396	1,056				3,685	1,311	3
DHS	1991-92		2,061	3,848	5,210	909			12,028	3,846	8
DHS	1996		1,287	6,110	8,585	6,107			22,089	6,862	0
DHS	2000			4,915	7,534	8,921			21,370	6,473	0
DHS	2003-06			1,691	4,846	5,523	3,080		15,140	3,950	0
DHS	2007-08			802	5,494	6,420	5,261		17,977	4,579	2
DHS	2009			205	5,573	6,800	6,623		19,201	5,011	0
DHS	2010				4,938	6,444	6,774		18,156	4,789	2
DHS	2011				4,359	6,283	6,594	683	17,919	4,598	0
DHS	2012				4,051	6,538	6,974	1,357	18,920	4,967	1
		217	**4,364**	**18,967**	**51,646**	**53,945**	**35,306**	**2,040**	**166,485**	**46,386**	**16**

Table 2.1: Unweighted case selection by survey and ten-year birth cohort

Country	Primary		Lower Secondary		Upper Secondary		Tertiary	
	Entry age	Duration	Entry age	Duration	Entry age	Duration	Entry age	Duration
Colombia	6	5	11	4	15	2	17	2+
D.Republic	6	6	12	2	14	4	18	2+
Guatemala	7	6	13	3	16	3	18	4+
Haiti	6	6	12	3	15	4	19	4+
Mexico	6	6	12	3	15	3	18	2+
Peru	6	6	12	3	15	2	17	2+

Note:
Source (UNESCO Institute for Statistics, 2012)

Table 2.2: Schooling levels with theoretical entry age and duration (in years)

with imputed dates in the other countries are retained. Cases without reported educational attainment are also dropped from the analysis, but this represents, at a maximum, 0.2% of cases in each country. This case selection is more likely to underestimate adolescent fertility than overestimate it as less educated women, who also have high adolescent fertility, are more likely to be unable to provide birth dates and schooling attainment.

The use of pooled surveys, or repeated cross-sectional data, extends the study's years of observation to span more than six decades of birth cohorts and increases the sample sizes of all schooling-specific sub-populations, some of which can be quite small in individual surveys. See Appendix Tables A.1, A.2, and A.3 for the number of cases in each schooling level in each country by parity and decade. While the larger sample sizes are important for increasing the precision of this study's estimates (Rafferty, Walthery, and King-Hele 2015), the data are not without their limitations. Retrospective birth histories are subject to reporting errors that can impact the quality of the estimates. Potential errors include misreported dates of birth for mother and children; unreported births, which are more likely if the child died; forward telescoping, which means that births are reported as happening closer to the time of the survey than they actually occurred; and transference, which moves a birth to an earlier date than it actually occurred to avoid answering a long battery of DHS child health questions. One study estimates that less than 2% of births are omitted and 2% are displaced in DHS surveys (Pullum and Becker 2014), and other research finds that forward telescoping is more common for older women (Heaton and Call 1995), who represent a smaller portion of the study sample. These reporting errors are likely to be more common in less educated women who also have higher adolescent fertility, which means they would tend to underestimate adolescent fertility rather than overestimate it. One final point of caution notes that these data are not about adolescent pregnancy but only about reported births. While access to abortion is prohibited altogether in the Dominican Republic and Haiti and restricted in the other study countries (Guttmacher Institute 2017; Kulczycki 2011), adolescents in the region do obtain abortions, most of which are unsafe (Guttmacher Institute 2017; Shah and Åhman 2004). As access to and use of induced abortion are likely differentiated by socio-economic status (and therefore, educational attainment), the story of adolescent pregnancies in these countries likely differs from that of adolescent births.

2.5 Analytical strategy

To carry out an accounting of long term, parity-specific and educationally nuanced demographic trends, this study undertakes seven core analyses. Before moving on to review the methodology employed and describing the purpose of each analysis in more detail, I list the seven analyses here briefly: 1. The first analysis measures the schooling expansion in each of the six countries by estimating the population proportion that attains each of the eight schooling levels of interest. 2. The second analysis estimates the proportion of women who enter motherhood in adolescence (experience a first birth in adolescence) both at the population level and within each schooling level. 3. The third analysis estimates the proportion of women with one adolescent birth who go on to have a second birth before the age of twenty, both at the population level and within each schooling level. 4. The fourth analysis estimates the proportion of women with two births in adolescence who go on to have a third birth before the age of twenty, both at the population level and within each schooling level. 5. To summarize the parity-specific adolescent fertility trends, the fifth analysis estimates the average number of adolescent births per woman at the population level and each schooling level. 6. The sixth analysis estimates the mean age at first adolescent birth at the population level and each schooling level. 7. And finally, the seventh analysis imputes the proportion of pregnancies leading to a first birth in adolescence that occurred before, after or coincided with school leaving.

The methods employed for each of the seven analyses differ in their details but share the same overarching principles. As a starting point, each analysis employs regression models rather than simply producing proportions and averages directly from the data. It does so to be able to (1) smooth out the considerable statistical noise that would result from year-on-year changes in the many educational divisions examined and (2) to be able to make verifiable evaluations of whether the many educational divisions are in fact statistically distinct from each other. Recall that despite the large total sample size in each country, the sample sizes in a given schooling level for a given parity in a given year, or even decade, can be quite small. To be more specific, total cases range from 32,445 in Guatemala to 405,499 in Mexico in datasets used for first birth analysis, while the number of cases by specific schooling levels range from 948 to 100,015 with an average of more than 17,000 cases per schooling level. In second birth analysis, total cases range from 15,066 in Guatemala to 145,752 in Mexico, while the number of cases by specific schooling levels range from 57 to 39,440, with an average of more 6,800 cases per schooling level. For third birth analysis, total cases range from 4,547 in Haiti to 58,227 in Mexico, while the number of cases by specific schooling levels range fom 4 to 18,088 with an average of 2,500 cases per schooling level. In essence, small sample sizes for some of the higher parities introduce a fair amount of uncertainty so the exact estimates should be interpreted with caution. However, the similarities in the patterns across countries and schooling levels add confidence to the overarching messages of the findings. See Appendix Tables A.1, A.2, and A.3 for the number of cases at each schooling level by parity.

In regards to the first overarching principle, the year-on-year trends are important for achieving the level of detail that can authoritatively describe the patterns of change over time. Additionally, given that previous research has found evidence of stagnation and reversals—nonlinear change—in adolescent fertility trends in Latin America and the Caribbean (Berquó and Cavenaghi 2005; Cavenaghi and Diniz Alves 2011; Lima et al. 2018; Neal et al. 2018; Rodríguez Vignoli 2014a; Velarde and Zegers-Hochschild 2017), it is important that this study's analysis is able to replicate nonlinear change where it has occurred. Here again, the four studies that previously looked at the demographic puzzle of the region's adolescent fertility were not able to detect the stagnation and reversals that have been found in other research. This is most likely because the four studies generally compared averages from two distinct surveys spaced a random number of years apart or compared averages produced from five or ten-year aggregates. As such, the methods lacked the detail necessary to describe nonlinear change.

To remedy this, the regression models used in this study test for nonlinearity in the trends it examines and employ semiparametric regression to model nonlinear change where it has occurred. By testing for, and employing nonlinear functions when appropriate, this study's estimates are better able to capture prominent phases of reversals, advances and/or stagnation in the population patterns it examines. Linear regression analysis (note that logistic and Poisson regression are also fundamentally linear) allows for various transformations to approximate nonlinear change, such as power or logarithmic transformations, but these transformations require assumptions about the functional form of the data and are limited in the shapes they can describe. That is, the assume a priori there is a linear functional form (or some mathematical transformation of a linear form) to the relationship between the variables of interest. Instead, semiparametric analysis lets the data speak for itself to estimate its appropriate functional form while simultaneously preserving many of the analytical and computational benefits of linear regression (as opposed to fully nonparametric estimation). Semiparametric analysis achieves this by replacing global estimates of the linear functional form between the outcome and predictor variables with local estimates of linear functional forms, often called smoothers or splines (Keele 2008). Determining the right number of smoothers to best depict the nonlinear fluctuations without overfitting (and thus creating too much unhelpful nonlinearity), can be a challenge, but this study uses a method that employs the data to automatically choose the smoothing parameters. Namely, restricted maximum likelihood (REML) smoothing selection. Ultimately, model testing was undertaken for all regressions to confirm whether parametric or semiparametric regressions provided a better fit, largely determined by which has the least bias in the random error terms. When testing indicated that change over time was nonlinear, the regression techniques employed were semiparametric generalised additive models with REML smoothing selection and estimated in R (R Core Team 2019) using the package GAMLSS (Rigby and Stasinopoulos 2005).

In regards to the second overarching methodological principle, or the aim of evaluating whether the eight chosen educational divisions are in fact distinct from each other, the analysis examines this question using techniques that account for the complex sampling designs of the surveys from which the data come. As a starting point, the analysis selects women who attain tertiary schooling as the reference group in all models and tests (1) whether all remaining schooling levels are distinct from tertiary, and (2) whether their change over time is different from that of tertiary's. In other words, the analysis first examines whether keeping all eight schooling levels separate or collapsing any combination of contiguous schooling levels provides a better-fitting, more parsimonious model. The analysis next examines whether an additive model, where the schooling-specific estimates follow similar rates of change (that is, they have parallel slopes) from differing starting points (distinct intercepts) appropriately describes the data, or if an interactive model, where the schooling-specific estimates have both distinct rates of change (distinct slopes) and distinct starting points (distinct intercepts), provides a better fit to the data.

To make these model selection determinations, standard statistical techniques do not apply because the demographic surveys in this study use complex sampling designs. Accordingly, standard techniques for variance estimation are not valid because they substantially underestimate the standard errors, and wrongly suggest much more certainty in the calculations than what is justifiable from the data (Lumley and Scott 2017). That is, in ignoring the complex survey design, estimated standard errors in these data are typically 40% smaller than what they should be, and almost every schooling level remains distinct and every model favours the interactive design whereas the models using design-based standard errors often indicate otherwise. As such, the analysis uses general maximum pseudo-likelihood estimation for multistage stratified, cluster-sampled, unequally weighted survey samples with variance computed by the Horvitz-Thompson estimator as presented in the survey package (Lumley 2020) in R. Design-based analogues of tests of analysis of variance (ANOVA), Wald chi-square and Akaike information criterion (AIC) guide model selection (Lumley and Scott 2017). In the case of Mexico's ENADID surveys, weights were rescaled to sum to the sample size rather than the population size, so that the variance calculations are correctly estimated, while in the DHS surveys, the given weights sum to the sample size and are retained unchanged. Additionally, even when survey subpopulations were analysed, full survey design information was retained in the variance estimation in all models. Estimates for each country and parity were modelled separately. It is important to note that because the number of cases can be quite small for some of the higher schooling levels at higher adolescent parities in a few countries, the model testing may be more a reflection of sample limitations than population patterns in such cases.

In preparing the data for analysis, each individual survey report's methodological appendix was used to verify that the distinct stratification and clustering processes of each survey's sampling technique were appropriately accounted for in the variance estimation. The regression models pool multiple surveys over time within the same country but each individual survey's clusters and strata were coded with unique identifiers to ensure variance estimation remained true to the individual survey designs. In a few cases where strata contained only one primary sampling unit, the variance contribution of the strata was set to the average variance contribution across strata, which offered the most conservative estimate of variance, or, in other words, resulted in the largest standard errors. Alternative options included ignoring those primary sampling units for the variance computation or centring them to the population mean rather than the stratum mean, but again, these were not used in model testing because they produced smaller standard errors.

With an understanding of the overarching statistical techniques of the analysis, the following paragraphs detail the specific measures examined. First, this study begins by estimating the patterns of schooling expansion. In each country, the estimates organize all females over 20 years of age into their highest attained schooling level, as reported in the surveys and translated to this study's eight schooling divisions: no school, incomplete primary, complete primary, incomplete lower secondary, complete lower secondary, incomplete upper secondary, complete upper secondary, and some tertiary. To estimate the changing proportion of females at each schooling milestone, by year of birth, it uses successive sets of binary logistic semiparametric generalised additive models with restricted maximum likelihood (REML) smoothing selection (Keele 2008). In the case of the schooling expansion patterns, the semiparametric models performed much better than linear models in all countries, giving evidence of nonlinear trends in the populations.

Next, the analysis turns to parity-specific adolescent fertility. Adolescent fertility is most commonly estimated with age-specific fertility rates but the measure is not parity-specific, it curtails adolescent exposure and can undergo considerable variability from tempo effects. By tempo effects, I refer broadly to distortions in fertility measures that occur due to changes in the timing of births in relation to changes in mothers' ages for example (Bongaarts and Feeney 1998). To be clear, the measure curtails adolescent exposure because an age-specific fertility rate for adolescents aged 15-19 effectively ignores all fertility before age 15 and averages fertility between ages 15 and 19, (very roughly the average at about age 17.5), thereby leaving many adolescent years unaccounted. Cohort parity progression ratios, in contrast, are among the most informative fertility measures but have not been used to measure adolescent childbearing in Latin America and the Caribbean before. Progression ratios are parity specific and consider only women at risk of having each specific order of birth. They are also robust to tempo effects and misreported dates of birth because they are more about the eventual progression to another birth rather than the exact timing of the birth in adolescence. Finally, adolescent parity progression ratios do not truncate exposure, as does the adolescent birth rate, but consider all fertility through the end of a woman's adolescence.

As such, the second analysis estimates the proportion of women who enter motherhood in adolescence (experience a first birth in adolescence) both at the population level and within each schooling level. That is, the parity progression ratio for first adolescent births. To estimate the progression ratio at the population level, model testing indicates that change over time is not linear and as such the estimates are modelled with country- and parity-specific, semiparametric, generalised additive binary logistic regression models with REML smoothing selection (Keele 2008). In contrast to the population-level ratios, model testing for the schooling-specific ratios indicates that a linear assumption is reasonable. That is, the probability of having an adolescent birth for each schooling group has monotonically increased (or decreased) over time. As such, linear logistic regressions (Dobson and Barnett 2018) examine the probability, or ratio in this case, of women progressing from no births to a first birth in each schooling strata before the age of twenty.

Methods used in the third and fourth analysis are identical to the second analysis, only this time, the progression ratios estimate the proportion of women with one adolescent birth who go on to have a second birth before the age of twenty, and the proportion of women with two adolescent births who go on to have a third birth before the age of twenty. Estimates are done both at the population level and within each schooling level. Here again, model testing indicated that in most cases, change over time at the population level is nonlinear (exceptions will be reviewed in the results), while change within specific schooling strata is linear.

The fifth analysis aims to summarize the parity-specific adolescent fertility trends, as a way to bring together the dynamic and distinct differences of each parity at each schooling level. It does so by modelling the average number of adolescent births per woman. As with the progression ratios, model testing indicates that change over time at the population level in the average number of adolescent births per woman is not always linear and the estimates are modelled with country-specific generalised additive Poisson regressions with REML smoothing selection (Keele 2008). In the case of school-specific average adolescent births per woman, linear Poisson regressions (Dobson and Barnett 2018) produce the estimates, again based on model testing that finds that a monotonicity assumption is reasonable. No offset in the Poisson regressions is required because all women in the analysis share an identical exposure of their entire adolescence.

The sixth analysis estimates the mean age at first adolescent birth at the population level and each schooling level to explore whether the declines in second and third births in adolescence are simply a reflection of underlying changes in the timing of adolescent births—that is that adolescent first birth are happening later giving less time for second and third adolescent births to occur. At the population level, the mean age at first adolescent birth is estimated with linear semiparametric generalised additive models with REML smoothing (Keele 2008). For estimates of mean age at each specific schooling level, testing indicated that change over time is also best modelled with semiparametric regressions. Successive sets of semiparametric generalised additive models with restricted maximum likelihood (REML) smoothing were conducted for each statistically distinct schooling strata (Keele 2008). Where model tested indicated that schooling strata were statistically

	Entry requirements		
Country	Age	When entry age must be met	School Calendar
Colombia	6.0	start of classes	February through November
D.Republic	6.0	31 August in admission year	August through June
Guatemala	6.5	start of classes	January through October
Haiti	6.0	31 October in admission year	September through June
Mexico	6.0	31 December in admission year	August through June
Peru	6.0	31 March in admission year	March through December

Table 2.3: School calendar and age requirements for entry to the first year of primary

identical, the mean age for the identical schooling levels was estimated in the same regression model.

Finally, to speak to the theoretical underpinnings described in the introduction, the seventh analysis imputes the proportion of pregnancies leading to a first birth in adolescence that occurred before, after or coincided with school leaving. That is, it looks at how changes in the six countries studied speak to changes in the enrolment or aspirational aspects of schooling and adolescent fertility's relationship. In the absence of self-reported data on the age at which women leave school in the surveys, this study imputes each woman's age at school leaving based on each country's theoretical age for grade schedule, its school calendar, and a nine-month pregnancy (see Table 2.3 for details). In this case, the analysis does not model the year-on-year changes but instead estimates ten-year cohort averages. Given the heavy assumptions used in the pregnancy timing imputation, the averages seemed a more appropriate way to convey the greater uncertainty in this analysis than in the previous analyses. As such, the ten-year cohort averages broadly categorize adolescent conceptions into three types: conceptions that occur before, after and coincide with school leaving. Adolescent conceptions that occur prior to school leaving are those that occurred more than nine months before the woman's theoretical age at school leaving. Adolescent conceptions that occur after school leaving are those that occurred more than four months after the woman's theoretical age at school leaving, so as not to include pregnancies that might have taken place during summer holidays that kept a girl out of school who might otherwise have had plans to continue studying. Adolescent conceptions that coincide with school leaving are those that occurred between nine months before and three months after the imputed timing of school leaving. Admittedly, this imputation provides only a very rough estimate. Changes in schooling schedules and entry ages, as well as the very common occurrence of grade repetition and progression through school at non-standard ages, are not possible to determine from the data.

2.6 Results

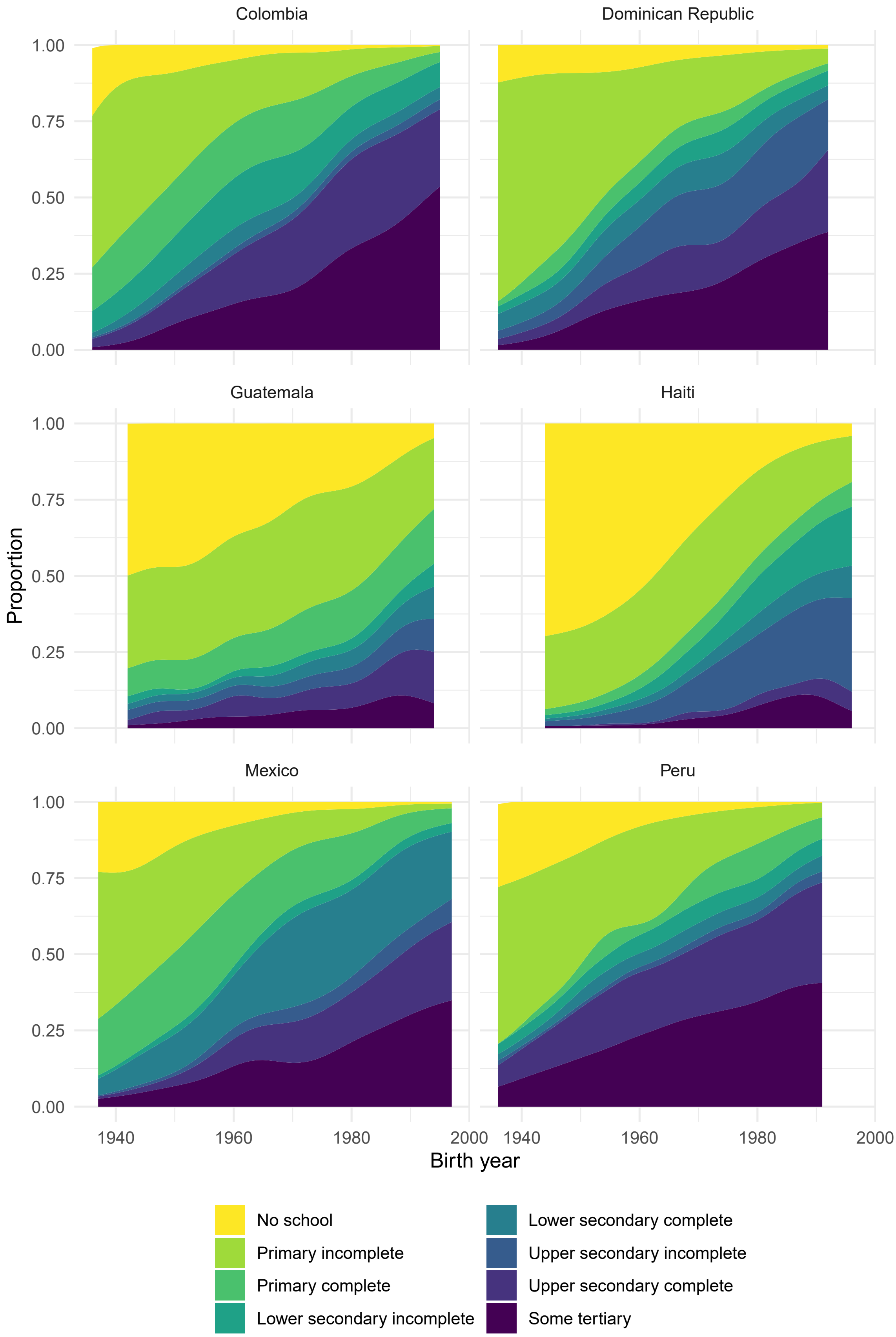
2.6.1 Schooling expansion

Results of the analysis of schooling expansion are depicted in Figure 2.2. The sweeping change is beautiful and impressive. Country differences are considerable, but in broad terms, in the earliest years, most women had no formal schooling or exited sometime during primary. A few decades later, most women reached secondary or higher. Specifically, among women born in 1944, the earliest birth cohort across all countries, between 68% (in Peru) and 95% (in Haiti) of women either had no schooling or finished sometime during the primary schooling years. For women born about five decades later in 1991, the latest birth cohort across all countries, between 51% (in Guatemala) and 91% (in Colombia and the Dominican Republic) reached secondary or higher. In looking closer at secondary and tertiary, the increase in tertiary attainment is laudable, but the largest proportion of women generally left school sometime during their secondary schooling careers. That is, tertiary attainment increased from between 1% (Guatemala and Haiti) and 12% (Peru) of women born in 1944 reaching university to between 10% (Guatemala and Haiti) and 47% (Colombia) doing so in 1991. Meanwhile, for secondary schooling in 1991, between 40% (Guatemala) and 59% (Mexico) of women left school during secondary. Only in Colombia did more women reach tertiary (47%) than left during secondary (44%) and only in Guatemala did more women have either no schooling or some primary schooling (50%) than left during secondary (40%) in the 1991 birth cohort.

Patterns of dropout and completion at each level are also telling, and trends suggest that for the most part, an increasing proportion of women are attaining certificate levels, though with substantial variation across countries. Mexico offers a strong trend of certificate-year attainment in that lower- and upper-secondary complete carry much larger population segments than do lower- and upper-secondary incomplete. This indicates that most school departures occurred between levels rather than within levels. Haiti, on the other hand suggests the exact opposite where most school departures occurred within levels rather than after certificate years. In Colombia and Peru, most women who attained secondary schooling made it all the way to upper-secondary complete; there was less early school departure at lower levels. Finally, in the Dominican Republic and Guatemala, school departures seem more evenly spread between those who completed or did not complete a given schooling level.

In essence, all six countries saw sweeping improvements in the educational attainment of their female populations. Nevertheless, dramatic differences in the underlying schooling-specific composition of the populations across countries, particularly in terms of patterns of graduation and dropout, promise fruitful grounds for studying schooling-specific changes in adolescent fertility.

Figure 2.2: Educational attainment of female population by year of birth



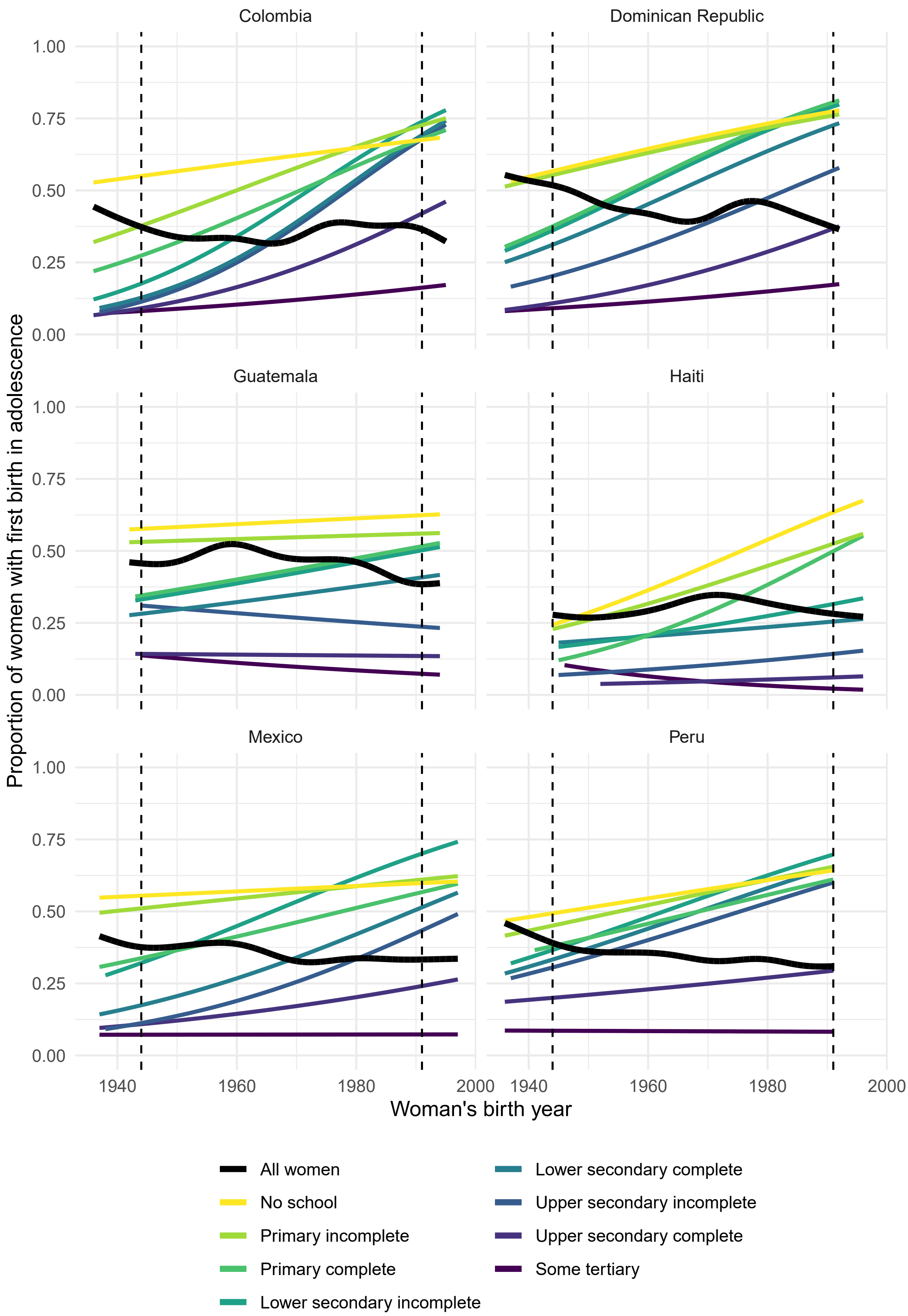
2.6.2 First births in adolescence

Results of the analysis of first births in adolescence are depicted in Figure 2.3. The contrast between population-level and schooling-specific trends is stark. Declines in the proportion of women with a first birth in adolescence at the population level (black lines) mask dramatic increases in the proportions within specific schooling levels (coloured lines). This seemingly counter-intuitive pattern cannot be understood without also considering the sweeping schooling expansions depicted in Figure 2.2. That is, while dramatic increases in first-birth likelihoods are seen for almost all of the specific schooling levels, increases at the population level were dampened by progressive — though at times uneven—advancement of the female population into higher schooling levels with comparatively lower risk.

Regarding the changing proportion of women who enter motherhood in adolescence across countries, the results indicate that between 28% (Haiti) to 52% (Dominican Republic) of all women entered motherhood in adolescence in the 1944 birth cohort. Nearly fifty years later, in the 1991 cohort, between 28% (Haiti) and 38% (Guatemala) of women had a first birth in adolescence. In most countries, population-level declines were quite modest and all six countries, to some extent, saw interruptions to their declines in adolescent fertility; that is, there was nonlinearity in the population-level trends. In fact, in Colombia and Haiti, fluctuations were such that the exact same proportion of women experienced a first birth in adolescence in the 1991 cohort as the 1944 cohort (37% in Colombia and 28% in Haiti). Mexico and Peru started out at similar proportions (38% and 39% respectively), but Peru saw greater decline. Specifically, Mexico's trends have been marked by stagnation, with 33% of women entering motherhood in adolescence for the past several decades. Peru's decline has been the steadiest of any country analysed, but it saw only about two percentage points per decade. The 1991 cohort in Peru (at 31%) was only slightly higher than Haiti's regional low of 28% of women entering motherhood in adolescence. Though the Dominican Republic started with the far highest proportion of adolescent first births (52%), it had the strongest decline even considering the reversals among birth cohorts in the 1970s. As such, the Dominican Republic did not have the highest proportion of the countries analysed in recent cohorts. Instead, Guatemala had the highest proportion (38%) and the Dominican Republic and Colombia both were tied for the next highest at 37% in the 1991 cohort.

Underlying the fairly modest changes at the population level in first births in adolescence are incredibly dramatic changes at schooling-specific levels. In broad strokes, higher levels of education consistently see lower adolescent fertility across countries and time whereas lower levels see high and increasing risk. In the earliest cohorts, the only schooling levels that saw more than half of women enter motherhood in adolescence were no school and incomplete primary. In the most recent cohorts, more than half of women experienced adolescent motherhood in practically every schooling level except upper secondary and tertiary. Interestingly, model testing suggested that schooling-specific trends were best described by linear terms, and thus did not see any nonlinear

Figure 2.3: Proportion of women with first birth in adolescence by attained schooling level



deviations seen in the trendlines at the population level.

But not all schooling levels saw increasing adolescent first births. Women who attained tertiary schooling in Mexico, Peru, Haiti and Guatemala did not see long-term increases in the incidence of first births in adolescence. In fact, the proportions declined in Haiti and Guatemala while in Mexico and Peru, the proportions remained unchanged. Additionally, in Guatemala, women who attained upper-secondary schooling (both complete and incomplete) also do not see long-term increases in adolescent first births. In contrast, in Colombia and the Dominican Republic, no education segment, not even tertiary, was resistant to long-term increases in adolescent first births. Ultimately, the proportions of women who reached tertiary schooling and had a first birth in adolescence ranged from 7% (Mexico) to 14% (Guatemala) in the 1944 cohort, and in the 1991 cohort, from 2% (Haiti) to 17% (Dominican Republic).

In looking at secondary schooling trends, Guatemala is the only country where women who reached upper-secondary schooling did not see increasing rates of adolescent fertility. However, in the other countries, upper-secondary generally saw less increase than lower-secondary, and graduates at every level saw less increase than dropouts. Interestingly, in almost every country in the earliest cohorts, upper-secondary graduates saw levels similar to tertiary attainers, but upper-secondary's proportions increased over time until, by the 1991 birth cohort, between 6% (Haiti) and 42% (Colombia) of upper-secondary graduates entered motherhood in adolescence. Still, the increasing incidence of adolescent motherhood for upper-secondary was not as intense as those at the other schooling levels below it. In fact, there was a strong pattern of convergence among women without schooling up through lower secondary attainment in most countries. That is, the spread between these lower schooling strata narrowed considerably over time, and in the most recent cohorts in these schooling strata, more than half and up two three fourths of women entered motherhood in adolescence. Indeed, the pattern of convergences emerges because the steepest increases occurred at lower secondary schooling (except in Haiti where the steepest increases were at primary schooling). Essentially, the general pattern across all countries was that lower-secondary saw the steepest increase in first births in adolescence, then primary, followed by upper secondary, then no school and finally tertiary with the least change.

Model testing confirmed that all education levels start at distinct proportions (distinct intercepts) and follow distinct rates of change (distinct slopes) over time in three countries: Haiti, Mexico and Peru. In contrast, in Colombia, upper secondary incomplete and lower secondary complete are indistinguishable; in Guatemala, lower secondary incomplete is not different from primary complete; and in the Dominican Republic, lower secondary incomplete and primary complete are indistinguishable, while primary incomplete is not different from no school in terms of their progression ratios to first births in adolescence. Note that in no case were complete and incomplete in the same schooling level indistinguishable. Instead, where strata were indistinguishable, it was always women with an incomplete schooling career where identical to the women who completed the level just below.

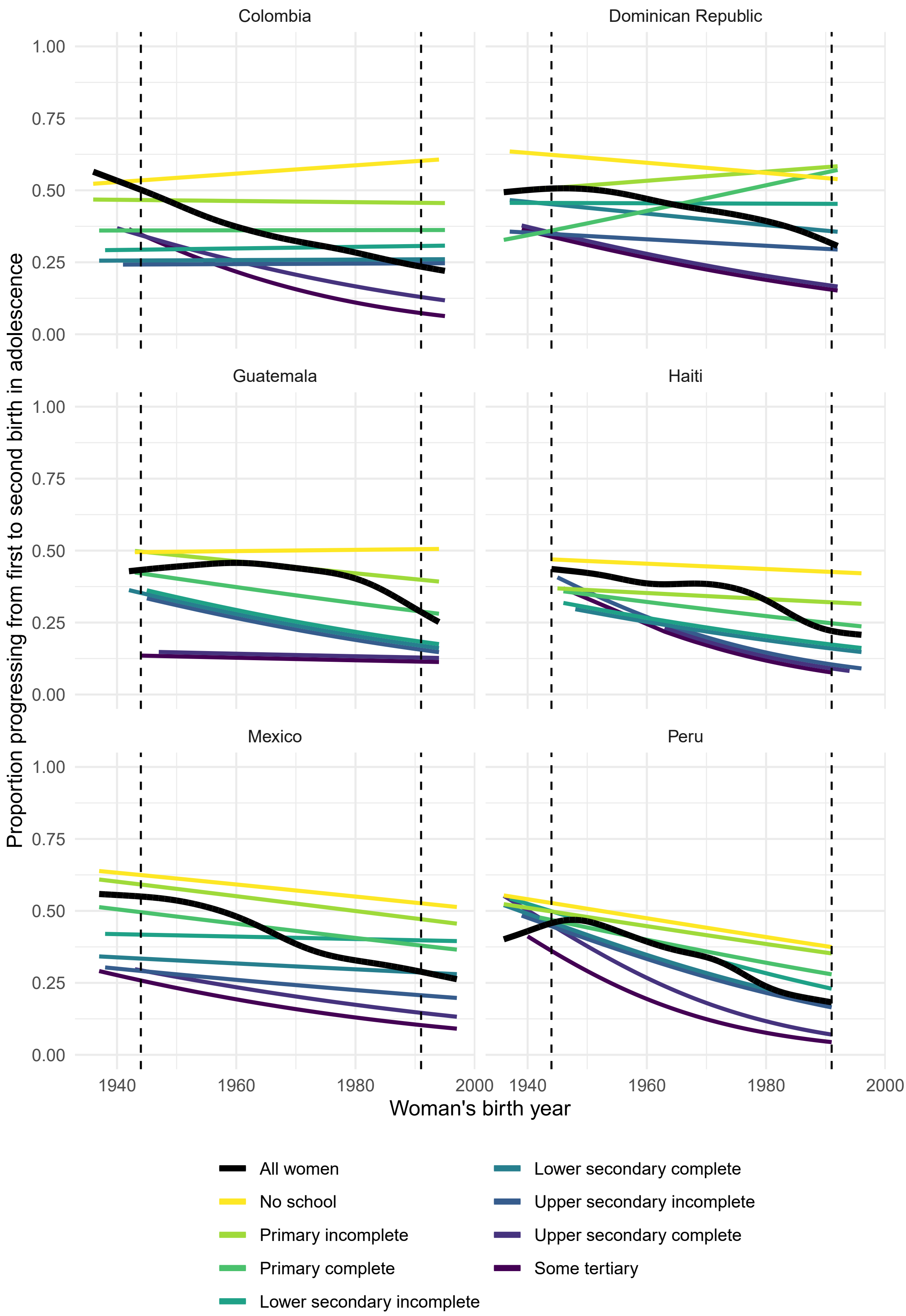
2.6.3 Progression to second adolescent births

Results of the analysis of progression ratios to second adolescent births are depicted in Figure 2.4. At the population level, declines in all countries were considerable, much greater in fact than the rather modest declines in first adolescent births. Indeed, in most countries, the 1991 cohort's ratio is at least half the 1944 cohort's ratio. Specifically, the 1944 cohort ratios span from 0.43 (Guatemala) to 0.55 (Mexico) and the 1991 ratios decline to 0.18 (Peru) to 0.32 (Dominican Republic). It is important to remember that progression ratios are conditional. While the ratio of all women progressing to a first adolescent birth is the same as the population proportion with a first birth in adolescence, the ratio of women progressing to a second adolescent birth is not the same as the proportion of the population with a second birth in adolescence. Instead, the ratio considers only women at risk of a second adolescent birth and refers to the proportion of existing first-time adolescent mothers who went on to have a second birth before turning twenty. Specifically, Colombia's 1944 cohort ratio of 0.50 means that 50% of women with a first birth in adolescence had a second birth before turning twenty, which falls to a ratio of 0.23 or 23% of adolescent mothers having done so by its 1991 cohort. In the earliest cohorts in all countries, these second adolescent birth progression ratios translate to about 20-25% of all women having had two or more births in adolescence while in more recent cohorts, around 10-15% did so.

The strongest population-level decline in progression to second adolescent births was seen in Peru, Colombia and Mexico. These three countries saw about a six percentage point decrease per decade. Haiti declined by an average of five percentage points per decade, the Dominican Republic by four and Guatemala by three (notice Guatemala's decades of stagnation). Although the Dominican Republic saw the strongest decline in first births, its decline in second birth progression was among the weakest, leaving the country with the region's highest progression ratio in the most recent cohorts. In contrast, Colombia and Haiti, which saw effectively no decline in first births, saw comparatively strong declines in second births. Colombia's decline was second only to Peru's, but because of Colombia's higher ratios in the early cohorts, its most recent ratios still rank slightly above those of Peru and Haiti. Finally, Mexico and Guatemala's ratios are identical (0.29) in the 1991 cohort after Guatemala's comparatively limited change and Mexico's decades of much greater decline.

Nevertheless, the schooling-specific patterns reveal a very different picture. Here again, model testing indicated that schooling-specific trends were best modelled with linear terms, and thus the trendlines did not see the dramatic nonlinear interruptions seen at the population level. Recall that for first births, it was broadly only women who attained tertiary that did not experience an increasing incidence of adolescent fertility. In contrast, for second births, many other schooling levels in addition to tertiary, saw declining progression to second adolescent births. However, declines in

Figure 2.4: Progression ratios from first to second birth in adolescence by attained schooling level



progression to second adolescent birth were not universal. In three countries, there are schooling levels that either saw increasing ratios or stagnation. These are in Colombia at the education strata of no school through upper secondary incomplete (that is, every level except tertiary and upper secondary complete); in the Dominican Republic, at primary complete, primary incomplete and lower secondary incomplete; and in Guatemala, at tertiary, upper secondary complete and no school. In every other country and at every other schooling level, there were declining second birth ratios, but the greatest declines occurred at the highest education strata, with declines attenuating progressively lower down the schooling ladder. Whereas women who reached tertiary schooling in the 1944 cohorts saw progression ratios between 0.14 (Guatemala) and 0.37 (Haiti), by the 1991 cohorts, those ratios were between 0.04 (Peru) and 0.15 (Dominican Republic).

Interestingly, for second birth progression ratios, upper secondary complete was generally as resistant as tertiary to change in second adolescent birth ratios. In the Dominican Republic, Guatemala and Haiti, the ratios for upper secondary complete were indistinguishable from tertiary, and in Haiti, this included upper secondary incomplete as well. In the remaining countries, the decline in upper secondary complete was nearly as strong as tertiary's decline and in fact, in Peru, the decline exceeded the pace of tertiary's decline. In contrast, in most countries, ratios for upper secondary incomplete were more similar to lower secondary schooling. Specifically, In Colombia, Guatemala and Peru, ratios for upper secondary complete and lower secondary incomplete were indistinguishable from each other, and in Guatemala, this included lower secondary incomplete as well. In Haiti, lower secondary complete and lower secondary incomplete were statistically identical. Model testing confirmed that all remaining schooling levels started at distinct proportions (distinct intercepts) and followed distinct rates of long-term change (distinct slopes).

It is important to emphasize how limited the change was at the lowest education strata, and when combined with an increasing incidence of first births among these groups, the picture becomes particularly alarming. In the earliest cohorts in some countries, these high progression ratios translated to as many as 35% of women in the lower schooling strata having had two or more births in adolescence, and this increased to as many as 45% in more recent cohorts.

2.6.4 Progression to third adolescent births

Results of the analysis of the progression to third births in adolescence are depicted in Figure 2.5. In proportional terms (but not always percentage point terms) declines in third adolescent birth ratios at the population level were greater than declines in second adolescent birth ratios. That is, in most countries, the 1991 ratios were more than half the 1944 ratios, but Guatemala's population-level pattern stands out for its almost total lack of decline until the 1980 cohorts. Recall that Guatemala's second adolescent birth progression ratios also saw stagnation over the same cohorts. In the 1944 cohorts, the third birth progression ratios ranged from 0.28 (Guatemala) to 0.41 (Mexico), and in the 1991 cohorts, they range from 0.08 (Peru) to 0.21 (Dominican Republic).

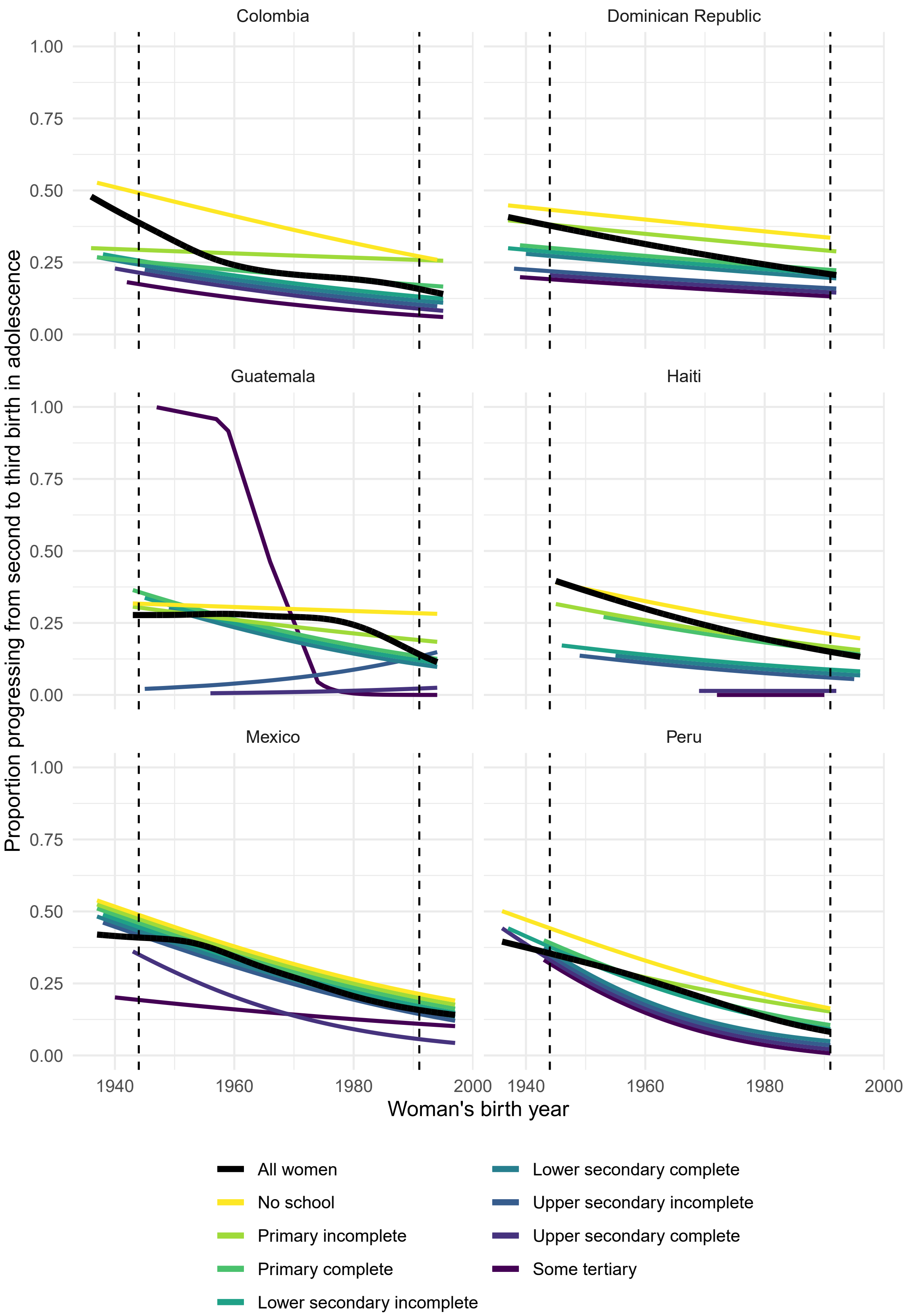
Again, these ratios are conditional. In the 1991 cohorts, between 8% and 21% of women with two births went on to have a third before the age of twenty in the six countries analysed, which translates to less than 3% of all women in the most recent cohorts having three or more births in adolescence. In the earliest cohorts, 5-10% of all women had three or more births in adolescence. Nevertheless, some of the lowest schooling strata see as many as 25% of women in the earliest cohorts with three adolescent births and as many as 15% in more recent cohorts.

In looking at schooling-specific change, most strata in most countries saw declines in third birth progression ratios. Only Guatemala had schooling strata that did not see declining ratios. Namely, upper secondary complete and upper secondary incomplete. In every other country and every other schooling level, the ratios declined over time. In contrast to second birth progression, the greatest percentage point decline is not seen in the higher education strata, but this is reasonable given that the lower strata had much higher starting points and greater room for decline.

Model testing reduced the eight original schooling levels to an average of four levels per country. Each country's collapsed education strata have a unique combination, but as a loose rule, secondary schooling levels generally cluster together more than the higher and lower schooling levels. Additionally, in Haiti and the Dominican Republic, the rate of change over time in all the education strata is indistinguishable (identical slopes) though the starting ratios are different (distinct intercepts). The remaining countries see both distinct rates of change and distinct starting ratios for their schooling-specific third birth ratios. In the 1944 cohorts, the highest ratios range from 0.39 (Haiti) to 1.00 (Guatemala), and in the 1991 cohorts, the highest ratios are between 0.16 (Peru) to 0.33 (Dominican Republic). Guatemala's unusual ratio for women who reach tertiary reflects a few early cases of university attainers all with third birth progression, switching to more cases in later cohorts all without third birth progression. As with previous analyses, model testing suggested that schooling-specific trends were monotonic (even Guatemala's tertiary trend is a linear regression term), and as such did not see the nonlinear interruptions seen in some of the trendlines at the population level.

While there are cases of fourth and higher-order births in adolescence (analysis not shown), the occurrence was rare. Between 1% (Guatemala) and 3% (Dominican Republic and Mexico) of women had four or more adolescent births in the early cohorts, and this fell to an estimated 0.04% (Peru) to 0.3% (Dominican Republic) more recently. Small sample sizes, particularly when categorised into schooling levels, introduced extreme uncertainty into the models of this higher-order progressions, but the patterns echo the near universal decline seen in progression to third births. Again, refer to tables in Appendix A to see sample size by country, parity and schooling level.

Figure 2.5: Progression ratios from second to third birth in adolescence by attained schooling level



2.6.5 Average adolescent births per woman

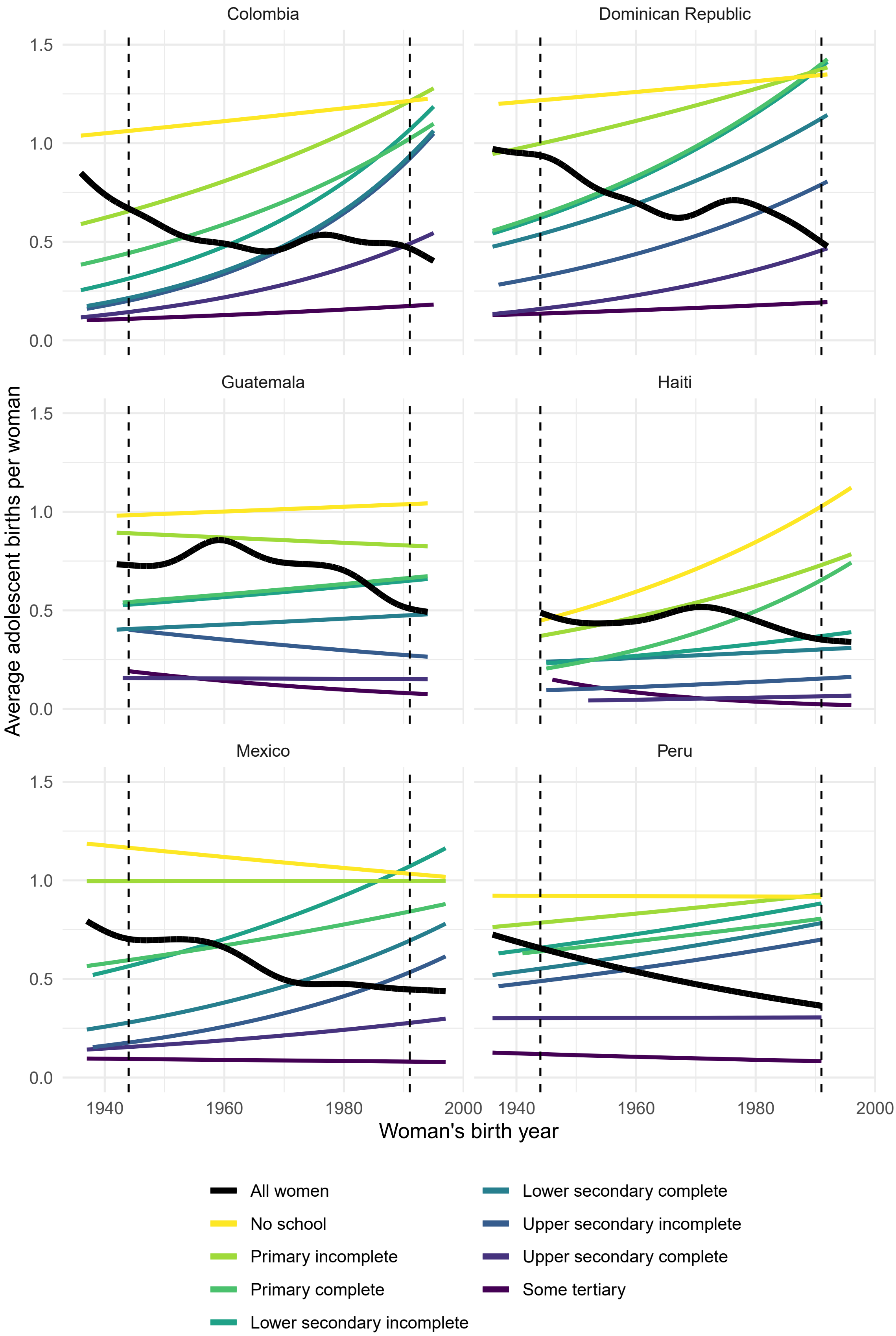
The conditional nature of parity progression ratios make it difficult to see how cumulative adolescent fertility played out in each country and at each schooling level. To address this, Figure 2.6 depicts the results of the analysis that summarizes cumulative adolescent fertility. That is, it estimates the average number of adolescent births per woman, or the average number of births all women had before turning twenty. The population-level estimates find that in the 1944 cohorts there were between 0.49 (Haiti) to 0.94 (Dominican Republic) adolescent births per woman on average, and in the 1991 cohorts, between 0.35 (Haiti) and 0.51 (Guatemala) adolescent births. Guatemala and the Dominican Republic see the highest cumulative adolescent fertility in the 1991 cohorts (0.51 and 0.50 respectively), followed by Colombia and Mexico (0.47 and 0.45) with Peru and Haiti (0.36 and 0.35) with the lowest average adolescent births per woman. Each country's population-level change over time strongly echoes the nonlinear trends seen in the first adolescent birth ratios. However, in this case, all countries see more decided decline over the long term, thanks to the declines in higher-order adolescent births. Notably, Colombia and Mexico's most recent decades have seen relative stagnation, and Peru's almost perfectly linear decline stands out against the fluctuations seen in other countries.

Importantly, the trends at each specific schooling level tell a slightly different story from the parity-specific trends examined previously. Again, the seemingly contradictory population-level declines alongside a backdrop of schooling-specific increase cannot be understood without accounting for the changing educational composition of the female population over time. Impressive increases in the numbers of women and girls attaining to progressively longer schooling careers generally outpace the increasing risks of adolescent fertility at specific schooling levels. As such, cumulative adolescent fertility at the population level is able to decline (though with exceptions) while cumulative adolescent fertility at most specific schooling levels sees dramatic increase.

In looking closer at the changes for specific schooling levels, recall that only Haiti and Guatemala saw declines in adolescent first births among tertiary attainers, but now Mexico and Peru—thanks to declines in higher-order births despite no change in the proportion with first births in adolescence—also see declines in average adolescent births among women who attain tertiary schooling. In Colombia and the Dominican Republic, declines in higher-order births among women who reach tertiary schooling substantially reduced but did not completely cancel out increasing adolescent first births in this schooling strata. That is, the cumulative adolescent fertility of these women increased over time, albeit only slightly. Across the region, women who reached tertiary schooling averaged between 0.09 (Mexico) and 0.19 (Guatemala) adolescent births per woman in the 1944 cohorts and between 0.02 (Haiti) and 0.19 (Dominican Republic) adolescent births in the 1991 cohorts.

Declines in cumulative adolescent fertility were also seen among women who complete upper secondary in some countries. Recall that only in Guatemala was upper secondary complete immune

Figure 2.6: Average adolescent births per woman by attained schooling level



to increasing adolescent first births. For average adolescent births, declines were seen in upper secondary complete in Haiti, as well as in Guatemala. Additionally, in Peru, the increase in upper secondary complete was exceptionally small (0.003 percentage points over nearly five decades), meaning that the increase in first adolescent births in that education strata was almost entirely cancelled out by the declines in higher-order births.

The role of declining higher-order births is particularly important for cumulative fertility trends among the lower education strata. Interestingly, a few of the lowest schooling strata also saw declines in average adolescent births. This happened for women without schooling in Peru, for women with primary incomplete in Guatemala, and women with no school and primary incomplete in Mexico. Nevertheless, women in these lower education strata still had alarmingly high cumulative adolescent fertility, at about 1.0 births per woman, so the declines in cumulative fertility offer only limited consolation.

The convergence seen in first adolescent births among the lower schooling strata is less pronounced in average adolescent births. For example, while primary incomplete and no school were indistinguishable in models of first adolescent births in the Dominican Republic, in cumulative adolescent fertility, they remained distinct. However, upper secondary complete and lower secondary complete in Colombia and lower secondary incomplete and primary complete in the Dominican Republic and Guatemala, are not different from each other in cumulative fertility nor in first birth models. Otherwise, every remaining schooling level followed a distinct rate of change (distinct slope) and started from a distinct average number of adolescent births (distinct intercept). Again, across the region, some schooling-specific averages remained astonishingly high. The 1991 cohorts' highest estimates ranged between 1.0 (Haiti, Guatemala and Mexico) and 1.4 (Dominican Republic) average adolescent births per woman. Peru is the only country where every schooling level remained consistently below 1.0 average births, but only just, with its high reaching 0.93 births in the 1991 cohort.

Almost as a rule, lower secondary and upper secondary dropouts saw steeper increases than their graduating counterparts in average adolescent births. For primary schooling, it was the opposite. Primary graduates saw much steeper increases than primary school dropouts. Additionally, women who reached lower secondary generally saw the steepest increases in cumulative adolescent fertility, followed by those reached primary school, then upper secondary, then those who had no schooling. Here again, model testing found that schooling-specific averages were consistently monotonic in their rate of change, which differs from the more nonlinear changes seen in schooling expansion and thus the population-level average adolescent births per woman.

2.6.6 Mean age at first adolescent birth

Results of the analysis of the mean age at first adolescent birth are depicted in Figure 2.7. It is important to note that this analysis does not consider age trends in first births across the entire female population but instead only among those with a first birth before the age of twenty. At the population level, the average age at first adolescent birth was quite similar across all countries. It ranged from 17.2 (Haiti) to 17.6 (Peru) in the 1944 cohorts and 17.4 (Dominican Republic) to 17.9 (Mexico and Peru) in the 1991 cohorts. In all countries, the average age increased over the long term, but Colombia and the Dominican Republic stand out for their relative stagnation. In fact, in Colombia, the average age at first adolescent birth has been declining since the birth cohorts of the 1960s.

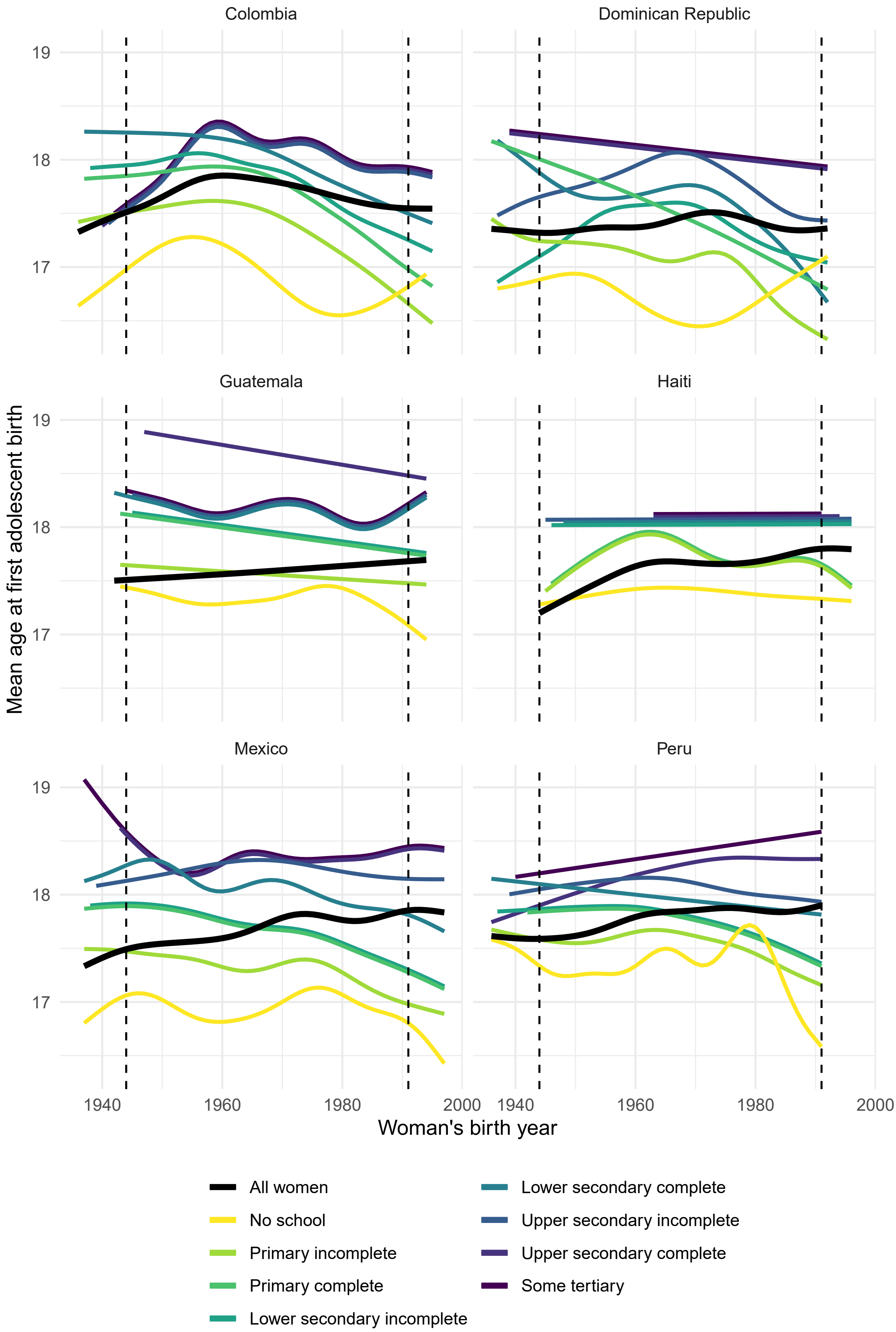
In contrast to the increasing mean age at first adolescent birth in the population, schooling-specific mean ages generally declined, and in some countries, particularly for no school, primary and lower secondary attainers, the decline is considerable.

Interestingly, the average age at first adolescent birth at the population level has remained, for the most part, very close to the theoretical terminal age for upper secondary even in spite of declines. That is, the mean age at first adolescent birth is just above age 17 and upper secondary schooling ends at age 16 in Peru and Colombia and at age 17 in Mexico, Guatemala and the Dominican Republic. (In Haiti upper secondary schooling ends at age 18.) Additionally, schooling careers that end with lower secondary are largely finished in the first half of adolescence (age 14 in most countries), while primary is largely finished by age 11. Even with the long-term declines in average age at first adolescent birth in the lower schooling strata, these groups still generally saw mean ages remain above age 17. What this all suggests is that there is little potential overlap between schooling and fertility for all but upper secondary and tertiary schoolgoers.

Nevertheless, the declines have important implications for high-order adolescent births. Most importantly, it has meant that within most schooling levels the average duration of exposure to the risk of higher-order adolescent births did not diminish. As such, adolescent mothers generally had more time on average for additional childbearing in adolescence, but this did not generally translate to more second and third births to adolescent mothers. Recall that in a few countries, a few education strata did see increasing progression to second adolescent births, but for the most part, the lower schooling levels (generally those up through lower secondary) either saw no change or very modest declines in progression to second adolescent births. Meanwhile, declines for third births were generally much stronger and occurred at most schooling levels.

Finally, schooling-specific changes in mean age did not generally show linear time trends, and model testing preferred semiparametric regressions. The nonlinearities indicate strongly that in most countries, the schooling-specific declines in mean age at first adolescent birth have largely occurred within more recent decades, and earlier decades saw more stability in mean age. Addi-

Figure 2.7: Mean age at first adolescent birth by attained schooling level



tionally, model testing indicated that many schooling levels shared the same mean age. Patterns here were very distinct from those seen in fertility trends. That is, mean ages within each schooling level's completers and incompleters tended to be more similar than not. Furthermore, the highest schooling levels often shared similar mean ages, even when their adolescent birth progression ratios differed. In contrast, some of the lower schooling levels had differing mean ages even with their progression ratios were indistinguishable.

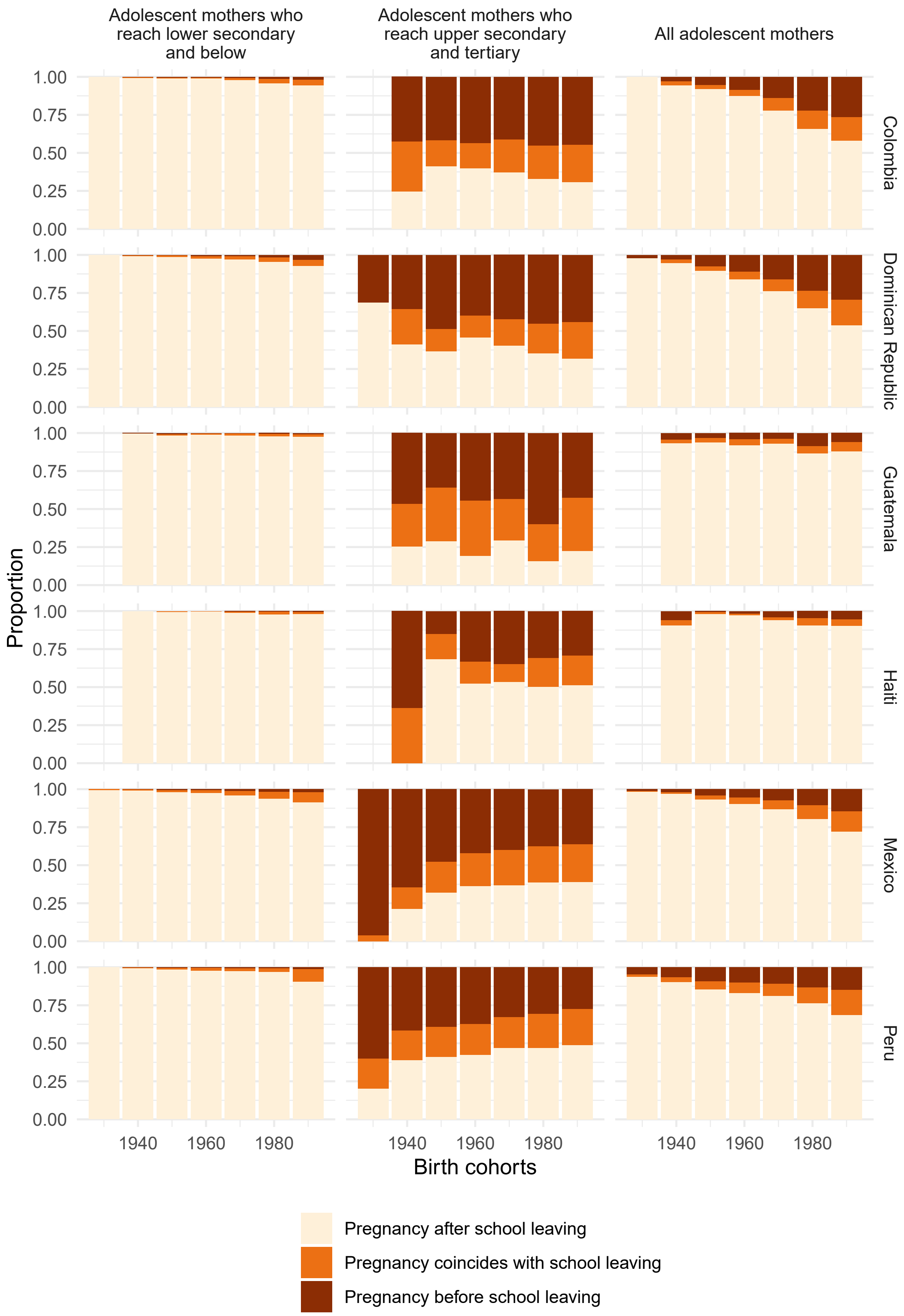
2.6.7 Imputed timing of conception and school leaving

Figure 2.8 depicts the results of the imputed adolescent first birth conception timing relative to school leaving. Results are depicted for three groups of adolescent mothers in each country. The first group is adolescent mothers in the lowest schooling strata: those with no formal schooling, those with primary schooling, and those who attained lower secondary schooling. The second group is adolescent mothers in the highest schooling strata: those who attained upper secondary and those who attained tertiary schooling. The third group includes all adolescent mothers and reflects changes at the population level. Remember that these estimates only offer very rough approximations given that they impute each woman's age at school leaving based on each country's theoretical age for grade schedule, its school calendar, and a nine-month pregnancy for each adolescent mother. Adolescent conceptions considered to have occurred after school leaving are those that occurred more than four months after the woman's theoretical age at school leaving. Adolescent conceptions considered to have occurred prior to school leaving are those that occurred more than nine months before the woman's theoretical age at school leaving. And adolescent conceptions considered to have coincided with school leaving are those that occurred between nine months before and three months after the imputed timing of school leaving.

Changes at the population level (among all adolescent mothers) were quite dramatic. Nearly all adolescent first births were conceived after women had left school in the earliest cohorts. Over time, the proportion diminished—in most countries quite markedly. The large proportion of conceptions that occurred prior to school leaving in recent decades in Colombia and the Dominican Republic is particularly noteworthy. Nevertheless, the majority of adolescent pregnancies across all cohorts in all countries have occurred after girls already left school.

Recall that the analysis on changes in mean age at first adolescent birth found that the average age at first adolescent birth has remained close to the theoretical terminal age for upper secondary. Additionally, the average age at first adolescent birth in the lower schooling strata was several years above the theoretical finishing ages for these schooling levels. These two findings indicate that among the lower schooling levels, there is likely little overlap between schooling and fertility. Instead, the overlap is likely concentrated among upper secondary and tertiary attainers. Indeed, Figure 2.8 supports this hypothesis. As seen in the figure, more than 95% of pregnancies to adolescent mothers with lower secondary schooling or below in each cohort occurred after the girl

Figure 2.8: Pregnancy Timing: whether conceptions that result in a first adolescent birth occur before, after or coincide with school leaving, by schooling level



had left school. In contrast, 25-50% of pregnancies to girls who reached upper secondary and tertiary occurred after the girls had left school, with the remaining 50-75% of pregnancies having coincided with school leaving or occurring before the girl left school.

Two aspects of the schooling-specific imputation are particularly surprising. First, in most countries, there are no pronounced patterns of change over time, except in Mexico and Peru where the portion of pregnancies occurring before school leaving among upper secondary and tertiary attainers diminishes slightly. (Ignore the earliest decade(s) when limited numbers of cases translate to high uncertainty in the estimated proportions.) This strongly suggests that the growing number of in-school pregnancies in the populations are more a manifestation of the changing educational composition of the female population than the result of underlying changes in adolescent fertility timing associated with each educational strata. That is, a growing proportion of women have reached upper secondary and tertiary schooling where their adolescent pregnancies are more likely to occur during their educational careers. However, among the segment of girls who attain upper secondary and tertiary, there are no exceptionally dramatic changes in their adolescent fertility timing. Similar proportions are conceiving after school leaving, conceiving at the time of school leaving and conceiving before school leaving, respectively, in recent cohorts as were in early cohorts. The absence of any marked change is especially interesting in Colombia and the Dominican Republic. Recall that Colombia and the Dominican Republic were the only two countries that saw increasing adolescent first birth ratios among women with tertiary schooling.

The second surprising finding is that in all countries, a larger number of pregnancies are imputed to have occurred before girls left school than coincided with school leaving. The occurrence of adolescent mothers in the region remaining in school or returning to school after a birth is not widely studied. In most cohorts, in fact, about twice as many pregnancies occurred before school leaving as occurred around the time of school leaving. When also considering that 25-50% of pregnancies occurred after school leaving, this finding suggests that adolescent pregnancies have not spelled the end of girls' educational careers for a heavy majority of cases over the last half century—though this does not preclude adolescent pregnancies from truncating what otherwise might have become of those schooling careers.

2.7 Summary and Discussion

This study has sought to conduct a thorough accounting of long term, parity-specific and educationally nuanced demographic trends in adolescent fertility in six Latin American and Caribbean countries. The study has looked at higher-order adolescent births, distinguished between upper and lower secondary, and separated graduates from dropouts at all schooling levels, all of which have not been done before and which contribute vitally to understanding the population change. The aim of the accounting was two-fold. First, it sought to untangle, in basic mechanical terms, how the region has maintained such high levels of adolescent fertility in the face of its educational expansion. Second, the accounting was meant to speak to a broader theoretical question about the relationship between schooling and fertility timing.

The accounting has assembled the puzzle pieces of the region's high adolescent fertility: underlying the stubborn persistence of high levels of adolescent fertility in Latin America and the Caribbean are dramatic schooling- and parity-specific changes. In broad strokes, modest declines and stagnation in the proportion of women who enter motherhood in adolescence at the population level is the result of an increasingly educated female population who have experienced dramatic increases in the proportions with first adolescent births at each specific schooling level—except, in most cases, among women who reach tertiary schooling. In contrast, strong declines in progression to second and third births in adolescence at the population level are the result of an increasingly educated female population moving to educational strata that not only have lower progression ratios but also have seen strong declines in higher-order adolescent births among those at risk. While limited case numbers at the highest parities and schooling levels, particularly in Guatemala and Haiti, add uncertainty to the estimates, the broad patterns echoed across countries add confidence to the findings. The interlocking fertility patterns have occurred alongside fascinating changes in the timing of adolescent births. In most educational strata, the mean age at first adolescent birth has become slightly younger, but this has not necessarily translated to greater interruptions to schooling careers within each schooling level. Indeed, these findings on the changes in the timing of adolescent births are key to addressing the broader theoretical implications, which have remained so far largely untouched in the presentation of the results.

Earlier, this study argued that little theoretical work exists on the relationship between schooling and the timing of fertility. In the absence of such theory, it draws from empirical findings to classify the relationship into two fundamental actors: patterns of enrolment and patterns of aspirations. Enrolment patterns matter because causal evidence finds that the time adolescent girls and women spend enrolled and present in school reduces their fertility (that is, it contributes to childbearing postponement). Aspirational patterns refer to the causal evidence that finds that schooling can lead to childbearing postponement and lower fertility even after adolescent girls and women are no longer attending classes. This categorisation of the relationship between schooling and fertility timing into enrolment and aspirational patterns adds vital clarification to the demographic puzzle examined in this study. In effect, the findings suggest that over the long term, adolescent fertility's link with enrolment has remained fairly unchanged while aspirational changes, in contrast, have been considerable.

In regards to constancy of the link with enrolment, recall that in spite of increasing proportions of women experiencing a first birth in adolescence (and at slightly younger mean ages) within most schooling strata, first births occurred, for the most part, after adolescents had already left school. Even first births that occurred to adolescents who reached upper secondary and tertiary schooling saw little effective change in the timing of those births with regards to school leaving. Tellingly, tertiary schooling, which is the only educational trajectory that lasts through the entirety of adolescence, is the only schooling level that has remained largely immune to increasing adolescent fertility. Essentially, the incidence of adolescent births that occurred while a girl was enrolled and present at school remained equally rare throughout the entire five decades analysed. Put differently, school enrolment's apparent ability to reduce fertility was as effective in the most recent cohorts as it was in the earliest cohorts.

Other research also finds that most adolescent mothers in the region leave school prior to conception (Flórez and Soto 2007). In South Africa, a context not far different from Latin America and the Caribbean's high adolescent fertility and relatively high levels of education, sees many adolescent mothers, particularly those who remain unpartnered and belong to higher socio-economic strata, eventually returning to school and catching up in accumulated schooling years with their childless peers (Grant and Hallman 2008b; Madhavan and Thomas 2005; Ranchhod et al. 2011). In Latin America and the Caribbean, existing research suggests that the adolescent mothers who stay in school or return to it do so largely because of support from their families (not partners), are younger at the time of the birth, and are from better-off socio-economic strata (Näslund-Hadley and Binstock 2011). Importantly, a study in Peru and Paraguay finds that adolescent mothers who do manage to stay in school are just as likely to continue to tertiary or graduate from secondary as women who wait to enter motherhood in adulthood (Näslund-Hadley and Binstock 2011). But in the high-income settings where it has been tested, a mother's schooling acquired after her child is born does not have the same intergenerational returns as schooling acquired before (Augustine and Negraia 2018), and a mother's age at birth is consistently predictive of how much schooling her child will complete (Duncan, Kalil, and Ziol-Guest 2017).

In regards to the pregnancies that coincide with school leaving, it does not necessarily follow that the pregnancies cause school dropout (McQueston, Silverman, and Glassman 2012). Instead, the relationship between adolescent fertility and school leaving is complex. Union formation, financial constraints, disenchantment with school, low performance, and poor quality lead many adolescents out of school before pregnancy, while for others, pregnancy simply adds a final excuse for leaving (McQueston, Silverman, and Glassman 2012; Näslund-Hadley and Binstock 2011; Sanchez et al. 2006).

While the ability of school enrolment to postpone fertility seems to have remained unchanged, what occurs after girls leave school—the aspirational aspect of each schooling level in regards to the timing of fertility—has radically transformed. In essence, the middle schooling levels that were once fairly elite, lost their selectivity and became different from the lowest schooling levels in terms of first births in adolescence. Essentially, the middle education strata saw the greatest increases in the incidence of first birth in adolescence, so much so that they effectively shared the same patterns as women with no formal schooling at all in recent cohorts. This repositioning of the social hierarchy was examined in two of the four previous studies looking at the demographic puzzle of adolescent fertility in the region (Batyra 2020; Esteve and Florez-Paredes 2014). The studies demonstrated that when adolescent first birth trends are categorised based not on their absolute schooling levels but on relative schooling positions, patterns have changed very little. The primacy of relative, rather than absolute, position is echoed in economic research that has also found that as schooling has expanded in the region, there have been declines in the marginal effects of schooling on women's autonomy and labour market rewards (Bol 2015; Urbina 2022). The studies argue that the meaning of schooling is shaped by the woman's relative position in the educational distribution of her cohort—that is, the positional value of education takes precedence over absolute skill levels.

Additionally, qualitative research repeatedly finds that many adolescent mothers lack other life plans and aspirations (such as further education) that would conflict with motherhood, and as such, they do not feel their fertility interrupts anything (Azevedo et al. 2012). The research also finds that adolescents in the region often doubt that additional schooling will translate to improved employment opportunities (Azevedo et al. 2012). But it is important to emphasize that the aspirational formulation is not meant to demean adolescent mothers, nor imply that their fertility is the result of their own lack of vision or ambition. Indeed, it is hard to imagine how restrictive gender norms, high levels of inequality, low levels of female employment, and widespread economic hardship and violence in the region can do anything but obstruct girls' opportunities and curb their perception of what dreams are attainable.

Nevertheless, for second and third births in adolescence, aspirational differences meant that the middle education strata supplied important protection that the lowest schooling levels did not. Namely, secondary schooling saw much stronger declines in progression to higher-order adolescent births than did primary and no school, meaning that cumulative adolescent childbearing of all educational strata remained distinct. A number of possible underlying trends could be at play, which have not been possible to explore here. This study's interest in long-term trends mean that other characteristics such as wealth and urban or rural residence, as well as partnership dynamics, sexual activity, fertility intentions could not be included in the models because the data capture a woman's status at the time of the survey, not at the time of her adolescent birth(s). In other research, these elements find strong educational gradation in adolescent fertility (Ali, Cleland, and Shah 2003; Bozon, Gayet, and Barrientos 2009; Di Cesare and Rodríguez Vignoli 2006; Esteve, García-Román, and Lesthaeghe 2012; Esteve, Lesthaeghe, and López-Gay 2012; Flórez 2005; Fussell and Palloni 2004; Glick, Handy, and Sahn 2015; Kravdal 2002; Kulczycki 2011; Vignoli 2017).

Changes in the region's patterns of marriage and cohabitation are also relevant. Having a partner dramatically heightens the risk of adolescent fertility and, conversely, becoming pregnant intensifies transitions to union formation (Grace and Sweeney 2014). Adolescent pregnancy rates are higher for those who have formed a union than those who have initiated sex but not formed a union (Covre-Sussai et al. 2015; Flórez and Soto 2013). In much of the region, the mean age of union formation has decreased, except among the most educated, with increasing rates of cohabitation more than offsetting declines in marriage (Castro Martin 2002; Castro Martín et al. 2011; Núñez and Flórez 2001). Relatively modest increases in adolescent fertility outside of a union have been found mostly among the oldest adolescents and those from the higher socio-economic strata (Flórez 2005; Flórez and Soto 2007; Núñez and Flórez 2001), who are also more likely to live in extended or composite households that provide more support for coping positively with single motherhood (Esteve, García-Román, and Lesthaeghe 2012).

Much of the changes that fall under the aspirational lens could simply reflect the changing demographic composition of each education level. That is, on the aggregate, the benefits of expanded education in the region have not been enough to overcome the continued influence of disadvantaged backgrounds seen among girls who are making it to higher levels of education in increasing numbers. The trends in adolescent fertility echo patterns seen in research on economic and educational inequality in Latin America. Research argues that educational expansion in Latin America has contributed to increasing inequality in schooling access, learning outcomes and earnings differentials (Behrman, Duryea, and Szekely 1999; Paes de Barros et al. 2009; Torche 2010). On the one hand, this study's results indicate that higher schooling levels are consistently associated with lower adolescent fertility across countries and time. Additionally, tertiary—the highest schooling level—has seen the least change in its incidence of adolescent fertility. Economic research finds that not only is Latin America the region with the most extreme inequality in the world, but its inequality has the unique quality of an asymmetric pattern of intergenerational persistence of class immobility at the top (Torche 2012). That is, it is characterised by strong reproduction at the top of the socio-economic hierarchy and more fluidity across the middle and lower segments. Particularly in education, the greatest gains (and least setbacks during economic crisis) have been among the wealthy and the greatest losses have been among the poor (Torche 2012). On the other hand, this study' results find a pattern of convergence among the lower schooling levels in their incidence of adolescent fertility, with the steepest increase in risk among those who attain lower secondary schooling. Here again, the economic research points to the stickiness of profiles of socio-economic disadvantage among these groups. That is, research suggests that improvements in access to schooling have been driven exclusively by gains at lower schooling levels. Though higher schooling levels have also seen expanded access, conditional access to the higher schooling levels has not improved. Conditional access refers to transition rates to a subsequent schooling level conditional on completion of the preceding level. Patterns in Latin America have meant that for many decades an increasingly select portion of lower secondary graduates were able to continue to upper secondary, just as an increasingly select proportion of upper secondary graduates continued to tertiary. Put differently, the influence of social origins on the probability of transitioning to secondary and tertiary schooling increased dramatically over the decades where data allow its study, the 1980s and 1990s and in some cases even in the 2000s (Marteleto et al. 2011; Torche 2010). Taken together, these findings suggest that only girls with the most privileged socio-economic profiles have been attaining tertiary schooling over the decades while the changing demographics of girls at all other levels have introduced greater risk of adolescent fertility.

Issues of the quality of schooling and availability of comprehensive sexuality education have also not been addressed but likely play an important role in influencing the formation and attainment of adolescents' fertility aspirations (Azevedo et al. 2012; Panchaud et al. 2019). Ultimately, differences in cumulative adolescent fertility within each schooling strata suggest for instance, that adolescents' take-up of effective contraception after a first birth see education-differentiated access barriers or education-differentiated partnership and family-formation intentions (Kroeger, Frank, and Schmeer 2015). Importantly, declining mean ages at first birth at many schooling levels, as estimated in this study, have meant that many adolescents have had more time on average for subsequent teen births, but this has not lead to a higher incidence of second and third births in adolescence within each strata. That is, there have been behavioural changes within educational strata that have enabled adolescents to postpone second births, but not necessarily first births.

The uniqueness of upper secondary complete became particularly apparent when considering additional adolescent childbearing. Though upper secondary complete was not as resistant as tertiary to increasing first births adolescence, there was little difference between upper secondary complete and tertiary in progression to higher-order adolescent births. As such, fertility patterns for upper secondary complete, were fundamentally different from lower secondary. Interestingly, health research is beginning to indicate that many of schooling's myriad benefits on health see a threshold effect; that is, the greatest benefits emerge at upper secondary schooling (Patton et al. 2016).

This study's finding that the middle schooling levels have seen the greatest increases in first adolescent births contrast with other research that finds that the lowest schooling levels have seen the most increase in adolescent fertility, but likely only because other research did not separate upper secondary from lower secondary, nor did it distinguish graduates from dropouts (Esteve Palós and Florez-Paredes 2014). This study's findings also add potential for refinement in other research in the region that finds that secondary schooling levels have seen the greatest declines in mean ages at first sex and at first birth (Bongaarts, Mensch, and Blanc 2017). Additionally, distinctions between upper and lower secondary could also translate beneficially to other parts of the globe where, for example, a recent study in Malawi (Grant 2015) finds that the greatest increases in adolescent fertility have occurred at secondary schooling levels. Ultimately, the value of separating secondary schooling levels into their substantively relevant divisions cannot be overstated. For most of the decades observed in this study, the largest proportions of women finished their formal education careers sometime during secondary schooling where adolescent fertility change has been most dramatic. Again, patterns of adolescent fertility for those who reach lower secondary have been very different from those who reach upper secondary.

At first glance, finding that lower secondary, rather than the education strata below it, have seen the most increase in adolescent fertility is puzzling. In other contexts it seems the negative selectivity of those left behind works strongest for the least schooled who see the greatest increase in early fertility (Berrington, Stone, and Beaujouan 2015; Raymo et al. 2015), while those who benefit most from higher education levels are those least likely to attend (Brand and Davis 2011). But the negative selectivity can work the other way. Higher education strata become less elite while the fertility patterns of the lowest strata remain largely unchanged (see Brzozowska 2014 for a Polish example). This is substantiated in the study's findings that the adolescent fertility patterns of each schooling level's dropouts are more closely aligned to the fertility of the school level just below, rather than with the graduates of the same schooling level. Indeed, diminishing returns to education are found to explain changing adolescent fertility patterns in Brazil (Gupta 2000) and the rapid educational expansions may reasonably lead to differentiated changes in returns to education, with the greatest change to those segments receiving the greatest influx of less elite students.

Additionally, nuances between the adolescent fertility trends of those who complete and do not complete each schooling level supports enrolment and aspirations distinctive influence on fertility timing. In terms of changes in mean age at first adolescent birth, graduates and dropouts in the same schooling level saw the most similar ages, and this makes sense as their time enrolled in school would have been similar. In contrast, the schooling-specific incidence of adolescent births saw a different pattern, one that speaks to certificate years having a differentiated aspirational impact on fertility than incomplete schooling careers. That is, the fertility of dropouts was more similar to the graduates of the level below than to the graduates of their same schooling level. Here, the more favourable life circumstances or greater interest in schooling of girls who are able to complete a certificate year in school also seems to translate to more ubiquitous or attainable aspirations of fertility postponement.

It is also important to note that the link between aspirational changes and fertility timing is considerably different in each country. Adolescent fertility intensities do not neatly coincide with the relative education rankings of the six countries. With cumulative adolescent fertility, for example, there are sizeable and unexpected differences. Though Haiti and Guatemala have the least schooled populations, Haiti consistently has the lowest cumulative adolescent fertility and Guatemala ended with the highest despite starting out with one of the lowest first birth progression ratios in the earliest cohorts. Colombia and Peru claim the most schooled populations, but while Peru's cumulative adolescent fertility is nearly as low as Haiti's in the recent cohorts, Colombia's is not far behind Guatemala's regional high. Mexico's early cohorts have the region's highest first birth progression, but relatively strong fertility declines put its recent cumulative adolescent fertility below

Colombia's. Despite still having more first births in adolescence than Colombia in recent cohorts, Mexico's lower second birth progression ratios drive the difference. Finally, though the Dominican Republic sees the region's highest proportion of women entering motherhood in adolescence in recent cohorts, its progression to second births is lower than Guatemala's, giving the Dominican Republic the region's second highest cumulative adolescent fertility most recently, just slightly below Guatemala's.

Indeed, the educational expansions and changes in adolescent fertility in this study have not happened in a vacuum. Each of the six countries have distinct timelines of fertility decline, histories of family planning, as well as chronicles of economic growth, crisis and restructuring (Cavenaghi and Diniz Alves 2009; Heaton and Forste 1998). All of these aspects likely play a role in the differentiated country-specific links between schooling's aspirational influence on fertility timing, but the relationship is not straightforward. For example, early family planning initiatives in Peru were interrupted by a military government and remained quite limited for some time, while in Colombia and the Dominican Republic, early and strong family planning initiatives were more widespread (Heaton and Forste 1998; Weinberger, Lloyd, and Blanc 1989). Today, Colombia is one of the few countries in the region with national implementation of youth-friendly health services (Huaynoca et al. 2015). Guatemala, on the other hand, is the only country in Latin America and the Caribbean with a recorded stall in its fertility decline, and, strangely, the stall does not appear to be explained by education (Grace and Sweeney 2016). Even so, such contextual differences make this study's broad similarities in adolescent fertility all the more remarkable. Over the long term, the relationship between specific schooling levels and adolescent fertility does indeed change dramatically. For the most part, it appears that only schooling careers that span the entire adolescence are associated with long-term resistance to increasing adolescent fertility. The stability of school enrolment's ability to reduce fertility appears to have persevered while schooling's aspirational influence has been modified under changing context and reorganised social hierarchies.

The implications of these findings for policy and practice are far-reaching. Initiatives seeking to reduce the region's high and stubborn levels of adolescent motherhood will find promising potential in focusing on the expansion of access to and completion of upper secondary and tertiary. Primary and lower secondary simply do not occupy enough years in adolescence to conflict with early fertility. Enrolment appears to have remained a consistent check on adolescent childbearing even when schooling-inspired aspirations have not.

Chapter 3

Adolescence in flux

Unmasking twenty-five years of change in subnational parity-specific adolescent fertility in Mexico

Mexico's adolescent fertility rate has halved over the last fifty years. In 2015, the country set a goal to, by 2030, halve the rate again and completely eliminate childbearing among girls 14 years and younger. The goal is ambitious but severely off track. National estimates show that declines in the adolescent fertility rate have slowed considerably since 1990. In fact, the proportion of women entering motherhood in adolescence (one third of all women) has effectively stagnated since the 1990s, with declines in the adolescent fertility rate coming only from declines in second and third adolescent births. Strategy documents for the new initiative target implementation at the municipal level—Mexico's smallest administrative unit—but very little is known about adolescent fertility in Mexican municipalities. The first official estimates for municipal adolescent fertility rates (for adolescents aged 15-19) were only released in 2020. No municipal estimates exist for the fertility of adolescents 14 years and younger. What is missing are estimates of adolescent fertility that are parity specific, include the youngest adolescent ages and cover the entire period since rates have stagnated.

This study uses data from five census and inter-census surveys to estimate parity-specific adolescent fertility in 2,457 Mexican municipalities from 1990-2015. The results detail the proportion of girls at ages 14.99 and 19.99 who have a first birth, as well as the proportion of adolescent mothers who have a second birth by age 19.99. The analysis reveals that underneath Mexico's rather stable aggregate fertility trends, municipalities see considerable diversity and change. In essence, the results unmask two and a half decades of flux. The policy implications of the findings are far-reaching. Not only do the estimates highlight priority municipalities that might otherwise be

overlooked by the national strategy, and they emphasize the importance of tracking and targeting first and second adolescent births separately. Not only do reductions of first and second births require different strategies, but the incidence of first or second births are not predetermined by each other. That is, a high incidence of second births to adolescent mothers is not exclusive to municipalities with high levels of first births in adolescence and neither are low levels of first births predictive of a low risk of second births.

3.1 Introduction

In 2015 Mexico launched a national initiative to reduce adolescent fertility—the first of its kind in the country. The National Strategy for the Prevention of Adolescent Pregnancies or Estrategia Nacional para la Prevención del Embarazo en Adolescentes (ENAPEA) aims to

(1) eliminate births to girls 14 years and younger and
(2) halve the number of births to adolescents 15 to 19 years old by 2030.

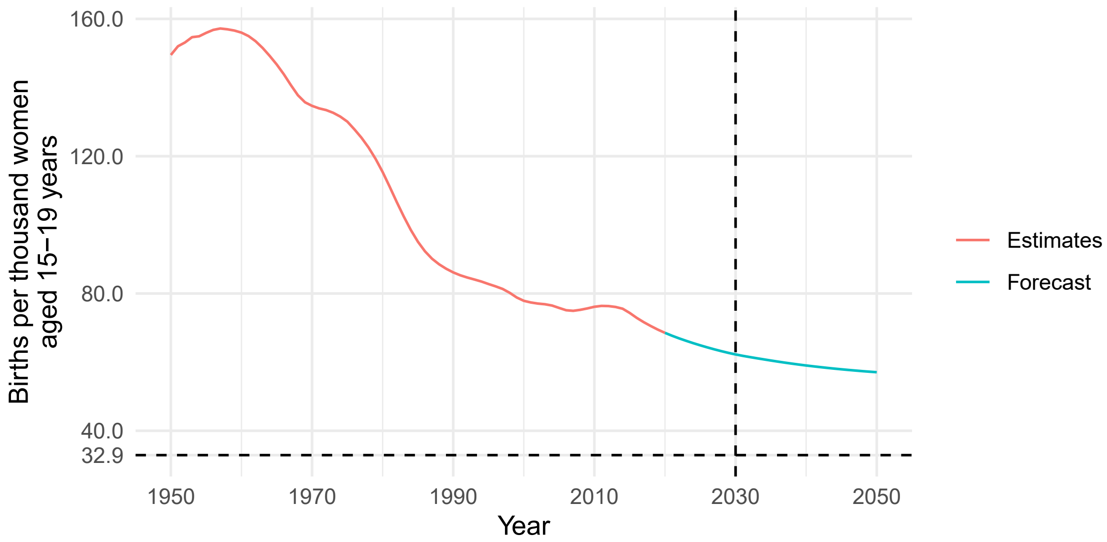
In concrete terms, this means that by 2030 Mexico hopes to achieve a rate of 0 births per thousand adolescents aged 10-14 years and 32.9 births per thousand adolescents aged 15-19 years (Gobierno de la República 2015).

Impetus for the nationally-coordinated effort to reduce adolescent childbearing is rooted in concern about the country's comparatively high incidence of adolescent fertility and its limited decline over recent decades (Gobierno de la República 2015). Mexico's most recent rate of 68.5 births per thousand women aged 15-19 years, referred to hereafter as either its adolescent birth rate or its $ASFR_{15\text{-}19}$ (age-specific fertility rate for women aged 15-19 years), is above the regional average for Latin America and the Caribbean (63 births). It also far exceeds the average for other upper-middle income countries (30 births) and is the highest rate of all Organization for Economic Cooperation and Development (OECD) members (average of 20 births) (Consejo Nacional de Población 2018b, 2021; United Nations Population Division 2019a).

Additionally, declines in Mexico's $ASFR_{15\text{-}19}$ since the 1990s are much more modest than those of the preceding decades, as can be seen in Figure 3.1. Without a rapid and dramatic intensification of the pace of decline, the 2030 goal is not achievable. Mexico's official forecast (also in Figure 3.1) projects an $ASFR_{15\text{-}19}$ of 62.2 in 2030—nearly double the target of 32.9 births.

Strategy documents for Mexico's ambitious, multi-sectoral initiative target implementation by municipality, the country's smallest administrative unit, prioritising those municipalities with the highest adolescent fertility and largest population size (Gobierno de la República 2015; Gutiérrez et al. 2015). However, nothing is known about fertility at ages 14 years and younger at the municipal level, making it impossible to benchmark and track progress toward the elimination of fertility in

Figure 3.1: Mexico's adolescent fertility rate from 1950 to 2050



Source: Consejo Nacional de Población 2018

early adolescence in municipalities. Additionally, nothing is known about parity-specific adolescent fertility at the municipal level even though a small but growing body of evidence suggests that first and repeat adolescent births can see very different trends, arise from different causes, and require distinct interventions (Garbett, Perelli-Harris, and Neal 2021; Hindin, Michelle J et al. 2016). A better understanding of age- and parity-specific municipal trends may well help break the apparent stalemate in Mexico's adolescent fertility decline by offering more targeted prioritisation.

This study aims to estimate subnational parity-specific fertility at all adolescent ages as well as their trends over time. That is, it explores whether municipal estimates follow the same pattern seen at the national level of stagnant first births and declining second births or whether the national patterns mask underlying subnational complexity. Importantly, the parity-specific estimates offered by this research include fertility of the youngest adolescents, or girls aged fourteen and younger. Again, early adolescent ages are ignored in existing municipal $ASFR_{15\text{-}19}$ measures. To be clear, the research objectives encompass using multilevel regression models to estimate the proportion of adolescents within each municipality with a first birth and a second birth at all adolescent ages from 1990 to 2015. It also estimates adolescent progression ratios in moving from first to second births in all municipalities.

The results are surprising. They unpack the national-level stagnation into a complex array of subnational patterns that vary considerably by age, parity and over time. The findings also confirm the importance of examining subnational patterns, rather than relying on national averages, for tackling adolescent childbearing. Additionally, the findings have bearing on a broader debate about the adequacy of the teen birth rate as the measure of choice in lower- and middle-income countries, given that repeat adolescent childbearing remains widespread in these contexts.

3.2 Research context

Several aspects of the context of this study merit deeper exposition before moving on to a description of the data and methods. This section first sets the scene with a description of why Mexico's demographic and educational landscape offer such an interesting case study. Next, it details why municipalities offer a more useful geography for subnational trends than do larger and more commonly examined states. Finally, it discusses what might be gained by looking at parity-specific change—at all adolescent ages—rather than pursuing the more common indicator of $ASFR_{15\text{-}19}$.

3.2.1 Mexico's demographic and educational context

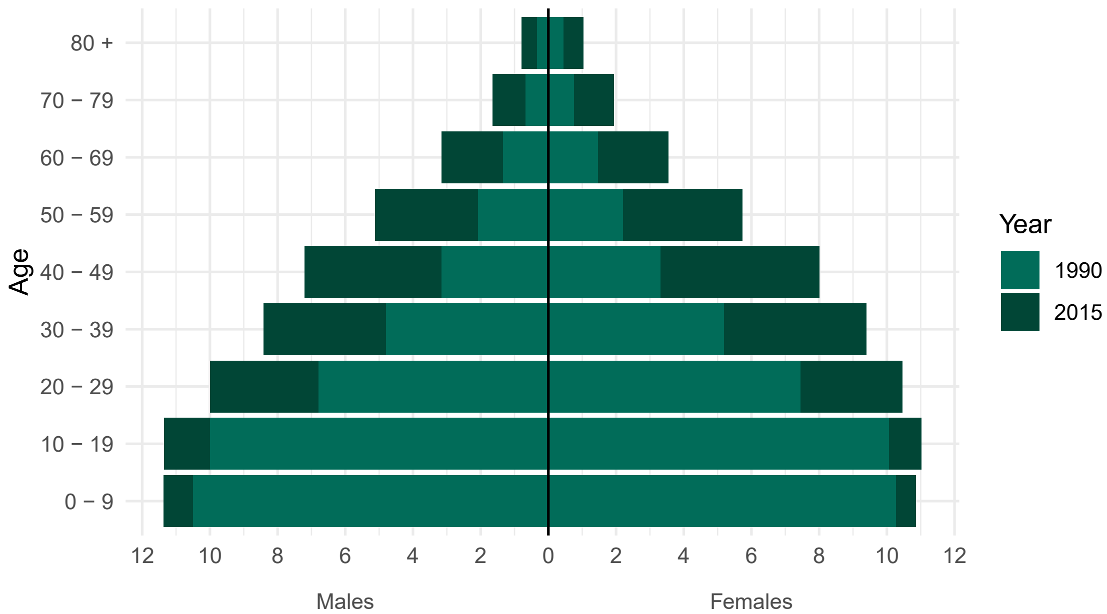
The Mexico of 1990 to 2015 provides an intriguing context in which to analyse adolescent fertility and education. Not only does the launch of the country's national initiative to reduce adolescent childbearing heighten the relevance of this study, but the country's educational, economic and demographic history, as well as the size of its population, provide additional significance. In many respects, the twenty-five years covered by this study are marked by relative prosperity for adolescents, which makes the lack of substantial change in adolescent fertility all the more puzzling.

Mexico is currently Latin America's second most populous country and the tenth most populous country in the world (United Nations Population Division 2019b). Though Mexico's total population grew from 81 million in 1990 to 121 million in 2015, the growth was most pronounced among older age groups, as seen in Figure 3.2. The country's adolescent female population changed relatively little, only increasing from 10 million to 11 million over the same period (United Nations Statistics Division 2021).

While non-adolescent women experienced fertility declines from 1990-2015 (though with much less change in their fertility than in the preceding decades), Mexico's adolescents saw very little change in their age-specific fertility rate from 1990, as is depicted in Figure 3.3. When compared against the considerable fertility changes in other age groups, the decline in the $ASFR_{15\text{-}19}$ seen previously in Figure 3.1 appears altogether less dramatic. Importantly, the trendline for adolescents from 1990 to 2015 (bolded red line in Figure 3.3) is nearly flat, while older age groups' trendlines decline. Indeed, adolescent fertility remains a striking outlier in the latter part of Mexico's fertility transition, which saw, over the course of a few generations, the total fertility rate fall from nearly 7 children per woman (in the 1960s) to 2.2 children per woman (in 2015) (United Nations Population Division 2020).

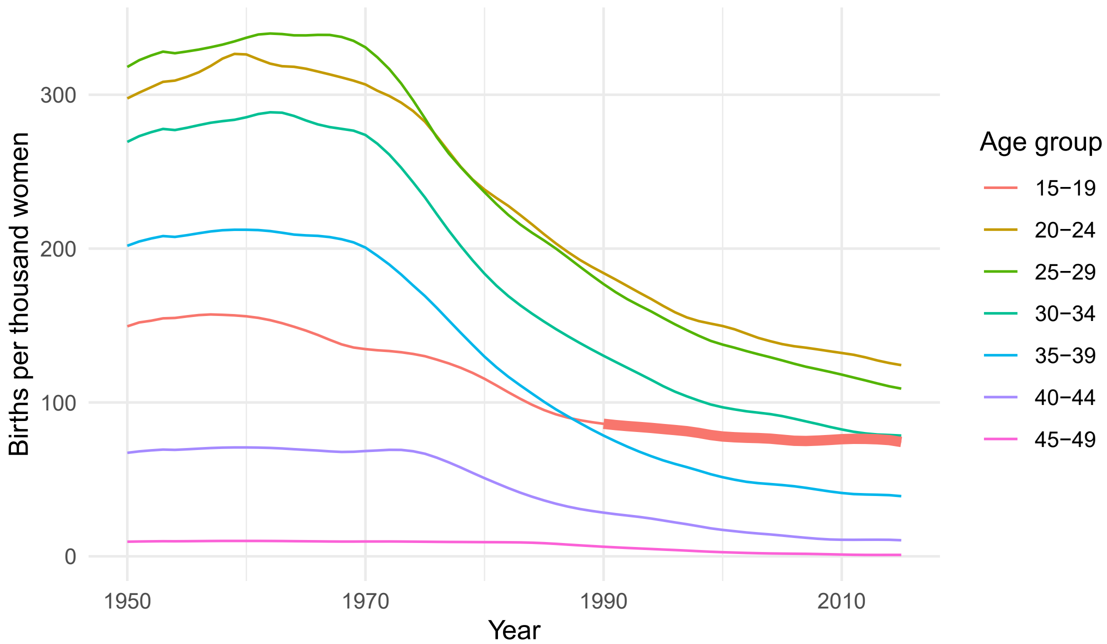
The 1990-2015 period was marked by relative economic and political stability. The 1990s opened an unprecedented era of free trade after the severe economic crises of the 1980s where plunging oil prices, subsequent devaluations of the peso and extreme inflation brought economic turmoil. Though macroeconomic growth over the subsequent decades has often been slower and more

Figure 3.2: Mexico's population pyramid in 1990 and 2015



Source: United Nations Population Division 2022

Figure 3.3: Mexico's age-specific fertility rates from 1950 to 2020



Source: Consejo Nacional de Población 2018 unequal than anticipated, the growth has been relatively stable nonetheless. Even after a few smaller, more short-lived financial crises, including the 2008 recession, Mexico currently boasts the world's fifteenth largest economy in terms of Gross Domestic Product (World Bank 2021a). The 1990-2015 period also saw the peaceful transfer of power from one political party with nearly a century-long hegemony, to another, marking an important milestone for democracy in Mexico (Moreno-Brid and Ros 2009). Additionally, Mexico was already a fairly urban population and the continued rural to urban shift, namely a decline from a 29% rural population in 1990 to a 20% rural population in 2015, appears quite modest when compared with the average in other upper-middle income countries with a 57% rural population in 1990 falling to 34% in 2015 (World Bank 2021b).

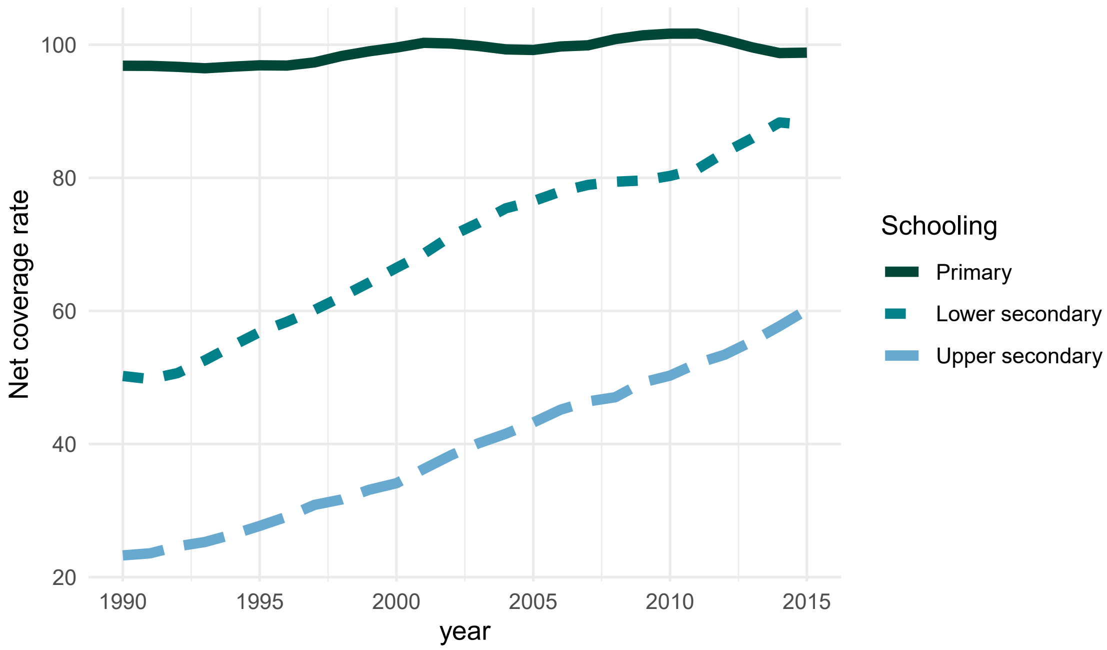
Mexico's economic progress and stable institutions also translated into solid achievements in the health arena both prior to the 1990s and thereafter. In regards to fertility, successive governments maintained a strong commitment to family planning and reproductive health—from the first national family planning program of 1972, which was the most progressive and ambitious in Latin America, through to the 1990s, which marked a shift to a broader understanding of sexual and reproductive health as a human right. Interestingly, special attention to adolescents dates back to the 1980s. The country's early family planning initiatives relied heavily on foreign assistance, but by the late 1990s, external interest began to wane as international donors increasingly saw Mexico as a wealthy country not facing the Aids and HIV crises seen in other parts of the world. In the face of this, Mexico transitioned relatively successfully to an internally funded, well-organised sexual and reproductive health system. Even with the phase-out of international assistance and a new political party that focused more on the country's economy, Mexico's family planning demand and coverage remained high (Ward, Santiso-Gálvez, and Bertrand 2015).

Worth mentioning is Mexico's heavy reliance on female sterilisation—a method ill-suited to adolescent contraceptive needs—with recent surveys indicating that just over half of married women using contraception have undergone sterilisation (Ward, Santiso-Gálvez, and Bertrand 2015). Meanwhile, mean age at sexual debut has grown slightly younger, and although the prevalence of contraceptive use among adolescents increased, in 2014, modern contraception was used in just under half of first sexual encounters, just as it was regularly used by just under half of sexually active adolescents (Hernández, Muradás, and Sánchez 2015).

There are a host of relevant educational achievements both prior to the 1990s and after. Free primary schooling for all was established in Mexico's 1917 Constitution (Diario Oficial de la Federación 1917). However, it was not until the 1960s that the first nationally-coordinated effort to expand primary education began and only in the late 1990s did primary education—particularly in rural areas—become universal (Rocha and Romero 2019). As such, at least at the national level, net enrolment in primary schooling has remained practically unchanged from 1990 to 2015, as seen in Figure 3.4. For example, in 2015, 99% of children nationally who should be in primary were (that is, children 6-11 years old), while in 1990, the proportion was 97% (Sistema Nacional de

Información Estadística y Geográfica 2022). Note that the net coverage rate considers students who are enrolled in the normative level that corresponds to their age, and late starters as well as those with grade repetition are not included (Instituto Nacional para la Evaluación de la Educación 2019).

Figure 3.4: Mexico's net enrolment rates from 1990 to 2015 by schooling level



Source: Consejo Nacional de Población 2018a

In contrast, adolescents' educational landscape at secondary schooling levels has seen dramatic change from 1990-2015 and is also depicted in Figure 3.4. In the 1980s, the approaching realisation of universal primary education and a stable youth population underpinned government efforts to expand lower secondary schooling, or the three years of schooling that follow primary's six years (Rocha and Romero 2019). In a 1993 constitutional amendment, lower secondary was added to the mandatory schooling cycle (Diario Oficial de la Federación 1993). In 1990, national net enrolment in lower secondary was at 50% of adolescents who should be in lower secondary were (that is, adolescents 12-14 years old), while by 2015, that proportion had grown to 88% (Consejo Nacional de Población 2018a).

Though the expansion of upper secondary schooling, which are the three years after lower secondary and which are necessary for entry into university, has also been impressive, there remains considerable room for improvement. Not until 2013 was upper secondary schooling added to the mandatory education cycle (Diario Oficial de la Federación 2012). In 1990, 23% of adolescents who should be in upper secondary were (that is, adolescents 15-17 years old), and in 2015, that proportion had grown to 62% (Consejo Nacional de Población 2018a).

In summary, over the last decades, the size of Mexico's considerable adolescent population has remained practically unchanged, though the country's adult population has aged and grown dramatically. Decades of economic and political stability, a strong health system and impressive gains in adolescent school enrolment, despite underlying inequalities, mean the country's apparently immobile adolescent fertility remains all the more puzzling. This fertility stagnation deserves a closer look.

3.2.2 The case for municipal fertility estimates

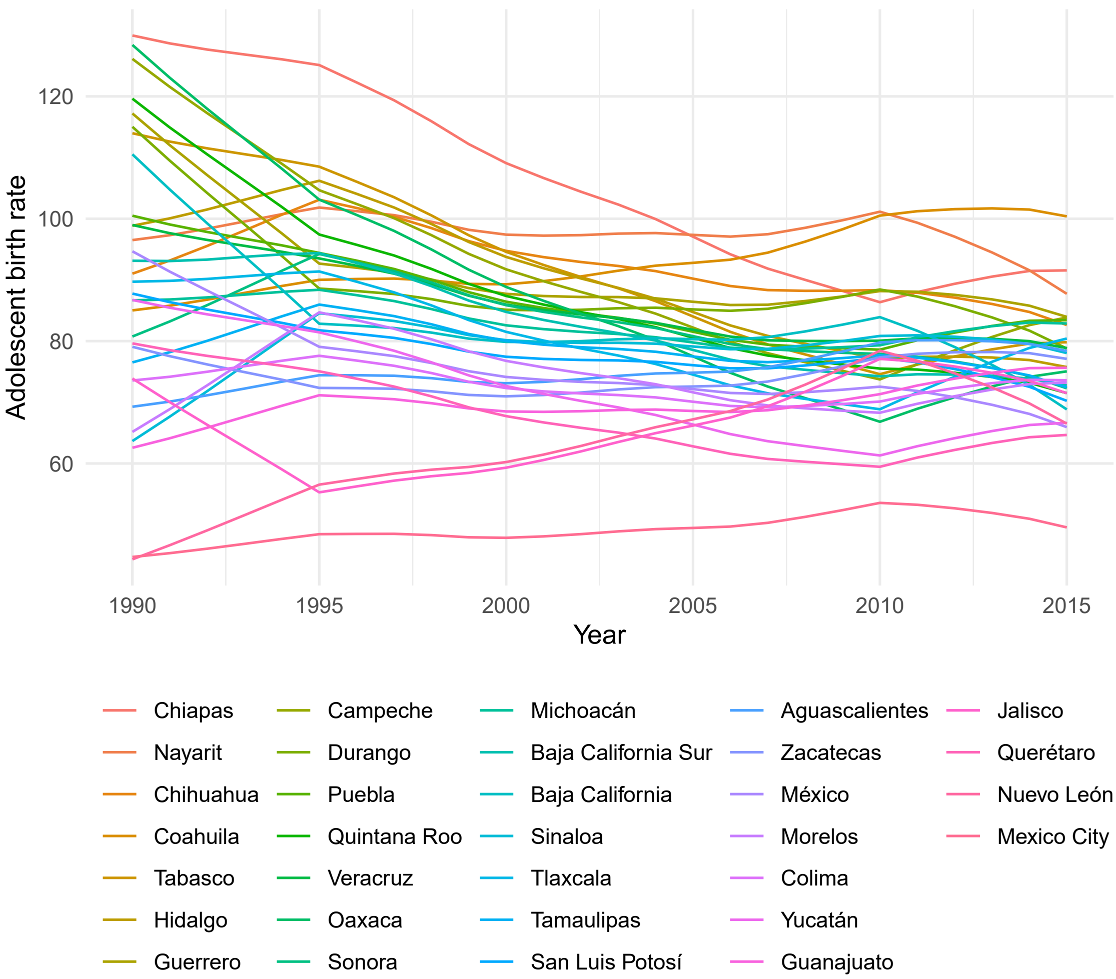
Mexico's strategy to reduce adolescent fertility aims to target implementation at the municipal level, prioritising those municipalities among the 2,457 total with the highest adolescent fertility and largest population size. However, little is known about adolescent fertility at the municipal level, particularly for all adolescent years and not just averaged across ages 15-19.

Study of subnational adolescent fertility in Mexico almost exclusively focuses on Mexico's 31 states (plus Mexico City), the country's primary administrative units. Indeed, there are official estimates for state-level adolescent fertility rates for the entire period of 1990-2015 (shown in Figure 3.5), but not municipal-level rates. I find only two sources that estimate and examine municipal trends, both of which are grey literature (Ailines Genis 2018; Meneses and Hernández 2019), though only for 15-19 year-olds in 2010 and 2015. Nevertheless, the state-level trends in Figure 3.5 hint at a much more complex story than what is suggested by the almost stagnant national rate over the same time period. Mexico's states span a considerable range in $ASFR_{15\text{-}19}$. For example, though Mexico City sat consistently below all other states, starting with 44.3 births per thousand adolescents aged 15 to 19 in 1990, its rate saw concerning increase, ending in 2015 with 49.6 births. Nuevo León, a northern border state, saw exceptionally high increase, with an $ASFR_{15\text{-}19}$ of 44.3 in 1990 increasing to 66.5 in 2015 (reaching as high as 78.4 in 2010). Meanwhile, Chiapas, the state with the highest $ASFR_{15\text{-}19}$ in 1990 of 130.0, saw its rate decline to 91.6 by 2015 (recall that Chiapas is also the state with the lowest enrolment in lower-secondary). The rates appear to follow a general pattern of convergence, with those states that had the highest $ASFR_{15\text{-}19}$ in 1990 seeing most decline while a few states starting with the lowest $ASFR_{15\text{-}19}$ seeing increase. Also noteworthy is the year 2010, which marks a reversal in most $ASFR_{15\text{-}19}$ trends. Most states that had declining rates from 1990-2010, suddenly saw increases, while other states that had increasing rates from 1990-2010, suddenly saw declines.

The grey literature exploring municipal trends in $ASFR_{15\text{-}19}$ in 2010 and 2015 bring out several valuable points not seen in the state-level trends. Importantly, (Ailines Genis 2018) finds that the densest concentration of municipalities with the highest teen birth rates are not always in the states with the highest rates, which suggests these areas are otherwise missed in most research. Also concerning is that a much larger portion of municipalities compared to states have seen increasing rates over time.

While it is expected that municipalities see much greater range in the intensity of adolescent fertility

Figure 3.5: Mexico's state-specific adolescent fertility rates from 1990 to 2015



Source: Consejo Nacional de Población 2018 than do states, the variation in municipal rates within states and scope of the range is surprising. While state-specific $ASFR_{15\text{-}19}$ in 2010 and 2015 ranges from 49.6 to 101.7, municipal rates range from 32.3 to 176.6 births in the Ailines (2018) estimates and from 8.7 to 217.6 in the Meneses (2019) estimates. In other words, some municipalities appear to have already met the 2030 target while others see a rate at more than six times the target.

Two other studies are relevant despite their focus on state-level estimates. One examines fertility trends in adolescents 14 and younger while the other looks at the relationship between schooling and adolescent fertility in Mexico (Gómez and González 2018; Meneses and Ramírez 2018). One offers a first look at subnational early adolescent fertility estimates, that is, fertility among adolescents aged 14 and younger (Meneses and Ramírez 2018). The findings suggest that early adolescent fertility has increased in almost all states over the last two decades. Additionally, the fertility has become increasingly concentrated among 14-year-olds, with displacement away from youngest ages (declines among those 13 and younger).

In summary, Mexico's $ASFR_{15\text{-}19}$ varies much more at the municipal level than it does at the state level (Gutiérrez, Sánchez, and Giorguli 2011) and herein lies the value in studying adolescent fertility at a subnational scale.

3.2.3 The case for parity-specific estimates

In turning to parity-specific trends, rather than $ASFR_{15\text{-}19}$, which cannot say anything about whether births are first, second or third births to adolescents, the picture becomes even more puzzling. The proportion of women entering motherhood in adolescence (at the national level) has seen very little change over the last half century. More than a third of women enter motherhood in adolescence — both today and sixty years ago — as is detailed in this thesis' previous chapter (see Figure 2.3). Mexico's declining $ASFR_{15\text{-}19}$ is a result of declines in second and higher-order births to adolescent mothers (see Figure 2.4), as is the case elsewhere in Latin America and the Caribbean (Neal et al. 2018). Meneses and Ramírez (2018) confirm the same pattern exists in early adolescent fertility in Mexico: in 1990 20% of births to adolescents 14 and younger were non-first births and in 2016, only 1% of births were. The stability of first births in adolescence in the face of the country's dramatic schooling expansion is puzzling.

Given the immobility of first birth trends at the national level, the exploration of parity-specific trends at the municipal level is critical both from a research and policy perspective. As already mentioned, existing research on the municipal $ASFR_{15\text{-}19}$ in 2010 and 2015 identifies a complex array of fertility trends (Ailines Genis 2018; Meneses and Hernández 2019). This chapter's parity-specific analysis that spans twenty-five years, instead of five years on non-parity specific analysis, can better highlight priority municipalities with particularly high or increasing adolescent fertility. Additionally, $ASFR_{15\text{-}19}$ trends may well mask underlying parity-specific changes that present a more consistent relationship with aggregate schooling.

Despite not using or having parity-specific adolescent fertility estimates, Mexico's 2015 strategy document acknowledges that approaches for reducing adolescent fertility are in fact highly parity dependent (Gobierno de la República 2015). For example, it discusses how first-time adolescent mothers, once they access health services for antenatal or obstetric care, face fewer barriers to accessing contraception than their childless peers. Healthcare providers can introduce adolescent mothers to more reliable, long-acting reversible contraception during pre- or post-partum health visits, while it is more difficult to reach childless adolescents. Municipalities are encouraged to expand contraceptive uptake among adolescent mothers through their interfaces with the health system. In contrast, the strategy document acknowledges that most childless adolescents still face social and cultural barriers to contraceptive access and use. It suggests broaching these barriers by improving comprehensive sexuality education in schools, running media campaigns to counter entrenched stigmas, and expanding youth-friendly health services. Likewise, the strategy notes that efforts to retain or reintroduce adolescent mothers into the schooling system require, among other things, help with economic and childcare needs as well as sensitisation of teachers and administrators to young mothers' right to education. The need for such initiatives is confirmed in other research (Chávez et al. 2010). Without parity-specific municipal estimates, Mexico's national strategy has no guidance on what locations need more or less of one approach or another, and when resources are limited, as is the case here, cost-effective targeting is imperative.

3.3 Data

The aim of this study is the estimation and examination of municipal-, age- and parity-specific adolescent fertility trends from 1990 to 2015. That is, the proportion of adolescents with a first birth, at each age point, in each municipality from 1990 to 2015. Also, the proportion of adolescents with a second birth, at each age point, in each municipality over the same period of time.

Data used for the parity-specific estimates pool five Mexican census samples and an inter-census survey from 1990, 2000, 2005, 2010 and 2015 (Instituto Nacional de Estadística y Geografía 2015, 2020). Ten percent of households were selected for a long-form questionnaire in the 1990, 2000, 2005 and 2010 census samples while the 2015 inter-census survey was designed to sample nearly 20% of the country's population. Mexico's short form census questionnaires, which are asked at every household, do not include the individual fertility data that is necessary for this study's parity-specific analysis. The 1995 population census did not include a long-form questionnaire in a 10% sample, which means it also does not have the necessary individual fertility data, and cannot be included in this analysis. The sample selection for the long-form census questionnaires varies slightly by census year, but all share a multistage probabalistic sampling methodology designed to be representative at the municipal level and wherein all municipalities enter the sample with

Year	Source	Total cases	cases of females 12-20 years old
1990	Census sample	8,118,242	905,684
2000	Census sample	10,099,182	989,794
2005	Census sample	10,282,760	959,863
2010	Census sample	11,938,402	1,129,637
2015	Inter-censal survey	22,692,265	1,978,177
		Total	5,963,155

Table 3.1: Unweighted case selection by source

certainty.

3.3.1 Data preparation

Variables used in the estimation of parity-specific adolescent fertility were the census year and the municipality of census enumeration for each adolescent, as well as her current age and number of children ever born at the time of the census survey. Data preparation for the estimation of parity- and age-specific adolescent fertility trends from 1990-2015 merits further detail. Selected individuals are all females aged 12 to 20 years old. Adolescents aged 10 and 11 years are not asked fertility questions in the census questionnaires and as such are excluded from this study's analysis. Though females aged 20 years old are no longer adolescents, including them in the analysis facilitates and improves estimation of the shape of the adolescent fertility age schedule. Table 3.1 details the unweighted sample size of each census source, which were pooled together into one dataset of just under six million individual cases.

A few data transformations were undertaken. For an indicator of first births, the number of children ever born was converted to a dichotomous variable: the value of one was assigned to cases where the census response indicated that the woman or girl aged 12 to 20 had one or more live births, and the value of zero was assigned to cases where the census response indicated the woman had no births. For an indicator of second births, the dichotomous variable took the value of one if the census reported the adolescent had two or more live births and the value of zero if the adolescent had one or no births at the time of the census. Missing data on the number of children ever born were coded as no births.

An alternate specification that removed cases with missing fertility data estimated higher proportions of women with births in adolescence by a few percentage points but did not otherwise change the broad patterns in the models. A total of 9.3% of adolescents in the pooled data were missing data on children ever born, with younger adolescents more likely to have missing responses than older adolescents.

Due to the considerable size of the pooled dataset, a few additional transformations ease the computational requirements of the analysis. First, the integer ages were respecified to the mid-year point and standardised to bring all values into the range of negative one and one. That means that age 12 was first respecified as 12.5, for example, under the assumption that the birthdays of the 12-year-olds in the dataset are evenly spread throughout the year such that 12.5 is the true average age of the 12-year-old sample. While some adolescents would only have just turned 12, just as many others would have been at the end of their twelfth year, and, taken as a whole, the average age of those whose age is reported as 12 is therefore actually 12.5. This specification takes additional meaning later in the study when the models are used to estimate adolescent fertility at the tail end of adolescence (age 19.99) and the tail end of early adolescence (age 14.99). Next, age 12.5 was assigned the value of negative one and age 20.5 was assigned the value of one. Ages in between were assigned their respective intervening values. For example, age 19.5 takes the value of 0.75 while age 13.5 takes the value of -0.75. Second, the census year was also standardised to bring all values into the range of negative one and one, preserving their relative distance from each other: 1990 becomes -1.0, 2000 becomes -0.2, 2005 becomes 0.2, 2010 becomes 0.6 and 2015 becomes 1.0. While there is no data from 1995, it would have taken the value of -0.6, so the larger gap between 1990 (-1.0) and 2000 (-0.2) still accurately reflects the 10 years between these data points rather than the 5-year gaps between the other data points. The transformation of age and year facilitates the speed of computation by putting all variables on the same scale without altering their meaning in any way.

3.3.2 Data quality

There is an outstanding debate about whether census or vital statistics lead to more accurate estimates of adolescent fertility in Mexico. The previously-mentioned research that estimates early adolescent fertility (births to adolescents 14 and younger) in Mexican states prefers rates estimated by vital statistics over those estimated by census data, because census data provide lower estimates than those from vital statistics (Meneses and Ramírez 2018). In Colombia, estimates of adolescent fertility rates — both early adolescent and later adolescent fertility — using vital statistics and survey data (but not census data) reach a similar conclusion of lower rates in non-vital data (Álvarez Castaño 2015). The official municipal estimates of Mexico's $ASFR_{15\text{-}19}$ uses vital statistics in a first step, before reconciling them to census-based estimates in a second step (Ailines Genis 2018).

The official municipal estimates of $ASFR_{15\text{-}19}$ come from Mexico's National Population Council (Consejo Nacional de Población or CONAPO). CONAPO's municipal estimates of $ASFR_{15\text{-}19}$ in 2010 and 2015 are derived from a combination of vital statistics and census data. The numerator for the municipal $ASFR_{15\text{-}19}$ estimates—the number of total births to adolescents aged 15 to 19 in each municipality—comes from a reconstruction of vital registration records. Because of limitations in vital statistics records due to the late or under-reporting of births, the estimates consider births recorded to have occurred in 2010 or 2015 but reported up to four or seven years after the respective year of interest. Whether four or seven years is the cut-off depends on the degree of under-utilisation of the registry in the state. In the case of 2015 estimates, where a full 7-year reconstruction is not possible, CONAPO used simple linear regressions to project the missing vital registration numbers. The denominator for the estimates, or the number of adolescents aged 15 to 19 in each municipality, comes from CONAPO's census and survey-based population projections.

In expressing a preference for vital statistics data, the two Mexican studies already reviewed do not acknowledge that the vital statistics-based estimates in Mexico are not independent of census data. While the numerator in adolescent fertility rates comes from the number of births registered to adolescent mothers, the denominator, or the number of adolescents in the population, comes from census data. As such, judgements about which might be more accurate are problematic. On the one hand, census data may face data quality issues if the individual answering the household's census questionnaire is not the adolescent in question and does not know the correct fertility responses for the adolescent. On the other hand, not all births are immediately recorded in vital statistics registers. It can often take several years for some of the more disadvantaged mothers, and the youngest mothers in particular, to register their births. Research that does not correct for this may erroneously estimate that some of the least economically advanced areas of the South, for example, have the lowest adolescent fertility rates in any given year (Meneses and Ramírez 2018). Additionally, any undercounting in the census-based total adolescent population can produce overestimated rates when using vital-statistics-based numerators. Ultimately, this research prefers census data so that both the numerators and denominators in the analysis come from the same source.

It is also important to note that these proposed estimates reflect the adolescent population within municipalities at the time of the census, not all of whom would have been born and lived continuously in the same place. As such, they do not disentangle how patterns of internal migration influence changes in the municipal adolescent fertility estimates. Historically, internal migration in Mexico saw movements from rural to urban locales, and from the poorer south to the better-off north. More recently, migration in Mexico is more about urban to urban movement (Pérez-Campuzano and Santos-Cerquera 2013). However, initial data explorations that looked at parity-specific estimates at the state-level among migrants compared to non-migrants found the differences to be inconsequential. As such, migration patterns are not explored in the parity- and age-specific fertility estimates.

3.4 Descriptive analysis

As a first approach to describing trends in adolescent fertility, this section presents a number of basic descriptive statistics from the data. Figure 3.6 presents several boxplots of a variety of census-based municipal proportions over time. These are: (a) the proportion of women aged

12-20 with a first birth, (b) the proportion of adolescents aged 19 years with a first birth, (c) the proportion of all women aged 12-20 with two births, (d) the proportion of adolescents aged 19 with a second birth, (e) the proportion of adolescents with one birth who progressed to a second birth (parity progression ratio among all cases) and (f) the proportion of adolescent mothers aged 19 who had progressed to a second birth (parity progression ratio for 19-year-olds).

Boxplots offer helpful information about the diversity seen in underlying statistics—adolescent fertility in this case. The medians (centre horizontal line within the boxes) gives the middle value in municipalities; the second and third quartiles (top and bottom horizontal lines of the boxes, also called the interquartile range) delimit the proportions seen in half of all municipalities; while the remaining municipalities are captured by the proportions within 1.5 times the interquartile range (vertical whiskers extending from the boxes), and any remaining outliers (points at the ends of the whiskers).

As expected, municipal first birth proportions, both at all ages as well as for 19-year-olds, show little change over time in their median. Nevertheless, the range in municipal values, particularly at age 19, suggests a pattern of convergence. That is, the interquartile range is smaller in more recent years than in earlier years. Also worth noting is that the median indicates that nearly 30% of 19-year-old adolescents have a first birth, which aligns closely with the findings for Mexico in the previous chapter. See Figure 2.3 but note that the 1970 birth cohort's estimates in Figure 2.3 corresponds roughly to the 1990 estimates in this chapter because the 1970 birth cohort exited adolescence in 1990. The 2015 cohort in this chapter corresponds roughly to the 1995 birth cohort in the previous chapter. Also note that estimates in Figure 3.6 give the proportion at the average age of 19.5 because it considers all adolescents from 19.0 to 19.9 while the previous chapter estimates the proportion at age 19.99. The proportions of adolescents with second births suggests a similar pattern of convergence. Due to the scale of the figures, the expected decline in second births only really becomes apparent when second births are examined as a progression ratios (bottom row).

Figure 3.7 maps municipal-based deciles of unweighted case numbers. Although the size of the pooled dataset is considerable, most municipalities have too few observations to provide reliable fertility estimates at any specific age point in a given year, particularly for second births and child-bearing in early adolescence. For instance, 80% of municipalities have fewer than 3,000 total observations, meaning that each integer age has on average less than 60 observations in any given year. The map also gives a rough picture of the country's population density, as sample sizes largely correspond to population numbers. Recall that the strategy documents for reducing adolescent fertility prioritise municipalities with larger populations.

Figure 3.6: Descriptive statistics of adolescent fertility in Mexican municipalities by year, 1990-2015

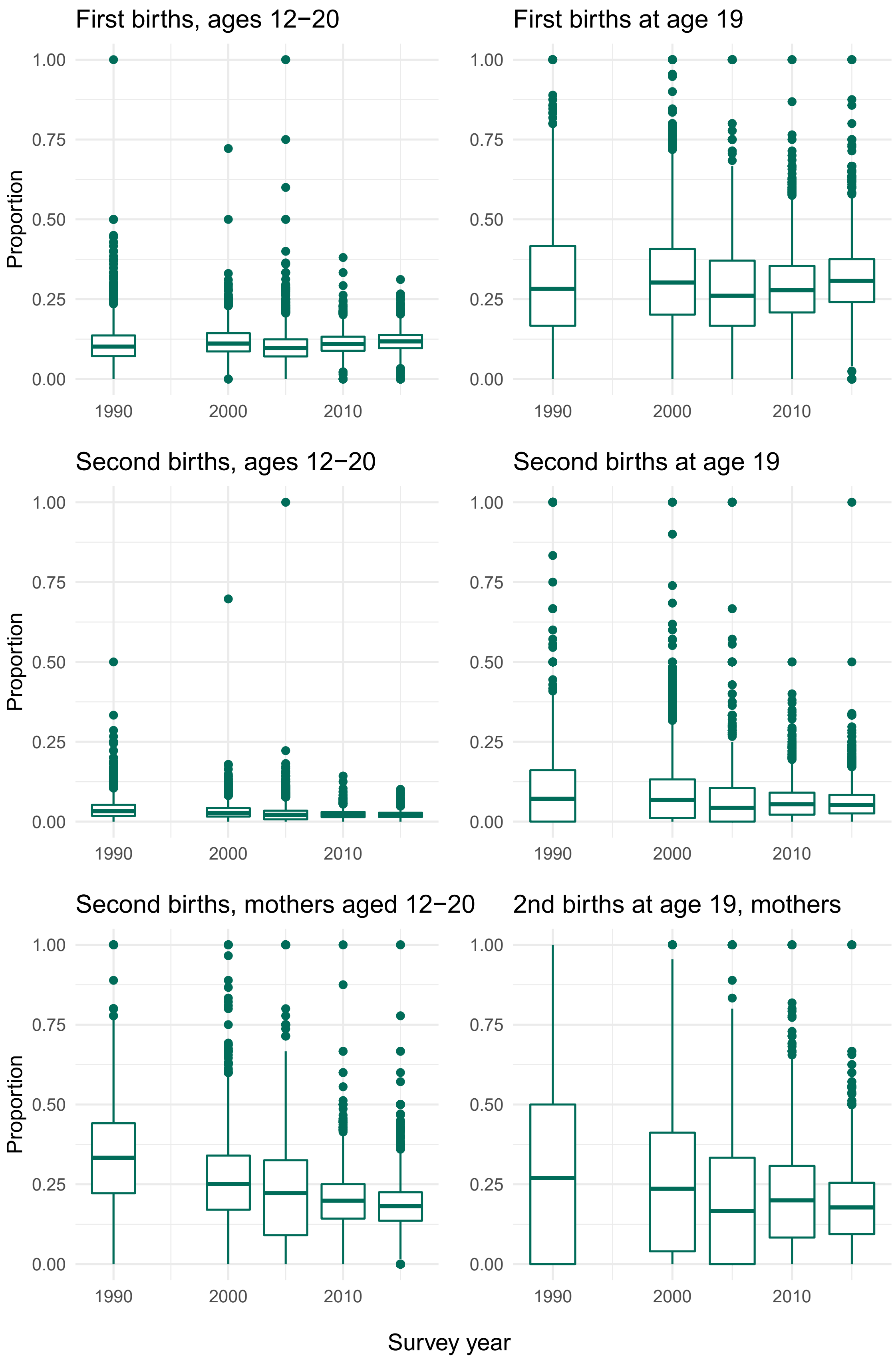
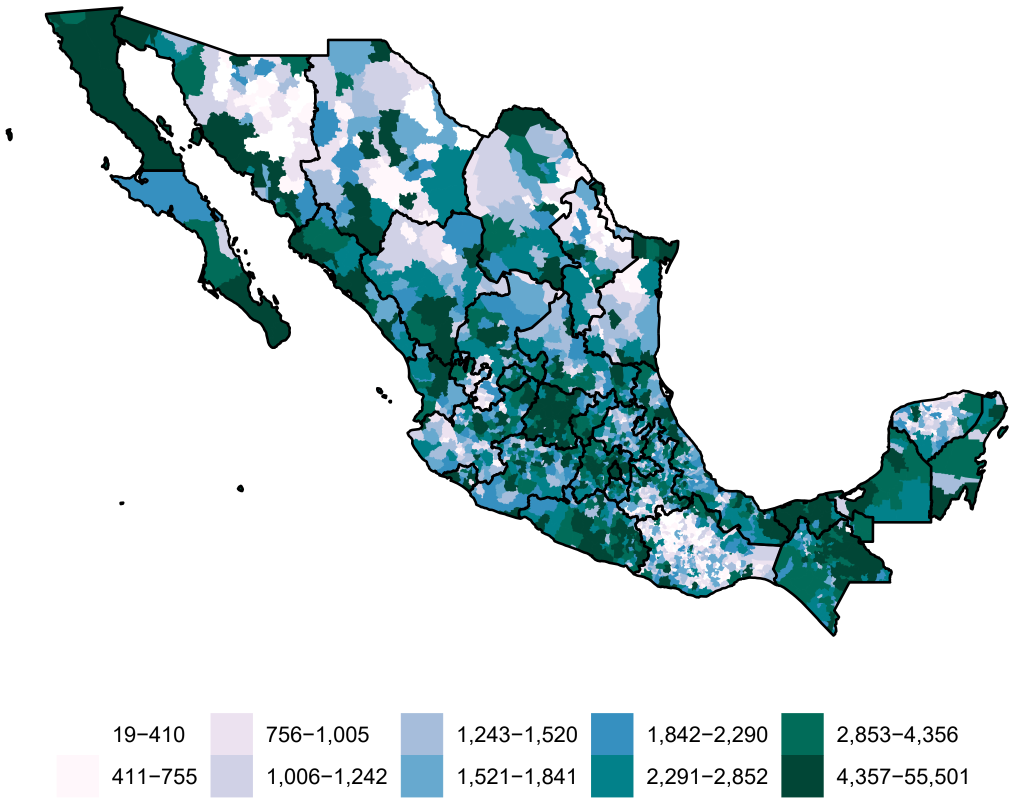


Figure 3.7: Mapped deciles of unweighted sample size by Mexican municipality, 1990-2015

All observations



3.5 Estimating adolescent fertility

To estimate the proportion of women from 1990-2015 in each municipality with a first and second birth in both early and later adolescence, this study uses two separate logistic multilevel models: one for first births and another for second births. For deeper analysis of patterns of second births in adolescence, the analysis also includes a look at parity progression ratios. That is, it uses the estimated first and second birth proportions to compute the proportion of adolescents with a first birth who go on to have a second in adolescence (by age and year in each municipality).

Multilevel models are multifaceted tools used for a variety of statistical purposes. This study's first analysis exploits multilevel models not for their powerful explanatory purposes but rather for their ability to improve the reliability of estimates based on small numbers of observations. As already noted, the vast majority of municipalities have less than 60 observations at each integer age in any given year. Because of this, raw estimated proportions of adolescent fertility at ages fourteen or younger, for instance, are highly variable and unreliable. That is, implausibly high and low estimates of the proportions of adolescents with births in the raw data are common simply due to random chance.

If we assume that patterns of adolescent fertility share certain commonalities within municipalities and across municipalities, we can not only produce more reasonable estimates, but the estimates can be stated with greater precision. In the case of this study, the multilevel models will explore shared commonalities across municipalities in the shape of the age schedule and in patterns of change over time for adolescent fertility. This is not to say that the models find all municipalities have identical patterns related to age and time, but rather this chapter's multilevel models are able to take knowledge about the proportion of adolescents with first (or second) births in the whole population and update it with knowledge about the proportion specific to each municipality. In other words, the models borrow information or strength from the other municipal groups to inform each municipality's specific estimates. This process is often referred to as the shrinkage factor, and the amount of shrinkage depends on the number of observations within each group (municipality in this case). When the sample size within a municipality is large, estimates are largely unaffected by the shrinkage factor, but when the sample size within a municipality is small and the data thus have little new information to offer, the estimates are 'shrunk' or pulled towards those seen in the overall population. In this way, there are fewer extreme values that are more likely the result of statistical noise than an accurate reflection of the true municipal proportion (Goldstein 1997). In the following paragraphs, we describe how we begin by exploring these similarities in age curves and time trends across municipal patterns, and how the final models relax many of these assumptions (once confirmed through model testing) to allow for the considerable subnational differences that are revealed. Ultimately, this study's multilevel model represents these commonalities in age patterns and change over time that are shared across all municipalities in its fixed coefficients. The model's random coefficients update the fixed coefficients to reflect each municipalitiy's distinct manifestation of age differences and change over time in its patterns of adolescent fertility.

While there is a crucial advantage in improving reliability, there remains some uncertainty surrounding how to treat design weights in multilevel models, which account for unequal probabilities of selection for individuals in the census samples. The issue is important because while incorporating design weights into OLS regressions, for example, will not change point estimates but instead only produce corrected standard errors, this is not the case in multilevel models. Both estimates and standard errors in multilevel model can vary depending on the weighting as well as the software programs and estimation procedures used (Carle 2009). Because the surveys from 2000, 2010 and 2015 come with design weights (the 1990 and 2005 samples are self-weighted), the treatment of design weights in the models in this analysis requires elaboration.

The multilevel models are carried out in R using the package lme4 (Bates et al. 2015), which uses an estimation procedure that optimizes a function of the log-likelihood using penalised iteratively re-weighted least squares. The log-likelihood is evaluated using the Laplacian approximation. Before including design weights into the likelihood function, the weights must be rescaled. Other research has found that simply including raw design weights, or the weights provided in the data, often produces more bias in the estimated parameters and standard errors than when rescaled weights are used. However, the choice for rescaling depends on various features of the design and data, and as such there is no single gold standard nor ability to determine a priori which rescaling method is most appropriate (Carle 2009). The two most widely accepted rescaling methods either scale the raw weights so that the new weights sum to the cluster sample size or so the raw weights sum to the effective cluster size. These two options can be presented more clearly with equations. For rescaling to the cluster sample size:

$$w_{ij}^{*} = w_{ij}\left(\frac{n_j}{\sum_i w_{ij}}\right)$$

For rescaling to the effective cluster sample size:

$$w_{ij}^{*} = w_{ij}\left(\frac{\sum_i w_{ij}}{\sum_i w_{ij}^2}\right)$$

In both equations, the rescaled weight for individual *i* in municipality *j* is represented by w_{ij}^{*}. The unscaled or raw weight is represented by *w* and n_j represents the number of observations in cluster *j*. Importantly, the scaling is done with the entire data sample, that is, it occurs before reducing the dataset to any subsample of interest (Carle 2009).

In this analysis, because all municipalities were included in the samples with certainty, no weights are needed at level 2. That is, all municipalities (level 2) have an equal probability of selection, while individual adolescents (level 1) have an unequal selection probability. I choose lme4 as the preferred estimation procedure because of its speed and efficiency, which is important given the considerable size of the dataset. Additionally, estimation procedures are effectively identical between lme4 and other packages that are designed to incorporate complex design weights (such as WeMix) when weights are only needed for level 1 units (Bailey et al. 2020).

To examine which rescaling method provides the least biased estimates, I fit the models using both rescaling methods as well as unweighted data and compare the results to the raw municipal proportions. The estimates differ only slightly, and the inferential decisions converge, giving confidence in the results. Ultimately, I select the models using weights rescaled to the cluster size (rather than the effective cluster size), as they produced estimates most closely aligned with the raw national proportions, and other research indicates that they generally produce the least biased estimates when the number of clusters are large and the research interest is focused on the point estimates rather than on other aspects of multilevel analysis, such as between-cluster variance discussions (Carle 2009). See Appendix B for additional details of the comparison of the various weighting methods. The model selection steps below refer to models with weights rescaled to the cluster size.

Apart from the impact the choice of weighting has on the estimates, there remains other sources of uncertainty. Understanding and communicating the uncertainty inherent in multilevel models is not straightforward except in Bayesian analysis. There is currently no clear option for computing standard errors for the municipal predictions (or the deviations in the random effects as opposed to the fixed effects) in the models employed in this study's analysis (J. Knowles and Frederick 2020). Short of a fully Bayesian analysis, bootstrapping is considered the gold-standard for deriving prediction intervals for multilevel models. However, the large size of the data and the complexity of the models meant that neither Bayesian analysis or bootstrapping were possible due to their prohibitive computational requirements.

In addition to questions of weighting, measurable uncertainty in multilevel models arises from three sources: (1) uncertainty in the residual variance, (2) uncertainty in the fixed coefficients, and (3) uncertainty in the variance parameters for the grouping factors. Bootstrapping is able to incorporate all three sources of uncertainty, but again, its computational requirements made it impossible for this study's data set. An alternative method using R package merTools (J. E. Knowles and Frederick 2020) incorporates all the uncertainty from the first two sources and part of the uncertainty of the third but treats the variance parameters as fixed, which reduces the computational requirements considerably while producing prediction intervals that are reasonably similar to more complex methods (J. Knowles and Frederick 2020). See Appendix B for estimated confidence intervals for the proportions of adolescents with a first and second birth in 2015 by municipality. Municipalities with the largest confidence intervals (and most uncertainty) generally are those with the smallest populations. What is important to emphasize is that there is uncertainty in the fertility estimates presented in this study. While the results identify and discuss the exact point estimates produced by the models and their change over time, the interpretation of the results should be undertaken with caution.

As a starting point in the estimation of municipal-, age- and parity-specific adolescent fertility estimates, I begin by fitting a null or empty model with only an intercept and random effects. This estimates the proportion of women with a first birth (across all ages 12-20 and across all years 1990-2015), and in a separate model, the proportion with a second birth. The equation is as follows:

$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_0 + u_{0j}$$

In this model, the intercept β_0 is shared by all municipalities while the random effect u_{0j} is specific to municipality *j*. Random effects are assumed to follow a normal distribution with variance σ^2_{u0}. For first births, the model produces a fitted value of 0.11 (from the fitted value = $\exp(\hat{\beta}_0)/(1+\exp(\hat{\beta}_0))$ and $\hat{\beta}_0 =$ -2.096) in a municipality where $u_{0j} = 0$ as the proportion of all women ages 12-20 across all years studied with a first birth. The random effects (u_{0j}) take values that put the fitted municipal proportions of all women ages 12-20 across all years studied with a first birth between 0.04 and 0.26 (from the intercept for municipality *j* = $\hat{\beta}_0 + \hat{u_{0j}}$) while the raw estimated municipal proportions produce a range of 0.009 and 0.27 (again, these are more unreliable). The proportion for Mexico as a whole (0.104), as calculated from a raw weighted proportion, matches the mean of all municipal estimates from the multilevel model, weighted by their population size. It is worth noting that in the results section, estimates for Mexico as a whole are taken from the mean of fitted municipal probabilities weighted by their population size. In multilevel linear models, population-level predictions can be derived by simply ignoring the random effects. In multilevel logistic models, the nonlinear transformation in the fitted values means the random effects still play a role in the population average.

For second births, the model produces a fitted value of 0.02 in a municipality where $u_{0j} = 0$ as the proportion of all women ages 12-20 across all years studied with a second birth. The random effects take values that put the fitted municipal proportions of all women ages 12-20 across all years studied with a second birth between 0.007 and 0.17 while the raw estimated municipal proportions suggest the range is between 0.000 and 0.22 (again, these are more unreliable). The raw weighted proportion for Mexico as a whole (0.024) matches that of the weighted mean of the modelled municipal estimates.

The first test is whether the multilevel models are better than single-level models, which would imply that there are important differences between municipalities in the incidence of adolescent fertility. That means testing a null hypothesis that $\sigma^2_{u0} = 0$ using the likelihood ratio statistic of the multilevel model and its corresponding single-level model without random effects. For both first and second birth regressions, the test statistic is in the tens of thousands, providing very strong evidence that the between-municipality variance is non-zero, or that the multilevel models provide better fits than a corresponding single-level model. (A test statistic of just 10.8 provides a p-value of 0.001 on a right-tailed chi-squared distribution for one degree of freedom.)

To the basic model, which only holds information about the hierarchical structure of the data, additional parameters are needed to be able to say something about the age schedule of adolescent fertility as well as any change over time from 1990 to 2015. It is important for the aims of this research to be able to estimate the proportion of adolescents with first and second births at specific adolescent ages. To do so, the first step is to explore how to best model the age schedule of fertility in the data. The most flexible approach is to consider age as a categorical variable in the regression equations with a dummy variable for each integer age. Figure 3.8 depicts the weighted means of all municipal modelled proportions with first and second births by age when age is included in the models as a categorical variable (dark green dots) as compared to the raw weighted proportions (black and grey dots). The alignment between the modelled estimates and raw proportions is not perfect, but very close.

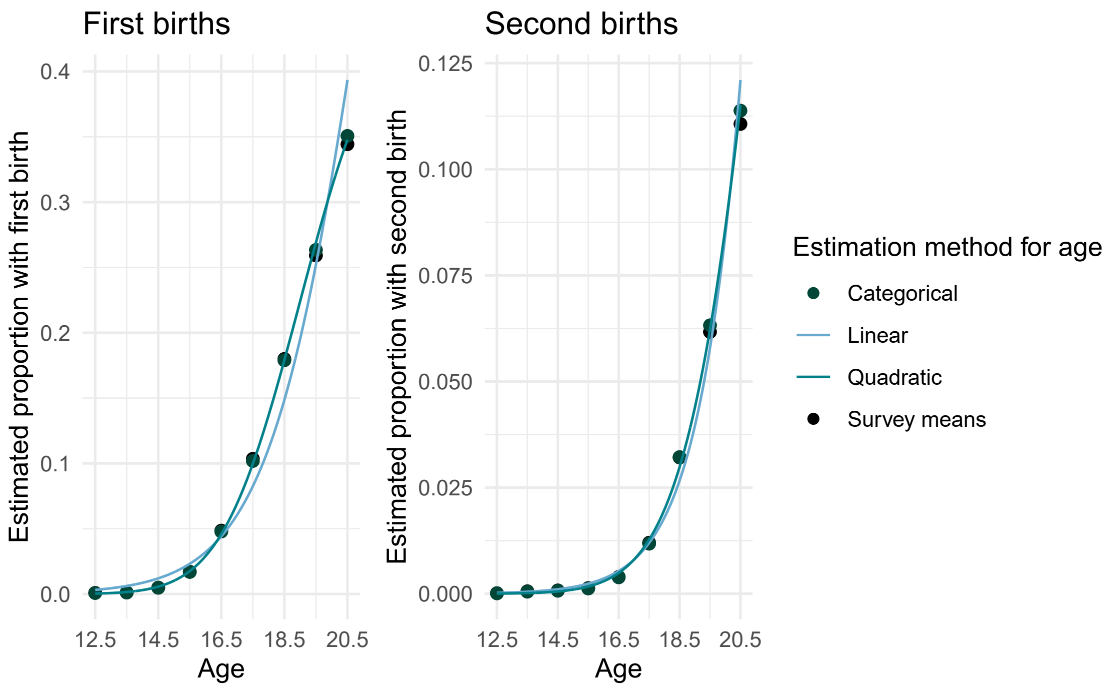
Nevertheless, the well-defined curvilinear form suggests that the age schedule can instead be modelled by a continuous variable, which offers several advantages. First, it allows the models to produce estimated proportions for any age point (such as 14.99 or 19.99), not just the integer ages of the categorical variables. Second, it better allows information to be borrowed across the entire age schedule to fill in gaps in data and improve reliability in municipalities where there are few or no observations at a given integer age. Third, it is more parsimonious in that instead of requiring 8 new variables (for ages 13 up to 20), it requires only one (if the term is linear) or two (if the term is quadratic) to capture the same age pattern.

Likelihood ratio tests for the linear and quadratic term confirm that both offer important improvements over the null model, and that the quadratic term offers a better fit than the linear term for both first birth and second birth models. Figure 3.8 depicts the weighted municipal means of the fitted values for the linear and quadratic terms. For first births, the improved fit of the quadratic age term is readily apparent while for the second birth models, the difference is less pronounced. Nevertheless, in the models for both parities, the linear term overestimates fertility at the younger adolescent ages and underestimates it at the older adolescent ages before overestimating it again at age 20. Importantly, the two age points of most interest to this research—14.99 and 19.99, because they capture the proportions with births at the end of early adolescence and the end of later adolescence—are best captured by the quadratic term. With the addition of a quadratic, continuous term for age, the models now stand as:

$$\text{log}(\frac{\pi_{ij}}{1-\pi_{ij}}) = \beta_0 + \beta_1 \text{age}_{ij} + \beta_2 \text{age}^2_{ij} + u_{0j}$$

To look at change over time, I explore the inclusion of a term for census year. Figure 3.9 depicts the estimated proportions with first and second births at age 19.99 when census year is included

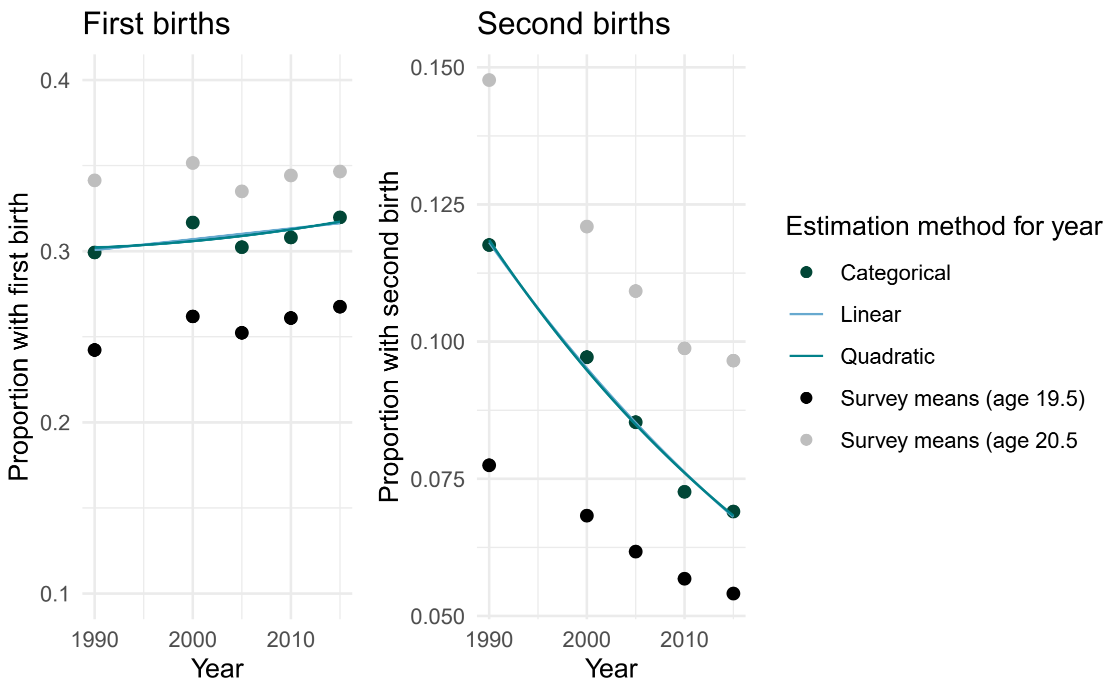
Figure 3.8: Comparison of estimated proportion of adolescents with a first and second birth by age, according to regression model type



in the models as a categorical variable (dark green dots) compared to a linear or quadratic term (lighter green lines). The raw weighted proportions at ages 19.5 and 20.5 are included (black dots) for comparison. In this case, the continuous variables are able to replicate fairly well the decline over time in second births. However, for first births, the continuous terms match the trend at the beginning and end of the study years, but not for the years in between, at least at the national level. Likelihood ratio tests indicate that the categorical terms offer a better fit than the continuous terms, and when comparing the continuous terms, the quadratic term for census year does not offer a better fit than the linear term. However, the model at this point assumes that change over time is the same in all municipalities (identical slopes)—that is, all municipalities see the same increase in first births and the same decline in second births—only that their starting levels in 1990 differ (random intercepts). For example, a municipality with $\sigma^2_{u0} = 0$ sees its proportion of 19.99 year-olds with a first birth increase from 0.33 in 1990 to 0.35 in 2015. At the national level, with municipal trends weighted by population size, the proportion of 19.99 year-olds with a first birth increased from 0.30 in 1990 to 0.32. Likewise, a municipality with $\sigma^2_{u0} = 0$ saw its proportion of 19.99 year-olds with a second birth fall from 0.13 in 1990 to 0.08 in 2015 while at the national level, the proportion fell from 0.12 to 0.07. That is, while the proportions differ, the increase of two percentage points in first births and decrease of five percentage points in second births is identical across all municipalities.

However, it is possible that municipalities differ in their patterns of change over time. Confirming this is important to the research aims of this chapter. Indeed, raw estimates of the proportion

Figure 3.9: Comparison of estimated proportion of adolescents with a first and second birth by year, according to regression model type



of all adolescents with a first or a second birth, seen in Appendix B, suggest there are diverse patterns of change over time with some municipalities seeing increasing proportions, others seeing decreasing proportions and some municipalities seeing both increases and decreases over the twenty-five years of the study period. Fortunately, the multilevel regressions can be expanded to model this diversity by including census year both as a fixed and as a random variable. Likelihood ratio tests confirm that adding census year to the random effects portion of the regression models offers important improvements. Likelihood ratio test statistics—when comparing the model without random effects on year to those with random effects on year—are in the thousands, providing very strong evidence that municipalities have differing patterns of change over time in adolescent fertility proportions.

For models of first and second births, likelihood ratio tests prefer the regression model with categorical terms for the census years followed by the models with a quadratic term for census year (as opposed to linear change over time). However, visual checks comparing fitted estimates from the categorical and continuous regression models in each municipality favour modelling change over time with a quadratic term for several reasons. The continuous terms seem to do better at smoothing out noise in municipal trends that are likely due to random chance in the adolescent population sampling. That is, in municipalities with large sample sizes, there is very little difference between the quadratic trendlines and categorical point estimates. In contrast, in municipalities with smaller sample sizes, difference can be more pronounced. In essence, the advantage of the quadratic term appears to be in smoothing out variability in low-population municipalities to present a more coherent time trend. The quadratic terms also have the advantage of enabling the examination of proportions in the years when there was no census, as well as facilitating the examination of broader patterns between prevalence and change over time—for instance, what the pattern of change is for municipalities that start the study period with the highest adolescent fertility compared to those that start with the lowest prevalence of adolescent fertility. With the addition of a quadratic term for census year in both the fixed and random effects, the models now stands as:

$$\begin{aligned}\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) =& \beta_0 + \beta_1 \text{age}_{ij} + \beta_2 \text{age}^2_{ij} + \beta_3 \text{year}_{ij} + \beta_4 \text{year}^2_{ij} + \\ & u_{0j} + u_{3j}\text{year}_{ij} + u_{4j}\text{year}^2_{ij}\end{aligned}$$

One final possibility, with important policy implications, is that the age schedule might also differ across municipalities. Currently, the model assumes that the shape of the age schedule is identical in all municipalities, though proportions at every age point may be higher or lower given the different municipal intercepts. For example, a municipality with above-average adolescent fertility will see above-average proportions at each age point. Likewise, a municipality with below-average adolescent fertility will see below-average proportions at each age point. If municipalities have distinct age schedules, some may see higher proportions of births at younger adolescent ages relative to births at older ages. Conversely, some municipalities may see very little childbearing among the youngest adolescents but comparatively more at older adolescent ages. To test this possibility, I include age in the random effects. Likelihood ratio tests confirm that municipalities have distinct age schedules and that the quadratic term for age offers a better fit than the linear term in both first and second birth regression models. An additional test indicates that municipal slopes and intercepts are not independent but rather covary, and as such the final model is:

$$\begin{aligned}\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) =& \beta_0 + \beta_1 \text{age}_{ij} + \beta_2 \text{age}^2_{ij} + \beta_3 \text{year}_{ij} + \beta_4 \text{year}^2_{ij} + \\ & u_{0j} + u_{1j}\text{age}_{ij} + u_{2j}\text{age}^2_{ij} + u_{3j}\text{year}_{ij} + u_{4j}\text{year}^2_{ij}\end{aligned}$$

This final model is able to identify several different kinds of priority municipalities for Mexico's intervention strategy, all of which represent proportions and patterns that have not been estimated or analysed before. These priority municipalities include those with the highest levels of adolescent first births and those with the highest level of second births, with the idea that strategies for reducing first births differ dramatically from those to reduce second births in adolescence. The models also identify municipalities where the incidence of early adolescent fertility, or childbearing at ages 14 and younger, is comparatively high. Given the strategic goal to eliminate all early adolescent fertility and the absence of any municipal-level early adolescent fertility measures, these estimates are imperative. Here again, effective strategies for reducing early adolescent fertility differ from those targeting older adolescents. Finally, the models identify municipalities where adolescent childbearing has increased over the period of study, either in early adolescence or later adoles-

	Model			
	First births		Second births	
	Regression Coefficeint	(standard error)	Regression Coefficeint	(standard error)
Fixed effects				
Intercept	-2.99	(0.01)	-5.30	(0.02)
Age	3.72	(0.01)	4.29	(0.04)
Age2	-1.25	(0.01)	-0.89	(0.03)
Year	0.02	(0.01)	-0.33	(0.01)
Year2	0.07	(0.01)	0.06	(0.01)
	Variance	(standard deviation)	Variance	(standard deviation)
Random effects				
Intercept	0.18	(0.42)	0.26	(0.51)
Age slope	0.05	(0.22)	0.68	(0.82)
Age2 slope	0.03	(0.17)	0.41	(0.64)
Year slope	0.05	(0.22)	0.06	(0.24)
Year2 slope	0.04	(0.20)	0.06	(0.24)
Observations	5,963,155		5,963,155	
Log Likelihood	-1,494,271		-538,950	

Note:
Age and year are standardised variables; all p-values < 0.0001

Table 3.2: Multilevel regression model results

cence or for first or second births. Increasing adolescent fertility is concerning in its own right, even if the municipalities do not (currently) have the highest incidence rates. As such, the results of this chapter focus on various fitted values of interest, rather than the regression models and their coefficients. Nevertheless, Table 3.2 presents the main and random effects of the two final models.

In the final models, the random effects take account of all unobserved differences in municipalities, after accounting for age and time, which might arise out of a host of possible causes. For example, adolescent fertility levels are influenced by patterns of schooling, levels of poverty and pre-existing norms around adolescent sexual activity and partnership formation, which differ across Mexico's diverse economic and cultural landscape. Multilevel models have the particular advantage of being able to incorporate observed differences when they are known. Often, these additional predictors are used to improve model estimates. In other instances, they are used to determine how much of the unobserved differences can be explained by known differences. However, the analysis here deliberately leaves out municipal-level indicators for two important reasons. First, existing research, finds an inconsistent relationship between various socio-economic indicators and adolescent fertility at both the individual and aggregate level (Ailines Genis 2018; Flórez 2005; Velarde and Zegers-Hochschild 2017). As such, including such indicators in the models may confuse rather than improve the estimated proportions. Second, the official municipal adolescent fertility rates were derived without adjustments from municipal-level socio-economic variables but rather only used individual indicators for age and time (Consejo Nacional de Población 2020; Meneses and Ramírez 2018). As such, in the second part of this chapter, the comparison of the relationship between official $ASFR_{15\text{-}19}$ and parity-specific adolescent fertility is more consistent when the parity-specific proportions are also estimated using only age and time, without adjustment from other socio-economic factors.

3.6 Results

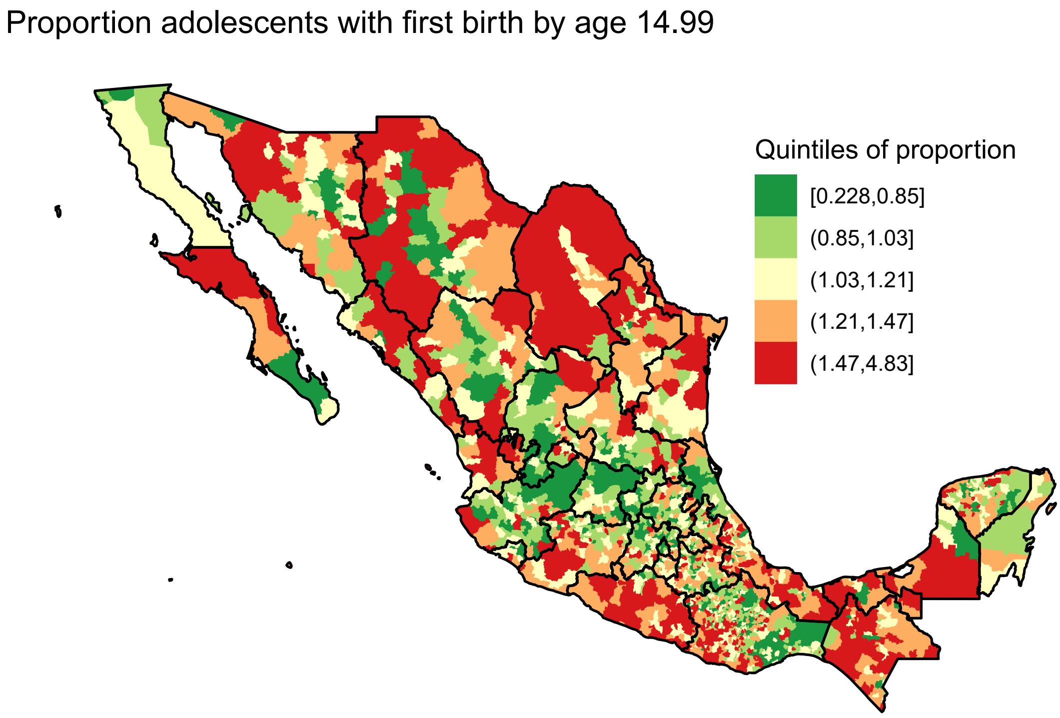
3.6.1 First births in adolescence

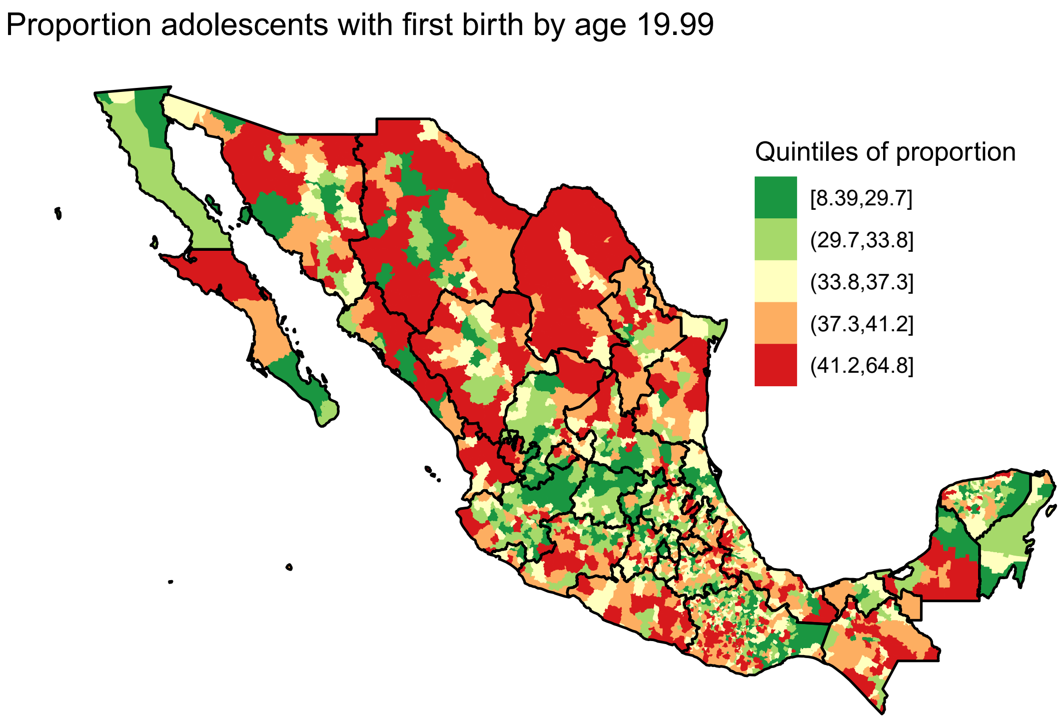
Figure 3.10 depicts the municipal estimates of the proportion of adolescents with a first birth by ages 14.99 and 19.99 in 2015, two age points chosen for their relevance to the two-part aim of Mexico's national strategy to (1) eliminate childbearing at ages younger than 15 and (2) halve childbearing among older adolescents. The maps categorize municipalities into quintiles, or five equally-sized groups of about 491 municipalities. The lowest quintile, shaded in dark green, identifies municipalities with the lowest incidence of adolescent fertility. Municipalities with the lowest incidence among 14.99-year-olds saw between 0.2% to 0.9% of adolescents with a first birth. At the other end of the spectrum, municipalities with the highest proportion are shaded in dark red, and identify areas where an estimated 1.4% to 4.8% of adolescents have a first birth by age 14.99. The middle half of municipalities (quartiles two and three) see between 0.9% and 1.4% of 14.99-year-olds with a first birth. The incidence of later adolescent fertility sees a much wider range, with municipalities seeing between 8.4% to 64.8% of adolescents with a first birth by age 19.99. The middle half of municipalities (quartiles two and three) see between 30.8% and 40.2% of 19.99-year-olds with a first birth. See Appendix B for a discussion of the uncertainty in these estimates.

Though municipalities see distinct fertility age schedules, the majority (61%) of municipalities' estimates fall into the same quintile at both age points. That is, if the municipality is in the quintile of the highest incidence of early adolescent fertility, in most cases it also falls in the highest quintile of later adolescent fertility. Nevertheless, not all municipalities follow this pattern. Figure B.11 in the Appendix highlights the municipalities that do not see matching quintiles at both age points. (In the map for age 19.99, the municipalities that do not match the quintile at age 14.99 are shown in a darker hue while those that do match are shaded in a lighter hue.) Of particular policy interest are the 140 municipalities (6%) that see a higher incidence of early adolescent fertility——are in the middle or top two quintiles at age 14.99—and a lower incidence of later adolescent fertility—in the bottom two quintiles at age 19.99. These municipalities, which are mostly scattered in the centre of the country, might be overlooked in current strategies that focus on municipalities with the highest adolescent birth rates given those rates only consider ages 15-19.

Figure 3.10 also bring out the regional clustering in the patterns of adolescent first births in 2015. The periphery regions of the north, south and coasts tend to see the highest incidence while the central regions tend to see the lowest. Additionally, the municipal mapping makes the inadequacy of state divisions (marked in black outlines) readily apparent. Every state except for Baja Califor-

Figure 3.10: Proportion of adolescents in Mexican municipalities with a first birth by ages 14.99 and 19.99 in 2015





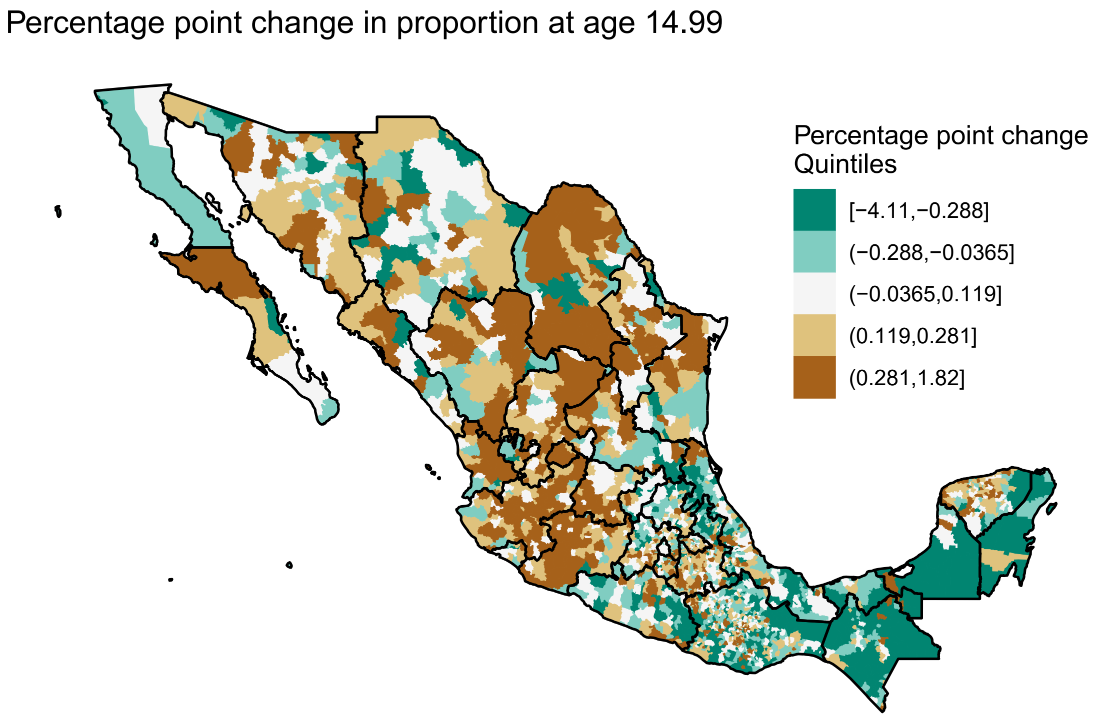
nia, in the far northwest has pockets of high adolescent fertility—or municipalities in the highest quintile. In fact, quite often, municipalities across state lines are more similar to each other than municipalities within the same state. For example, many of the northern states see high adolescent fertility mirrored in their border municipalities, creating corridors of high fertility alongside cross-state corridors in lower fertility.

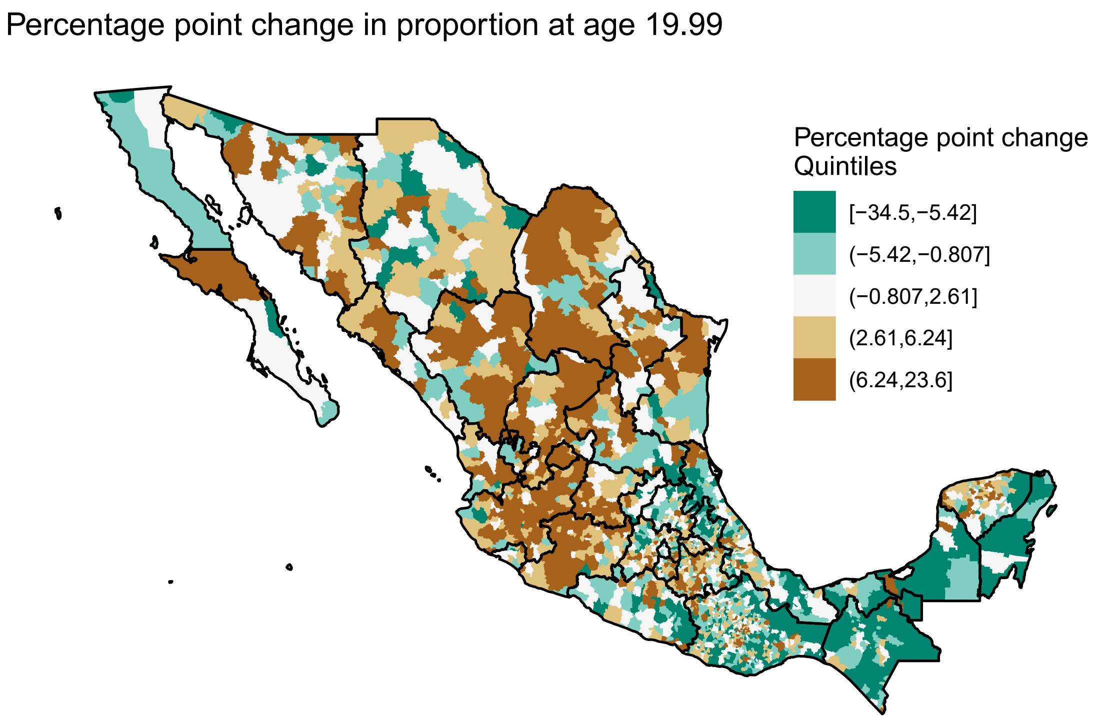
In looking at change over time in the incidence of first births in adolescence the picture changes rather dramatically, as seen in Figure 3.11. A fairly strong divide appears between the north and south of the country, with increase in the incidence of first births over the past twenty-five years clustering in the north and decrease occurring in the south. This means that many of the northern municipalities with the highest first birth proportions in 2015, as well as many of the central municipalities with the lowest proportions, have seen an increasing incidence of women entering motherhood in adolescence. Meanwhile, many southern municipalities, which stood out for having the highest incidence of first births in adolescence in 2015, have actually seen the most decline over the past decades.

In essence, limited change at the national level masks underlying flux at the municipal level. To be clear, for Mexico as a whole, the proportion of women entering motherhood in adolescence has changed comparatively little. The proportion of adolescents with a first birth by age 14.99 increased from 1.0% to 1.1% from 1990 to 2015. Meanwhile, the proportion with a first birth by age 19.99 increased from 29.4% to 32.0% over the same period. (Again, these national estimates are derived from the mean municipal estimates weighted by their population size.) At the municipal level, in contrast, more substantial change has been the norm, rather than the exception. Only 13% of municipalities saw similar increase in their proportions at age 14.99 as occurred at the national level (up to 0.1 percentage point increase). When considering changes at age 19.99, only 16% of municipalities saw similar increase in their proportions (up to 2.6 percentage point increase). A full 44% of municipalities saw declines in their proportions at both ages while the remaining municipalities saw greater increase than what occurred at the national level (43% at age 14.99 and 40% at age 19.99).

To look closer at this flux, it is helpful to divide municipalities into those that saw increase and those that saw a decrease in the incidence of women entering motherhood in adolescence. First births in adolescence increased in a majority of Mexican municipalities from 1990 to 2015. That is, an estimated 1,364 municipalities (56%) saw an increase in the proportion of adolescents with first births both by age 14.99 and 19.99. Of these municipalities with an increasing incidence of first births, the middle half (second and third quartiles) saw their proportion increase by 0.1 to 0.3 percentage points at age 14.99 and by 2.4 to 7.9 percentage points at age 19.99. In proportional terms, the increase is more dramatic, particularly for the youngest. The middle half of municipalities with an increasing incidence of first births saw their proportions at age 14.99 increase by between 11.2% to 44.2% and at age 19.99 increase by between 7.2% and 28.3%. National-level

Figure 3.11: Percentage point change in the proportion of adolescents in Mexican municipalities with a first birth from 1990 to 2015





estimates increased by 9.1% and 8.9% at ages 14.99 and 19.99 respectively.

Nevertheless, not all municipalities experienced an increase in the incidence of first births in adolescence. Among the 1,093 municipalities with a decreasing incidence of first births, the middle half (second and third quartiles) saw their proportion decrease by 0.1 to 0.5 percentage points at age 14.99 and by 2.1 to 8.8 percentage points at age 19.99. In proportional terms, these municipalities saw their proportions at age 14.99 decrease by between 8.5% and 30.6% and at age 19.99 decrease by between 5.6% and 19.5%. The municipalities with the greatest percentage point change are also those with the greatest proportional change and vice versa—those with smaller percentage point change are those with less proportional change.

As a general rule, the model maps a negative correlation between intercepts and slopes. That is, municipalities with the lowest proportions of 19.99 year-olds with first births in 1990 tend to see the greatest increase over time. Conversely, municipalities with the highest proportions in 1990 tend to see the strongest decline. Municipalities with more average proportions see less change. However, there are many municipalities that stand out as exceptions to the pattern of negative correlation between intercepts and slopes. For instance, there are plenty of municipalities that started the period of observation with relatively low proportions and subsequently experienced considerable decline. The opposite is also true. There are plenty of municipalities that started with higher proportions and also saw some of the greatest increase. Meanwhile, there are municipalities with minimal change over the past twenty-five years that span a wide array of starting proportions. In essence, there is a complex and dramatic flux in Mexico's patterns of adolescent first births, which is masked by seemingly immobile national trends. See Appendix B for a more in-depth exploration of the correspondence between intercepts and slopes.

3.6.2 Second births in adolescence

Figure 3.12 depicts the municipal estimates of the proportion of adolescents with a first birth who progressed to a second birth by age 19.99 in 2015 (parity progression ratio) followed by a map of the proportion of adolescents with a second birth by age 19.99. Second births among adolescents aged 14.99 (not shown) have become exceptionally rare. The progression ratio is a powerfully informative measure because of its correct accounting of the population at risk of a second birth. To illustrate, two municipalities may share the same proportion—say 10% of adolescents with two births by age 19.99. However, if these two municipalities have different proportions with first births, the 10% of 19.99-year-olds with second births means something different. For example, if in one municipality 20% of 19.99-year-olds have a first birth and 10% have a second birth, that means that a full 50% of the population at risk of a second birth has had a second birth. In contrast, if in one municipality 40% of 19.99-year-olds have a first birth and 10% have a second birth, that means that 25% of the population at risk of a second birth had a second birth. That is, even though the proportions with second births are the same, the true risk of second births is twice as high in the first municipality as it is in the second. Again, see Appendix B for a discussion of the uncertainty in these estimates.

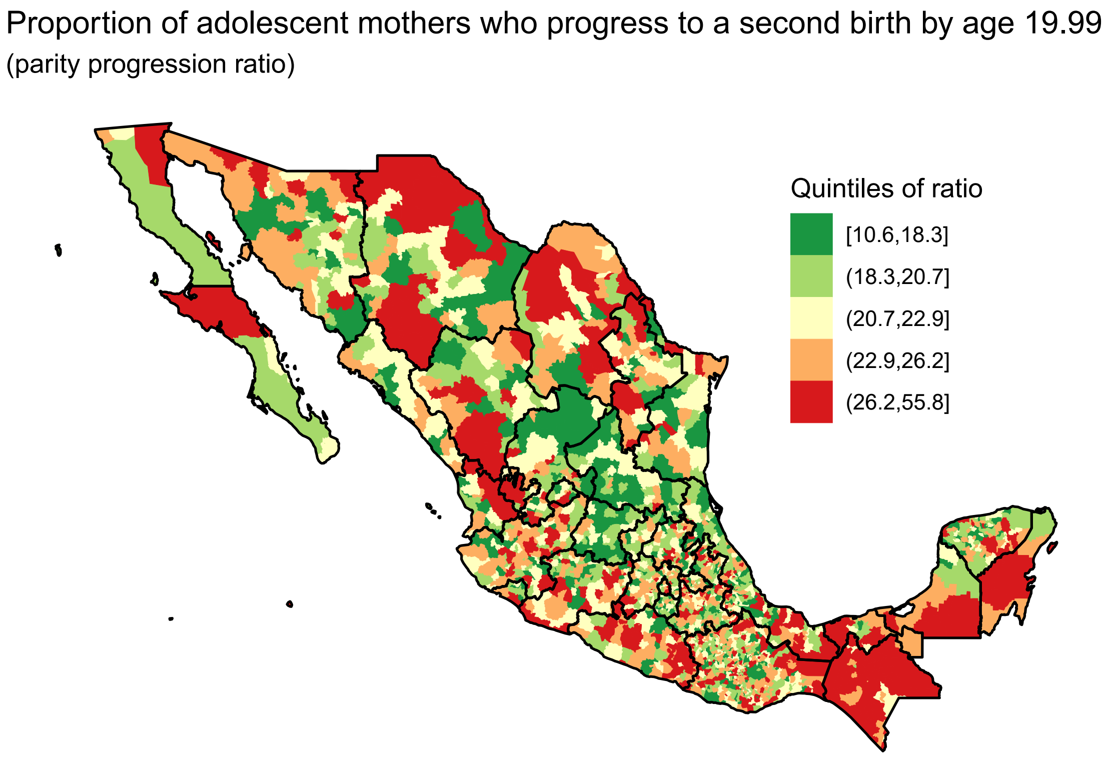
The maps in Figure 3.12 categorize municipalities into quintiles, or five equally-sized groups of about 491 municipalities. The lowest quintile for ratios, shaded in dark green in the top map, identifies municipalities with the lowest risk of second births in adolescence where between 10.6% to 18.3% of 19.99-year-olds in 2015 at risk of a second birth have a second birth. At the other end of the spectrum, municipalities with the highest risk are shaded in dark red and identify areas where an estimated 26.2% to 55.8% of 19.99-year-olds at risk had a second birth. The middle half of municipalities (quartiles two and three) saw between 18.9% and 25.1% of 19.99-year-olds at risk of doing so, progressing to a second birth.

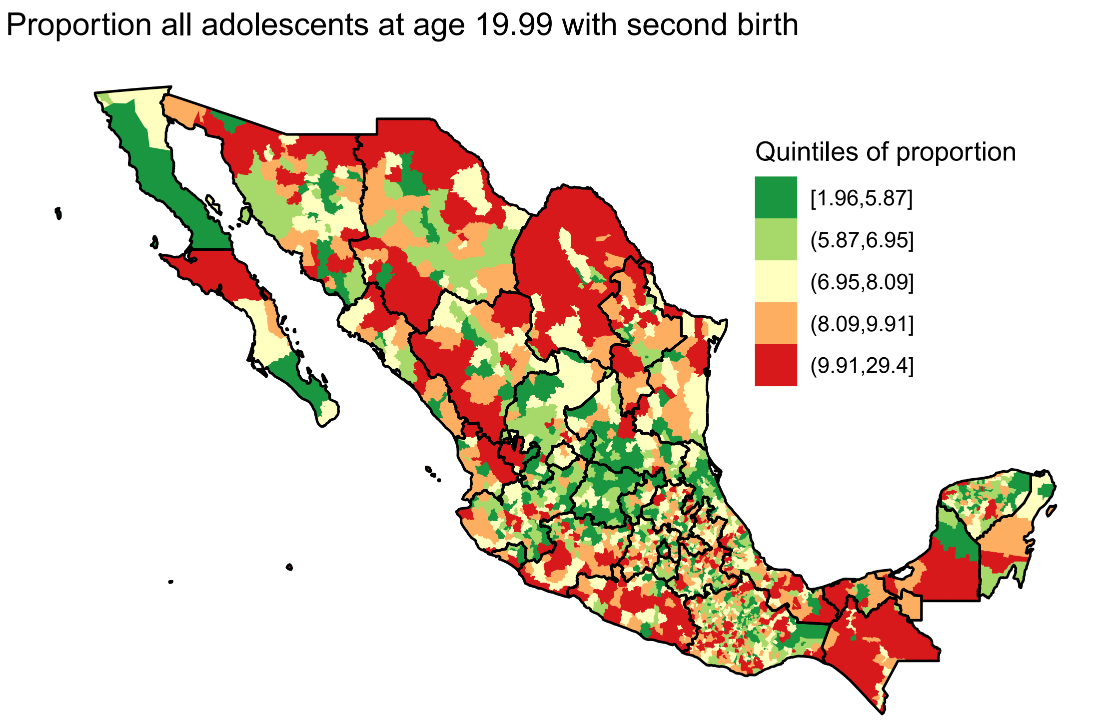
The proportions of 19.99-year-olds with a second birth sees a lower and narrower range, as shown in the lower map in Figure 3.12. In 2015, municipalities see between 2.0% to 29.4% of adolescents with a second birth by age 19.99. The middle half of municipalities (quartiles two and three) see between 6.1% and 9.3% of 19.99-year-olds with a second birth. Just under half of municipalities (45%) share the same quintile for second birth progression ratios as second birth proportions. Figure B.13 in the Appendix highlights these municipalities that do not see matching quintiles in ratios and proportions by showing them in a darker hue. Of particular policy interest are the 271 municipalities (11%) with average or above-average ratios but below-average proportions. In these municipalities, 20.7% or more of adolescents at risk of a second birth have experienced a second birth even though their proportions are comparatively low, with less than 7.0% of all 19.99-year-olds in the municipality with second births. These municipalities, which are mostly scattered along a western-central corridor that runs from the north to the south of the country would merit focused interventions for reducing second births, but might otherwise remain overlooked given their comparatively low incidence of first and second births.

In looking at the geographic patterns in Figure 3.12, many parts of the north that saw the highest first birth proportions do not see the highest ratios of progression to second births. Instead, high progression ratios are more strongly clustered in the south where first birth proportions were also high. Additionally, many central, interior municipalities see high progression ratios despite patterns of low first birth proportions. While the 278 municipalities (11%) with above-average incidence of first births and above-average incidence of second birth progression ratios would likely fall under current priority municipalities as those with the highest adolescent fertility, other municipalities with concerning patterns might be overlooked. For instance, the 549 municipalities (22%) with average or above-average second birth progression ratios and below-average first birth proportions. In these locations, relatively high risk of second births might go unseen given the lower incidence of first births. These municipalities are strongly concentrated in central, interior states.

Change over time in the incidence of second births in adolescence is depicted in Figure 3.13. The divide between the north and south seen previously for changes in first births is not quite as

Figure 3.12: Proportion of adolescents at age 19.99 with a second birth in Mexican municipalities in 2015





defined for changing progression ratios (upper map), though it is still there for changing second birth proportions (lower map). Here, the municipalities with the least decline in progression ratios over the last twenty-five years—even increase in some few cases—are most strongly concentrated at the far northern border. Many of the southern border and southwestern coastal municipalities that had some of the highest ratios in 2015 have seen some of the greatest decline over the past decades. This differs slightly from the geographic clustering in the incidence of first births. For changes in first birth proportions, the far north-western border areas saw comparatively less increase, while municipalities below them, though still in the northwest, saw strong increase.

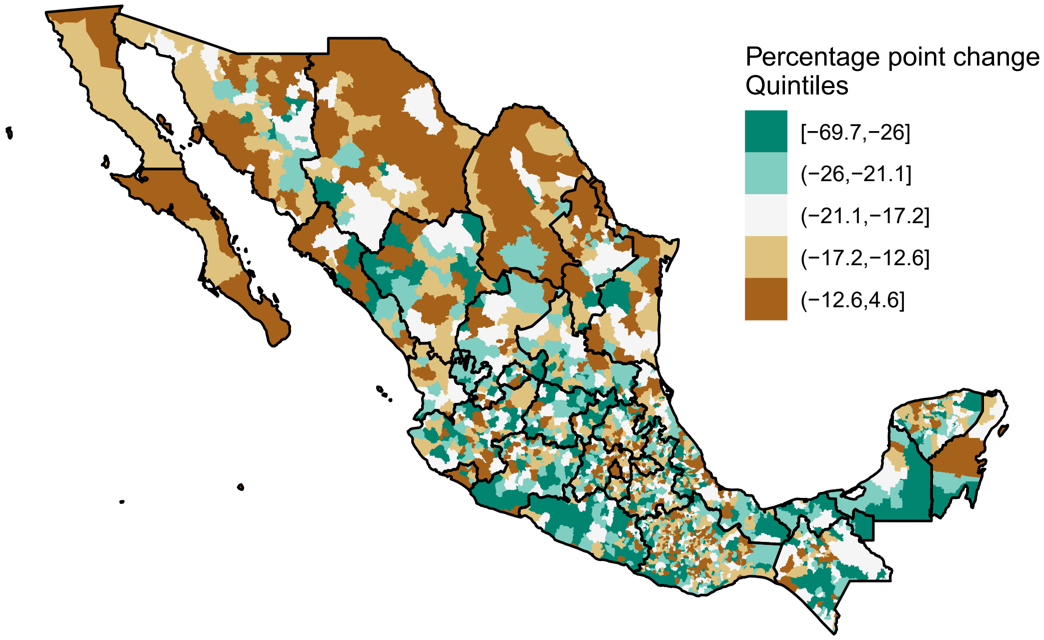
Here again, change at the national level masks considerable subnational diversity. For Mexico as a whole, 36.9% of adolescents with a first birth progressed to a second birth by age 19.99 in 1990, declining to 22.6% having done so in 2015. This corresponds to the proportion of women with second births by age 19.99 decreasing from 11.3% in 1990 to 7.3% in 2015. (Again, these national estimates are derived from the mean municipal estimates weighted by their population size.) At the municipal level, just over a quarter of municipalities saw up to a 14 percentage point decline in their progression ratio, while about three quarters of municipalities saw greater decline, except for ten municipalities (0.4%) that saw their progression ratios increase over the last twenty-five years. Only in these ten municipalities has the risk of having a second birth increased—in every other municipality in the country the risk has declined. However, in a total of 49 municipalities (2%), the proportion of 19.99-year-olds with two births increased from 1990-2015 due to substantial increases in first births alongside limited decline in progression to second births. The few municipalities with increasing risk in progression to second births cluster along the northern border with a few in the far south. Municipalities with increasing proportions of adolescents with two births cluster in northern border states as well as in Jalisco and Michoacán (central west).

The middle half of municipalities (second and third quartiles) saw their progression ratios decrease by between 14 and 25 percentage points from 1990 to 2015, corresponding to a 38.6% to 53.3% reduction in their ratios. National estimates saw a 14 percentage point decline, or a reduction of 39%. While it is interesting that most municipalities do not share the same quintile in percentage point change and proportional change, as well as that municiaplities with the greatest percentage point change are not necessarily those with the greatest proportional change (see Appendix Figure B.16 for maps of proportional change), what is more relevant is the considerable contrast in patterns between first and second births.

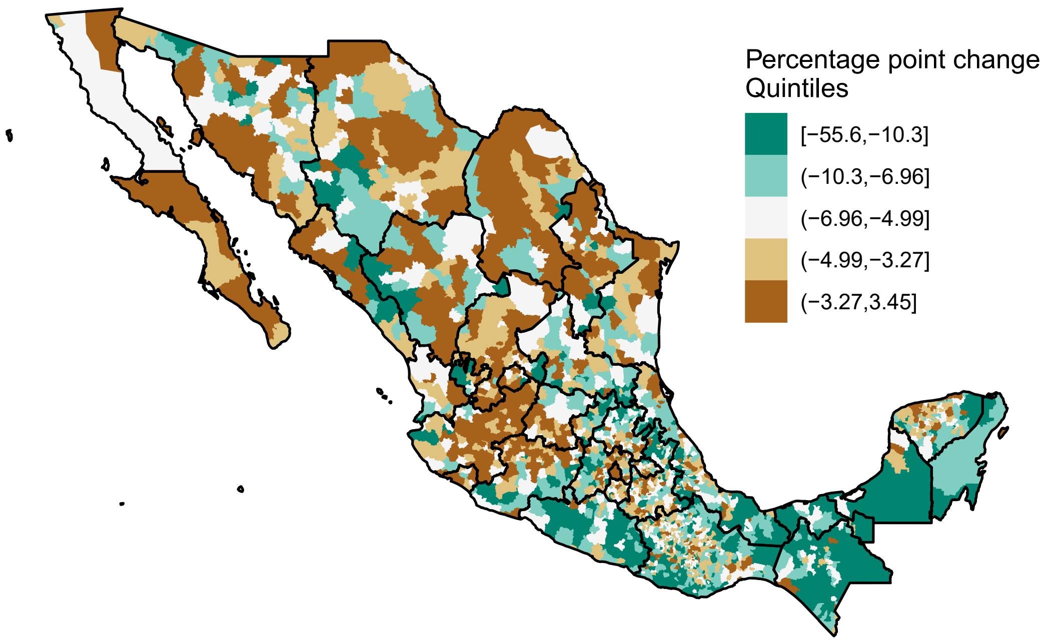
Indeed, there is comparatively little correspondence between patterns of first birth proportions and second birth progression ratios, and this is perhaps the most important finding for the second birth estimates. It means that a certain trend for first birth proportions does not guarantee a certain trend for patterns of progression to second births. That is, the risk of progressing to a second birth varies considerably across municipalities with similar patterns of first births. As with first births, there is a negative relationship between intercepts and slopes for second birth proportions, in that

Figure 3.13: Percentage point change in second adolescent births in Mexican municipalities from 1990 to 2015

Percentage point change in proportion of adolescents with one birth who progress to a second birth by age 19.99



Percentage point change in proportion with second birth by age 19.99



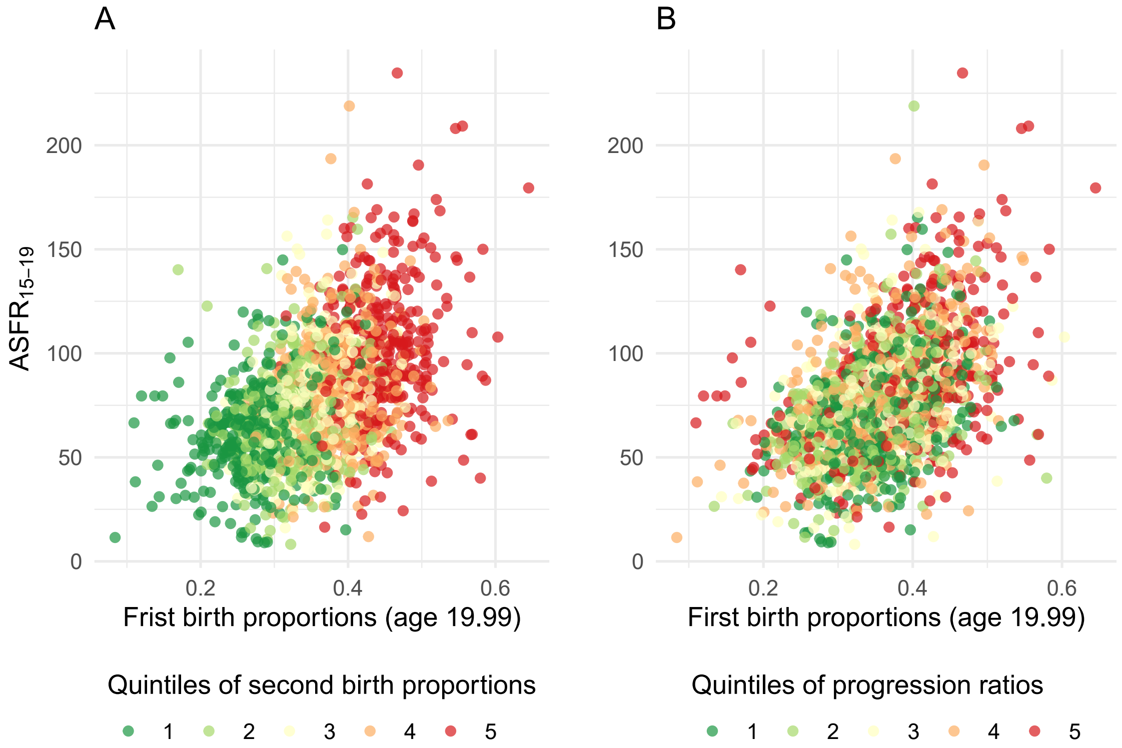
municipalities with the highest ratios tend to see the greatest decline and municipalities with the lowest ratios tend to see the least decline. However, when patterns of first births are taken into account, the picture becomes much more nuanced. For example, while most municipalities with the highest first birth proportions also saw the highest progression ratios in 1990 and the greatest decline in progression ratios over time, there are plenty of municipalities that although they had the highest first birth proportions, they had relatively low progression ratios in 1990 as well as more limited decline. Likewise, many municipalities with the low first birth proportions saw high risk of progression to second births and considerable diversity in their pace of decline. Other exceptions include the many municipalities with the strongest declines in progression to second births alongside some of the strongest increases in first births. See Appendix B for a more in-depth exploration of this correspondence between intercepts and slopes across parities.

Despite the complexity and diversity of these unmasked parity-specific patterns, they have the potential to add sorely needed clarity to the puzzle of Mexico's adolescent fertility. Subnational flux, rather than stagnation, reopens the possibility that adolescent fertility is indeed changing in tact with the country's impressive gains in schooling and other advancements, only that these changes have been masked by the seeming rigidity of fertility at the national level. In a final step, it is worth clarifying how these diverse parity-specific patterns relate to the recently-released official municipal $ASFR_{15\text{-}19}$.

Figure 3.14 plots the 2015 official municipal $ASFR_{15\text{-}19}$ against this research's first birth proportions in two subplots. Plot A colour codes all municipalities by quintiles of their second birth proportions (the same as what is shown in the lower map in Figure 3.12) while Plot B colour codes all municipalities by quintiles of their second birth progression ratios (the same as what is shown in the upper map in Figure 3.12). The positive relationship between $ASFR_{15\text{-}19}$ and first birth proportions is expected—municipalities with higher $ASFR_{15\text{-}19}$ tend to have a higher incidence of first births in adolescence. Additionally, the positive relationship between $ASFR_{15\text{-}19}$ and second birth proportions is also expected—municipalities with the highest first and second birth proportions (red dots) tend to have higher $ASFR_{15\text{-}19}$ than municipalities with the lowest first and second birth proportions (green dots).

However, there is considerable variability in $ASFR_{15\text{-}19}$ for any given first-birth proportion. For example, municipalities where less than 20% of women have a first birth in adolescence still see their $ASFR_{15\text{-}19}$ range from less than 25 births to more than 100 births per thousand adolescents aged 15-19. While some of this variability could be due to measurement error (see Appendix B for a discussion of uncertainty in the estimates), Plot B adds additional insight into this dramatic range. These same municipalities, where an estimated 20% or fewer women have a first birth in adolescence, see highly disparate progression risk. For example, only the municipalities with the lowest progression ratios (green dots among this group with first birth proportions of less than 20%) have low $ASFR_{15\text{-}19}$ while those with high progression ratios have high $ASFR_{15\text{-}19}$ (red dots

Figure 3.14: Comparison of parity-specific adolescent fertility and $ASFR_{15\text{-}19}$, 2015



in the group with first birth proportions of less than 20%). The lack of a clear division in the colours in Plot B is indicative of the lack of strong correspondence in first birth proportions and second birth progression ratios already described above, but in general, municipalities with lower progression ratios (green dots) cluster at the lower $ASFR_{15\text{-}19}$ values while those with higher progression ratios (red dots) cluster at the higher $ASFR_{15\text{-}19}$ values.

3.7 Summary and Discussion

This study set out to explore whether the patterns of first birth stagnation and second birth decline seen at the national level also define Mexico's subnational municipal trends. Specifically, it produces estimates of age- and parity-specific proportions and progression ratios in 2,457 Mexican municipalities over the last 25 years. Instead of finding uniformity, the estimates reveal a diverse array of trends in both first and second births in adolescence that have important policy implications. I cannot find that these parity-specific municipal patterns have been estimated before. Additionally, I cannot find that any measures of fertility among adolescent aged 14 and younger at the municipal level have been estimated before.

Mexico's fascinating adolescent context over the last quarter century presents a puzzle of stability and change. Against the backdrop of political and economic stability, as well as strong reproductive health services, the size of its adolescent population changed very little. The apparent stagnation in adolescent fertility (when measured as $ASFR_{15\text{-}19}$) stands in contrast to the country's healthy pace of development and dramatic improvements in schooling, particularly in secondary schooling or the school years that span adolescence. The diversity in the municipal trends, as uncovered by this study, are a critical first step towards unravelling this seeming paradox. There has been change in adolescent fertility, only it is occurring at the subnational level and in such a fashion that its overlapping contrasts manifest as national immobility.

In the first instance, stability in $ASFR_{15\text{-}19}$ arises from an increasing incidence of first births in adolescence alongside a decreasing incidence of second adolescent births at the national level. But this was already known from previous research and detailed more specifically in the previous chapter. This study's findings indicate that at the subnational level, the picture is quite varied, and municipalities are split between those that saw increasing adolescent first births (56% of municipalities) and those that saw decreasing adolescent first births (44% of municipalities). As a general rule, municipalities with the lowest first birth proportions in 1990 saw the greatest increase over time while municipalities with the highest proportions in 1990 saw the greatest decline, which follows a pattern of convergence in patterns of first births. However, plenty of municipalities do not follow this generalisation. There are many municipalities, for instance, with high first birth proportions in 1990 that saw almost no change or even sharp increase over the last two and a half decades. Additionally, while the vast majority of municipalities (98%) saw a declining proportion of adolescents with second births, patterns of progression among adolescent mothers at risk of a second birth see greater diversity and do not correspond tightly with levels or changes in first births.

Rather than revisiting in detail the changes, diversity and geographic patterns of the municipal estimates, these summary paragraphs will focus on the broader meaning of these complexities. However, it is worth noting that simply identifying and mapping these fertility trends at smaller geographic areas can make a pivotal contribution to efforts to reduce adolescent fertility, as was the case in the United Kingdom. The country's recent ten-year adolescent fertility reduction initiative employed detailed subnational adolescent fertility maps to reveal that areas with similar socio-economic characteristics did not always have similar adolescent fertility, which made the rates seem less inescapable (Hadley, Chandra-Mouli, and Ingham 2016). Though it may not seem so at first glance, the underlying flux and complexity in Mexico is hopeful. It suggests that change in adolescent fertility is possible. Indeed, adolescent fertility in Mexico has not remained unchanged in the face of dramatic improvements in education and development.

Mexico's national strategy to reduce adolescent fertility recognizes the value of targeting interventions at the municipal level, but it prioritises municipalities with the highest $ASFR_{15\text{-}19}$ and largest populations (Gobierno de la República 2015), which overlooks many important dimensions brought to light in this study. First, the focus on first births instead of $ASFR_{15\text{-}19}$, results in a very different municipal map (see for comparison Ailines Genis 2018). Indeed, $ASFR_{15\text{-}19}$ does not perfectly correspond with the incidence of parity-specific adolescent fertility, and there seems to be more geographic heterogeneity in the incidence of parity-specific adolescent fertility than in $ASFR_{15\text{-}19}$. For example, the municipalities with the highest $ASFR_{15\text{-}19}$ are not always the same with the highest incidence of first births in adolescence, and municipalities with the highest risk of progression to second births are not always those with the highest proportion of first births. Additionally, neighbouring municipalities show much more diversity in the incidence of parity-specific adolescent fertility than in $ASFR_{15\text{-}19}$ and, as such, many more states have municipalities with the highest incidence of first births than municipalities with the highest $ASFR_{15\text{-}19}$. Essentially, there appear to be many municipalities with an above-average incidence of first births that do not have an above-average incidence of $ASFR_{15\text{-}19}$ and would thus miss out in interventions that only target the highest $ASFR_{15\text{-}19}$.

This study also offers a first look at municipal estimates for early adolescent fertility, or births among girls 14 years and younger. Here too, there is value in recognising that age schedules differ across municipalities, especially given that Mexico aims to eliminate all childbearing in adolescents 14 and younger. Unfortunately, it appears that first births in early adolescence have increased in the majority of Mexican municipalities. Importantly, this study finds that there are municipalities with above-average early adolescent fertility but average or below-average later adolescent fertility, which suggest they would likely otherwise be overlooked in initiatives that focus on targeting places with the highest $ASFR_{15\text{-}19}$.

While this research does not set out to examine the underlying drivers of these changes in the adolescent fertility landscape in Mexico, it is worth exploring what other literature suggests might be happening. Causal evidence that exists at the individual level supports the idea that simply keeping adolescents “incarcerated” (in school or work) limits their initial pregnancy risk exposure, no matter the schooling level they have achieved, while attainment of progressively higher levels of education changes the aspirations of adolescents in a way that orients them away from early childbearing (Baird et al. 2010; Duflo, Dupas, and Kremer 2015; Gulemetova-Swan 2009; Kalamar, Lee-Rife, and Hindin 2016, 2016). Additionally, Mexico’s extensive and widely-lauded cash transfer program *Oportunidades*, which, among other things, conditions benefit payments to poor mothers on the school attendance of their children, find that the program also delays sexual activity, fertility and marriage among adolescent girls who are beneficiaries (Gulemetova-Swan 2009; Kalamar, Lee-Rife, and Hindin 2016). But in the case of Mexico’s municipalities, it appears that these individual-level relationships do not necessarily to translate neatly to aggregate patterns of change. For example, strong improvements in schooling in the south of Mexico, where educational access has long lagged behind other parts of the country, align with declining adolescent fertility seen there. However, many northern and coastal municipalities share a growing incidence of adolescent first births (and limited declines in second births) despite seeing continued improvement to their much stronger schooling indicators.

Indeed, Mexico's stability in national measures of first births in adolescence in the face of the country's dramatic schooling expansion is puzzling. However, evidence from the first study in this thesis demonstrates that the incidence of adolescent fertility in Mexico has increased dramatically at all schooling levels except for those levels that extend through all adolescent years—that is, upper secondary complete and tertiary. Additionally, the mean age at first adolescent birth for all but the highest schooling levels has become younger. Together, these findings suggest that the diversity in municipal trends could well be related to underlying differences in adolescent fertility risk at specific schooling levels, and the interaction of changes in the composition of each municipal population's schooling profile and changes in the intensity of risk at each schooling level. That is, there are differences across municipalities in what proportion of their adolescent populations that attain lower secondary, upper secondary or tertiary, and, simultaneously, there are likely to be differences in how much or little the risk of adolescent fertility has increased at each of these schooling levels.

Other Mexican studies have argued that high rates of adolescent fertility has persisted because the mass educational changes in birth cohorts from the 1930s to 1970s occurred at ages that were too young to conflict with the timing of transitions to motherhood and union formation. The studies conclude that aggregate postponement would not be visible until schooling expands to the point where enough women are still in school at the ages when they would otherwise begin childbearing (Kroeger, Frank, and Schmeer 2015; Lindstrom and Paz 2001). This echoes research in Europe that clarifies that the observed childbearing postponement from the 1970s to the 2000s was closely tied to women finishing their education at progressively later ages. Though the age at first birth dramatically increased over this period, the timing of first births changed very little when measured in terms of years since leaving education (Neels et al. 2017; Ní Bhrolcháin and Beaujouan 2012). It remains unclear whether or not Mexico's schooling expansion conflicts with the timing of adolescent first births among cohorts after the 1970s, the period not studied by Kroeger et al. (2015) or Lindstrom and Paz (2001). Dramatic schooling changes may not yet conflict with adolescent childbearing timing given that the bulk of the educational changes have continued to occur at ages before motherhood entry. Recall that net enrolment rates indicate that only two thirds of adolescents 15-17 years old were in upper secondary schooling in 2015 and the vast majority of adolescent mothers in Mexico leave school before becoming pregnant (Llanes Díaz 2010). Relatedly, the expansion of Mexico's *Oportunidades* cash transfer program has been highly geographical—appearing first in the centre of the country in the late 1990s before expanding into the rural communities on the coasts and in the south in the 2000s before finally including more urban areas and disadvantaged communities in the north after 2014 (Hernandez Olmos 2016; Ordóñez-Barba and Silva-Hernández 2019). Furthermore, some research indicates that although *Oportunidades* was instrumental in helping Mexico reach near universal primary education, it has been less effective in inducing change in lower- and upper-secondary schooling, or the ages most directly related to adolescent fertility outcomes (P. Schultz 2004)

Issues of education quality also come to the fore with such rapid expansion of school enrolment, as well as with findings that disenchantment with school and its poor quality lead many adolescents out of school (before pregnancy) (Näslund-Hadley and Binstock 2011). Most of Mexico's impressive schooling expansion has happened without matching efforts to improve the quality of teaching that occurs in the classroom. Often, the country's powerful teacher's union is blamed for blocking reform. The union has been successful in ensuring strong investment in teacher salaries without allowing checks that encourage quality teaching, and comparatively little is left over in the national budget for other monetary inputs to improve learning (Guichard 2005). Mexico performs poorly in international assessments of reading, mathematics and science, and has seen almost no improvement over the last two decades (OECD 2011; Salinas, De Morales, and Schwabe 2019). Additionally, the availability of quality, comprehensive sexuality education in recent decades in Mexico faces challenges not just from growing opposition from conservative groups but poor implementation (Azevedo et al. 2012; Chandra-Mouli et al. 2018; Panchaud et al. 2019). Interestingly, there is evidence that Mexican youth's preferred place, though not necessarily the most common place, for obtaining information about sexuality and sexual health is from medical personnel (Juárez and Gayet 2005), which is encouraging in some respects given evidence from other developing contexts where adolescents cite unprofessional attitudes, lack of respect for youth's concerns and lack of understanding of issues of confidentiality of medical personal as a leading barrier to accessing sexual and reproductive healthcare (Onukwugha, Hayter, and Magadi 2019). However, accessing healthcare among youth remains uneven in the country (Gómez and González 2018).

Aspects of increasing rates of drug, gang and gender-based violence as well as exceptionally low levels of youth employment mar the picture of stability and progress for Mexico's adolescents (Berlanga Gayón 2015; Pan American Health Organization 2012; Rosen and Zepeda 2016). Both have strong geographic clustering, with higher rates of violence in the North than in the South, alongside higher rates of unemployment in the North and South compared to the centre of the country. Importantly, there is some evidence that higher mortality among close kin is associated with earlier childbearing (Berg, Lawson, and Rotkirch 2020), but this possibility has not been explored in Mexico, though there is research that finds that community violence is related to low birth weight in the country (Torche and Villareal 2014). Issues of adolescent employment are of persistent concern in Mexico. Youth who are neither studying nor working are often called NEETs in English (not in employment, education or training), or nini in Spanish (ni estudia ni trabaja). In Latin America, including Mexico, anxiety about this population arises from its contribution to the persistence of intergenerational inequality, its links to crime and violence, and its potential for impeding emerging demographic windows of opportunity (De Hoyos, Rogers, and Székely 2016). Rates of NEETs among females are particularly high in Mexico (Centro de Estudios de las Finanzas Públicas 2018). Evidence from Mexico indicates youth employment is declining among adolescents, with employment increasingly concentrated among those over the age of 20 (Llanes Díaz 2010), and evidence from elsewhere in Latin America and the Caribbean indicates that female's limited prospects and low expectation for labour force participation are closely tied to early childbearing (Azevedo et al. 2012; Ibarraran et al. 2014; Novella and Ripani 2016).

Part of the shift in risk could be suggestive of a social convergence as well, or at least a shifting population composition by social strata. Just as the previous chapter found a pattern of convergence in first adolescent births across all but the highest schooling levels, this study finds a pattern of convergence across municipalities in Mexico. That is, as a general rule, municipalities with the lowest first birth proportions in the earliest years saw the greatest increase over time while municipalities with the highest proportions in 1990 saw the greatest decline.

Parity-specific adolescent fertility in Mexico has long been understood to differ considerably by socio-economic and educational strata (Welti Chanes 2006). For adolescents in more disadvantaged strata, adolescent childbearing is common, and a birth marks the beginning of family formation where adolescents will more often than not have more than one birth before turning twenty. Indeed, women in all but the highest strata enter into unions and marriages at young ages, and, according to some research at younger ages on average than in the past (Lima et al. 2018). There exist strong cultural aspects for having children immediately after marriage (Juárz et al. 2013). In contrast, adolescent fertility in more advantaged strata is more likely to be among unpartnered youth for whom the pregnancy was unplanned. No subsequent adolescent births follow. Importantly, girls in advantaged strata (where a growing share of adolescents now finds themselves) are experiencing more and earlier sexual activity in adolescence than they were in the past, thus increasing their exposure to adolescent first births (Di Cesare 2007; Gómez Muñoz 2018; Welti Chanes 2006). Themes of a the vastly different context of unions and fertility for adolescents in distinct socio-economic strata are also seen in the compelling qualitative work (Stern 2004). In terms of what this means for policy, Mexico's national strategy acknowledges that contraceptive uptake can be easily promoted among adolescent first-time mothers through their healthcare providers, but higher-strata mothers may need little additional investment to reduce second birth risks while lower-strata mothers still likely require pointed intervention. It is possible that mothers from lower socio-economic strata have seen little change in their progression risk, only that the decline in second births appears universal because of the growing size of Mexico's middle class.

Further research that can unpack subnational trends into differences by (changing) socio-economic strata as well as quantify the shifting socio-economic composition of the population, will be key to further improving the targeting of policy interventions. More distal determinants of adolescent fertility, such as municipal-level indicators of schooling and poverty are available but existing studies of state and municipal $ASFR_{15\text{-}19}$ in Mexico often find that socio-economic distinctions at the aggregate level have limited explanatory power for the adolescent childbearing trends seen in the country. Specifically, when municipal $ASFR_{15\text{-}19}$ was compared to the proportion of females aged 15-19 enrolled in school (in simple bivariate regressions), there was only a very slight negative relationship where municipalities with higher enrolment saw marginally lower teen birth rates (Meneses and Hernández 2019). When state-level $ASFR_{15\text{-}19}$ was compared to each separate component of Mexico's index of multidimensional poverty (Gómez and González 2018), only education and healthcare access, which is not otherwise part of the multidimensional poverty index, showed a negative relationship where greater enrolment and healthcare access was also associated with lower adolescent fertility across Mexican states. In contrast, aggregate measures of household poverty, dwelling deficiencies (such as access to electricity and running water as well as overcrowding), and use of contraception at sexual debut, among other indicators, had no association to aggregate adolescent fertility risk.

Instead, examining the proximate determinants of fertility—such as age at sexual debut, frequency of sexual activity, union formation, pregnancy intention, contraceptive prevalence, miscarriage, abortion—and how these may be shifting over time and across localities and socio-economic groups in Mexico should be a critical next step. However, representative, subnational data on the proximate determinants of adolescent fertility in Mexico is exceptionally sparse and existing state-level surveys are often not comparable over time (incongruent questions for example), making detailed analysis difficult. For example, this study has looked at live births, and trends for adolescent pregnancies would be considerably different. An estimated 55% of pregnancies in Mexico are unplanned, and 54% of unplanned pregnancies are estimated to end in abortion in the country, even though abortion access is considerably restricted (Juárz et al. 2013). I find no estimates on what proportion of adolescent pregnancies in Mexico are unplanned and what proportion of adolescent pregnancies end in abortion. Nevertheless, municipal differences in adolescent fertility found in the present study could potentially be due in part to differences in the proportion of adolescent pregnancies that are terminated. Research from the Guttmacher Institute estimates that the abortion rate per thousand adolescents aged 15-19, which is 44.1 at the national level, is as low as 18.7 in Yucatán in the south and as high as 77.3 in Coahuila in the north in 2009 (Juárz et al. 2013) In 2009, state-specific adolescent fertility rates per thousand adolescents aged 15-19 spanned 52.4 in Mexico City and 99.8 in Nayarit, with the national rate at 75.7 (Consejo Nacional de Población 2018b). While these state-level estimates confirm that subnational disparities are considerable, cursory analysis showed no association between rates of adolescent births and abortions across states. That is, states with high $ASFR_{15\text{-}19}$ were no more likely to have low abortion rates than they are to have high abortion rates (see Appendix B for details). Additionally, while the induced abortion rate is higher in more developed regions of the country and lower in less developed regions, by state the picture is more complex. States with the highest levels of development have both some of the lowest abortion rates (such as Nuevo León and Chihuahua) and highest abortion rates (such as Baja California Sur, Colima and Mexico state). Abortion rates are shown to be low in a number of northern border states, but many women in these locations cross into the United States to seek abortions. This is the case in Nuevo León and Chihuahua, for example, where, incidentally, the unmet need for contraception is also among the lowest in the country (Juárz et al. 2013). And abortion rates in Mexico City are high in part because of women who travel there from surrounding states given that, from 2007 to 2019, it was the only place in the country where terminations were allowed (Juárez, Bankole, and Luis Palma 2019). There is no existing data that allows for an assessment of trends over time in adolescent abortions, least of all trends within municipalities.

Note that during most of the period covered by this study, induced abortion was illegal in Mexico, and only in 2007 did it become legal in Mexico City (Juárz et al. 2013). Access to abortion in the country is legislated at the state level meaning that states have considerable differences in legal exceptions under which terminations are allowed. Additionally, Mexico City's decriminalisation in 2007 led to nearly half of states in the country passing constitutional clauses to protect a fetus from conception, though in some cases without corresponding changes to the penal code (Juárez, Bankole, and Luis Palma 2019). Importantly, qualitative evidence suggests that few women in states with restrictive laws have been aware of where and under what conditions terminations are allowed (Juárez, Bankole, and Luis Palma 2019). From 2019 to 2022, nearly a third of states decriminalised abortion and several recent Supreme Court decisions opened the door to further decriminalisation nationally, but these recent changes do not apply to the time period covered in this study (Castañeda 2021; Estrada 2022).

Differences across municipalities and change over time in sexual activity, union formation, pregnancy intention, and use of contraception among adolescents is likely to also contribute to municipal differences in adolescent births, and trends likely vary considerably, though subnational data is scarce. Existing evidence suggests that both adolescent sexual activity and use of contraception has increased over time in Mexico as a whole. For example, 16% of females aged 15-19 reported having initiated sexual activity in 2000 while 21% reported having done so in 2012, with that figure increasing to 30% in 2018 (Gutiérrez et al. 2012; Instituto Nacional de Estadística y Geografía 2018; Olaiz-Fernández et al. 2006). Meanwhile, national surveys indicate strong gains in the proportion of adolescents using contraception both at their first sexual experience and their most recent sex, with reports that the proportion has increased from about a fourth of adolescents (in 2000) to over half of adolescents (in 2014) (Gutiérrez et al. 2012; Instituto Nacional de Estadística y Geografía 2014). Importantly, evidence points to lower contraceptive use rates at first sex and most recent sex among adolescents whose sexual debut occurred at ages 12-14 compared to those whose debut was at ages 16-19 (Gutiérrez et al. 2012). Additionally, where analysed, subnational variation is considerable, as are differences by rural and urban residence and socio-economic status (Allen-Leigh et al. 2013).

Various surveys indicate that in recent years, nearly all of adolescents in Mexico report knowledge of at least one method of modern contraception (between 90% to 97% nationally, depending on the survey) (Gutiérrez et al. 2012; Instituto Nacional de Estadística y Geografía 2009). However, despite widespread knowledge, there remain major barriers to access and uptake, alongside strong cultural and social incentives for early childbearing. At the national level, Guttmacher estimates that in 2015-2019, the majority of sexually active adolescents in Mexico intend to become pregnant, but among those who did want to avoid pregnancy, a substantial portion had an unmet need for contraception. The 2015-2019 estimates indicate that only a fourth (23%) of sexually active adolescent aged 15-19 want to avoid pregnancy, but 43% of whom are not using contraception (Guttmacher Institute 2022). In comparison, 64% of all sexually active women of reproductive age are estimated to want to avoid pregnancy. In essence, among the segment of adolescents looking to avoid pregnancy, there exist strong barriers to access as their unmet need for contraception is extremely high, more than double the average for all women of reproductive age (19%) (Guttmacher Institute 2022). One study notes that the most significant barriers for the youngest adolescents (those under age 15) were embarrassment and concerns of anonymity (Gómez-Inclán and Durán-Arenas 2017). Other research documents cultural incentives and trends that relate high levels of adolescent pregnancy to intentional choice, and how adolescents see pregnancy as a way to gain social status (Rocca et al. 2010). Others caution that pregnancy intention is highly dependent on question wording and is particularly difficult to measure among adolescents (Sedgh, Singh, and Hussain 2014; Vignoli 2017). Subnational variation plays a part here too. Evidence from 1992 showed considerable state-level differences in patterns of union formation in adolescence. With between 1.9% (Mexico City) to 6.5% (Veracruz) of adolescents reporting their first union by age 14, and between 31.4% (Mexico City) to 44.4% (Oaxaca) reporting a first union at ages 15-19 (Instituto Nacional de Estadística y Geografía 1992). Importantly, evidence suggests that not only do adolescents have the highest unmet need for contraception of any age group, but the adolescents with the highest unmet need are those in a union rather than those who are sexually active but not in a union (Allen-Leigh et al. 2013). Gender norms in the region make it difficult for young women to negotiate contraceptive use with their partners. For example, strong gender stereotypes dictate that women should be asexual or sexually inexperienced and passively accept their male partners' sexual demands (Azevedo et al. 2012). Use of contraceptives are seen to imply promiscuity and a lack of trust in each other's fidelity and commitment (Lenkiewicz 2013).

All this to say that the trends in convergence of levels of adolescent fertility across municipalities, as estimated in this study, could well reflect dramatic social shifts in the population—particularly in the proximate determinants of fertility—that have yet to be explored in subnationally. The possibilities are many and complex, but in broad strokes, it seems plausible that the less developed municipalities who generally saw the highest adolescent fertility levels in 1990 alongside the greatest declines over time, could have made considerable advances in contraception uptake and availability as well as declines in the desirability of early childbearing initiation that usually accompany advances in schooling expansion and economic development. Meanwhile, the more developed municipalities who generally had lower adolescent fertility levels in 1990 alongside the greatest increases over time could have been contending with increasing levels of adolescent sexual activity and more sexual activity at younger adolescent ages that were not matched by sufficient contraception uptake that accompanied possible changes in cultural proscriptions against adolescent sexual activity outside of unions.

Elsewhere in Latin America, a small handful of subnational research echoes these mixed messages from Mexico. Subnational trends do not see uniform decline, even when national rates of teen childbearing are falling. Such is the case in Colombia where adolescent fertility among older teens is increasing in the coastal regions and declining elsewhere, and, particularly concerning, rates among girls fourteen and younger are increasing everywhere (Álvarez Castaño 2015). Importantly, adolescent fertility's association to poverty and socio-economic status is not necessarily uniform within a country. In two Colombian cities with similar levels of adolescent fertility, rates differ strongly in the two locations among the lowest socio-economic strata but are quite even among the higher strata (Flórez 2005). Across several Latin American countries, it appears that education matters most in the areas with highest adolescent fertility. That is, in the subnational regions where teen childbearing is high, individual schooling is strongly related to the probability of adolescent fertility, but the relationship is less pronounced in areas with lower adolescent fertility (Núñez and Flórez 2001). In Chile, in contrast, rates of adolescent fertility in urban areas are closely tied to poverty, but in rural areas teen childbearing is high no matter the poverty rates (Velarde and Zegers-Hochschild 2017). Other research also finds that urban and rural differences matter for adolescent fertility patterns elsewhere in Latin America (Di Cesare 2007; Gómez and González 2018). However, there does not seem to be a clear overarching pattern of change over time. While rural and poor women generally continue to have the highest incidence of adolescent fertility in the region, rates of change can vary in surprising ways—with, as an example, the incidence increasing in urban settings and declining in rural contexts in some places (Berquó and Cavenaghi 2005; Neal et al. 2018).

Notwithstanding the remaining question of how shifting social and educational contexts interplay with Mexico's subnational adolescent fertility changes (see Appendix C for some initial exploration of a number of distal determinants), which belie simple summary, there is much to be gained from this study. Age- and parity-specific adolescent fertility estimates at the municipal level offer much to the direction of Mexico's national strategy to reduce adolescent childbearing. This study has revealed a picture of adolescence in flux, or a diverse array of municipal trends in first and second adolescent births across the country. It has also highlighted a fair number of priority municipalities that would otherwise be overlooked in the current prioritisation strategy. In conclusion, the benefits of paying attention to subnational and parity-specific adolescent fertility trends cannot be overstated.

Chapter 4

The key to context

The surprising and varied importance of peer fertility influence, schooling status, and relative deprivation at different adolescent ages on the likelihood of teenage childbearing in Mexico

Adolescence spans ten years of dramatic physical, emotional, and cognitive change. Childbearing at different ages in adolescence underscores these considerable developmental differences. For example, motherhood at 13 years of age carries vastly different risks, meaning and consequences than does motherhood at 18 years. The same can be said for the differences between a 17-year-old mother of two and a 19-year-old giving birth to her first child. Abundant research explores how individual characteristics—such as poverty, school dropout, or early sexual debut—heighten the likelihood of fertility in adolescence. However, teenage childbearing is not solely influenced by individual circumstances. While there is research that explores how broader cultural and socio-economic contextual factors play a role in an individual girl's fertility risk, no research explores quantitatively how the importance of context changes over the adolescent age schedule and at different parities. This study, with data from Mexico's 2015 inter-census survey and multilevel modelling techniques, finds compelling evidence that the importance of context differs dramatically across the adolescent years, and also differs by schooling status and position of relative deprivation. The findings also indicate that the childbearing patterns of a girl's adolescent peers form a considerable and quantifiable portion of the contextual phenomena that impact an adolescent girl's individual likelihood of entering motherhood in adolescence.

4.1 Introduction

The aim of this study is to explore evidence for the existence of quantifiable contextual phenomena in adolescent fertility. That is, the study explores whether girls with similar socio-economic characteristics have different probabilities of experiencing a birth in adolescence based on whether they live in one place or another, as well as whether girls with differing characteristics but living in the same area have more similar probabilities of adolescent fertility than girls living elsewhere. Such a pattern may arise in part because adolescents living in the same area are subject to common contextual influences. The exploration of contextual phenomena in fertility patterns is not new, but no demographic or health research explores whether or how the importance of context differs at different adolescent ages, whether or how it differs for girls who are in school compared to those who are out of school and whether or how it differs according to a girl's position of relative deprivation. For example, if a girl is out of school in an area where most of her peers are in school, her relative position of deprivation differs from that of a girl with similar characteristics who is out of school in an area where most of her peers are also not attending school.

The research is approached in stages, using multilevel logistic hierarchical regression analysis to explore adolescent childbearing in Mexico, an upper-middle income country with comparatively high levels of adolescent childbearing. Multilevel regressions are particularly powerful for investigating contextual effects, which manifest as patterns of clustering and variation in the data (Snijders and Bosker 2012). The first research objective is to investigate whether there is in fact clustering in the data. Specifically, clustering within Mexican municipalities, which is indicative of the existence of a possible contextual dimension to adolescent fertility. The next research objective investigates to what extent municipal-level differences in the incidence of adolescent fertility are explained by the composition of municipalities' adolescent population. That is, the clustering of adolescent fertility within areas may simply reflect the varying composition of the population in terms of their individual characteristics, with some municipalities having much higher concentrations of out-of-school youth or more households in poverty and thus higher adolescent fertility for example. It also explores how the association between individual characteristics and adolescent fertility depend on an adolescent's relative disadvantage or advantage to her peers. The third research objective explores whether the importance of contextual phenomena differs in magnitude for different groups of girls. For example, whether the influence of context is greater for younger adolescents than it is for older adolescents or greater for girls who are in school compared to girls who are out of school. The final research objective explores whether the fertility of an adolescent's peers forms a quantifiable part of the observed contextual phenomena. Additionally, it examines whether the association between the fertility climate prevailing among an individual girl's peers and the girl's own individual fertility likelihood is modified according to the girl's age. That is, whether the importance of the adolescent fertility context differs across the adolescent age schedule.

Rich theoretical and policy-related underpinnings lend the study importance that extends far beyond its country-specific context. The study strengthens the case for approaching adolescent childbearing not just as the result of individual circumstances but rather a combination of myriad behavioural and structural interactions—the meaning of which changes across the adolescent age schedule. Indeed, the prevailing theoretical framework for conceptualising adolescent pregnancy, the ecological model, describes qualitatively how factors that lead to adolescent childbearing can be organised into progressively expanding spheres of influence, starting with the individual then broadening to the family, community and beyond (Banati and Lansford 2018; Corcoran 1999; Sallis, Owen, and Fisher 2008; Svanemyr et al. 2015). Likewise, prevailing recommendations on effective programming to reduce early childbearing advocate for interventions at multiple levels; broad legal and political support as well as community, family and parental engagement are vital components (United Nations Population Fund 2015; World Health Organization 2011). Finally, life course theory also views the human experience as embedded in social relations, a “multilevel phenomenon”, that is defined by interwoven “age-graded trajectories and transitions”(Elder 1994). Evidence from neuroscience and psychology points to remarkable differences in adolescents’ cognitive capabilities over the adolescent age schedule, but these findings have yet to be translated to the field of demography. Likewise, evidence from sexual and reproductive health and rights literature points to differences in adolescents’ risk of coerced sex and restrictions on agency over the adolescent age schedule. Given that so little representative data exists on childbearing among the youngest adolescents, documenting the existence of quantifiable contextual phenomena and exploring how the influence differs among younger and older adolescents breaks new ground in understanding childbearing among the most vulnerable mothers.

4.2 Background

This paper takes Mexico as case study. Mexico is Latin America’s second most populous country and the tenth most populous country in the world (United Nations Population Division 2019b). As a region, Latin America and the Caribbean’s adolescent childbearing levels exceed global trends when compared against countries with similar levels of total fertility and economic development (Azevedo et al. 2012). Furthermore, Mexico’s adolescent fertility rate of 68.5 births per thousand women aged 15-19 years is above the regional average for Latin America and the Caribbean (63 births) (Consejo Nacional de Población 2018b; United Nations Population Division 2019a).

In 2015, Mexico launched a fifteen-year strategy to reduce adolescent fertility—the first of its kind in the country. Importantly, the strategy aims to eliminate births to girls 14 years and younger and halve the number of births to adolescents aged 15 to 19 years by the year 2030. In concrete terms, this means that by 2030 Mexico hopes to achieve a rate of 0 births per thousand adolescents aged 10-14 years and 32.9 births per thousand adolescents aged 15-19 years (Gobierno de la República 2015). However, what limited research exists for fertility among girls 14 years and younger suggests that it has increased over the last two decades (Meneses and Ramírez 2018). Meanwhile, declines in fertility among adolescents aged 15 to 19 years have been limited over the same period, with declines arising from fewer second and higher-order births to adolescent mothers while the proportion of women entering motherhood before their twentieth birthday has remained largely unchanged (Consejo Nacional de Población 2018b; Rodríguez Vignoli 2014a).

4.2.1 Contextual effects in demographic fertility literature

The study of contextual effects in demographic fertility literature is not new. Individual and contextual associations between education and fertility offer a rich example. It is well documented that an individual adolescent's education is strongly associated with her fertility; women with limited schooling will initiate childbearing in adolescence at a higher rate than will women with more ample schooling (Grönqvist and Hall 2013; Gupta and Mahy 2003; Lappegård 2000; Rodríguez Vignoli and Cavenaghi 2014; Towriss and Timæus 2018).

There is causal evidence that, at the individual level, schooling has both an enrolment effect, which reduces adolescent fertility for as long as the adolescent is enrolled and present at school, and an aspirational effect, which reduces adolescent fertility by inspiring changes in her life goals and expectations as she obtains higher levels of education (Black, Devereux, and Salvanes 2008; Cygan-Rehm and Maeder 2013; Duflo, Dupas, and Kremer 2015; Grönqvist and Hall 2013; Monstad, Propper, and Salvanes 2008; Silles 2011; Stoner et al. 2017). It seems reasonable that these individual effects are not independent of the surrounding educational climate. Indeed, demographic literature documents a variety of contextual effects of education on a variety of aspects of fertility.

Research in Africa, which sees the largest body of demographic literature on the contextual effects of education on fertility outside of high-income settings, emphasizes the advantages of higher levels of aggregate education. Areas with better aggregate education see benefits spillover so that even the least educated women see lower fertility, later marriages or more interest in contraception than similar women in places with lower aggregate education (Benefo 2006; Frye and Lopus 2018; Kravdal 2002, 2012). Importantly, when aggregate education is ignored—and only individual education is accounted for—the strength of education's association with lower fertility in populations is severely underestimated (Kravdal 2002).

Interestingly, the influence of aggregate education is not consistent across individual education strata. That is, as aggregate education access improves, highly-educated women typically see stronger fertility declines and marital postponement than less-educated women (Frye and Lopus 2018; Jejeebhoy 1995). In consequence, future fertility reductions in Africa are expected to accelerate more intensely as education expands and socio-economic development improves than what would be assumed if only individual education is considered (Kravdal 2012).

There is no clear consensus on why contextual phenomena matter for individual fertility, the exact mechanisms through which it works, and how best to measure it. In looking at education, Kravdal's (2002) theoretical descriptions offer the clearest review of possible mechanisms. He argues that the influence of aggregate education likely operates on fertility through three related pathways. These include (1) social learning, or knowledge and attitudes that are transmitted directly through communication and observation; (2) social influence, or passive imitation of behaviours to gain social approval and avoid social sanction; and (3) the more diffuse community influence arising from how others' ideas, resources and behaviours shape society and social institutions. Individual women interact with peers and neighbours, sharing information and setting examples either explicitly or tacitly about contraception, sexual behaviours and female role aspirations that create interaction chains that plausibly include the entire population within a given geographic space or specified time.

Whatever the theoretical underpinnings, research must translate theoretical pathways into operational paradigms in order to explore quantitatively the possibility of contextual effects on fertility. In the first instance, the research must delineate the geographic scale of the contextual phenomena—existing research indicates that the geographic scope of contextual variables matter. The African literature finds that educational context is important at many different geographic levels: both at the country level in multi-country comparisons (Frye and Lopus 2018), and at the community level either in multi-country comparisons or within a single country (Benefo 2006; Derose and Kravdal 2007). Nevertheless, it seems that educational context operates more strongly at smaller local levels than it does at larger regional levels. For example, in two studies where the comparison was made, the effect size of educational context at a broader province level was about half that estimated at the village level, and when village-level and province-level indicators were included in a single model, only the village-level educational context—and not province-level—mattered for fertility outcomes (Kravdal 2002, 2012).

In the second instance, the research must operationalise the specific contextual phenomena. In operationalising the context of education, the African literature usually summarizes the schooling profile of all women at all reproductive ages within a specified geographic area. Because schooling is limited in the African settings where it has been studied, this typically comprises measures of just a few years of school, such as the percentage of women ages 15-49 years who have had any formal schooling or who have had at least three years of schooling (Benefo 2006; Frye and Lopus 2018; Kravdal 2002), or the average years of schooling among women aged 15-49 years (Kravdal 2002, 2012).

The importance of appropriately operationalising contextual phenomena becomes even more apparent in looking at what demographic literature says about how educational context matters for adolescent fertility. A rare article that explores contextual effects on adolescent fertility in Africa, rather than lifetime fertility, finds that only individual education matters and not aggregate education (Gupta and Mahy 2003). However, the study's measure capturing aggregate education is rather inflexible—a dichotomous variable based on the proportion of all adults (men and women) with eight or more years of schooling, taking the value of one if more than 20% of adults in the cluster have this level of schooling. It is not clear from the paper how many communities met this criterion, or why the 20% threshold was chosen, but the eight-year cut-off implies that it is unlikely to describe many communities. What is more, strong gender inequalities in educational access in the region may mean that women within the better-educated clusters still have very little education. As such, there could be limited social learning spillover benefits to adolescent girls even in communities that meet the threshold, and the research conclusions could simply reflect a poorly-defined measure of educational context rather than the lack of association between adolescent fertility and aggregate education. Given that Africa's (and Latin America's) educational landscape has changed so dramatically over the last decades, it seems reasonable that the current educational climate influencing an adolescent girl is better measured by the educational profile of her adolescent peers, rather than measures that include all women that are thus more static. In fact, one study in Africa explores the independent influence of current and past aggregate education and concludes that current education matters more than past education for first birth timing. (Derose and Kravdal 2007).

Likewise, a Latin American study that measures educational context by the degree of gender inequality in schooling, or the ratio of women's to men's years of schooling (ages not specified), found that it had no relationship to fertility among young women aged 20-24 years. Here again, the finding could be more a reflection of a poorly defined measure than the lack of importance of aggregate education. Latin America today generally sees much less gender inequality in schooling than Africa (Eloundou-Enyegue and Stokes 2004) and as such may not be the defining aspect of aggregate education that matters for young women's fertility. I find only one demographic study (Chiavegatto Filho and Kawachi 2015) in the region that considers educational context for adolescent fertility specifically, and even there, educational context is viewed as a control variable, ancillary to the measure of income inequality. The study found that Brazil's rates of adolescent fertility are related to municipal levels of income inequality. Areas with higher income inequality also see higher adolescent fertility. The study also finds that the context of adult women's educational attainment, measured as the proportion of women aged 20-49 with tertiary schooling in the municipality, has a consistently negative association with adolescent fertility though the coefficient is comparatively small and measured with a fair amount of uncertainty.

In looking at what these lessons imply for the purposes of the present study, the issue of geography is fairly straightforward. That is, this study examines Mexican municipalities for reasons that prioritise potential policy relevance and practicability over a possibility of finding stronger contextual effects at a smaller scale. These reasons are detailed in the discussion on data. The motivation for the operationalisation of this study's contextual variables draws on a range of evidence from demographic, neuroscience, psychology, and health research as well as statistical practicalities. The research is reviewed in the following paragraphs and the statistical issues are considered within the methods discussion. In contrast to the weak links between educational context and adolescent fertility in existing demographic literature as described above, evidence from other fields argues for the presence of strong contextual influence and peer effects in adolescence.

4.2.2 The salience of context for adolescents

Adolescents seem uniquely placed to be influenced by context. Recall that Kravdal (2002) theorised that contextual effects in fertility occur through social learning and social influence. Adolescence is marked by a process of growing independence from parents and family and a reorientation towards peer group socialisation (Baird et al. 2021). Indeed, adolescents are naturally motivated to build and explore new social networks and peer groups (Crone and Dahl 2012). Just as neuroscience has found that the infant brain is geared toward certain types of learning—for example, it conveniently "expects" the language and visual experiences that are imperative for organising the body's visual and language systems and relevant neural circuitry—the adolescent brain is geared toward social learning (Suleiman and Dahl 2017).

Suleiman and Dahl (2017) categorize the social learning that defines so much of adolescence into two interrelated realms. The first realm encompasses social relationships, which include "social roles, peers, potential romantic partners, social hierarchies, identity as a sexual being and interest in sexual behaviour". The second realm encompasses learning about individual identity and one's place within existing social hierarchies, which is highly driven by desires for belonging, acceptance, respect and admiration alongside sensitivity to rejection, embarrassment, humiliation and disrespect (Crone and Dahl 2012; Suleiman and Dahl 2017; United Nations International Children's Emergency Fund 2017a). Compared to adults and children, adolescents show enhanced sensitivity to social cues, particularly those from peers, and they place a higher value on opportunities for peer socialisation (Baird et al. 2021; Crone and Dahl 2012; Saxbe et al. 2015; Somerville, Jones, and Casey 2010; Victor and Harari 2015). Again, adolescence is marked by a heightened sensitivity to context, or "external stimuli" (Banati and Lerner 2021).

Interestingly, the adolescent brain appears to process social cues similarly to how it processes information about rewards (Saxbe et al. 2015). This neural overlap between social information processing and reward processing is believed to underscore why so much of the adolescent tendency toward risk taking and search for novel experiences occurs in social settings (Crone and Dahl 2012; Steinberg 2008; Victor and Harari 2015). In both laboratory and real life, adolescents show greater risk-taking than adults or children when they are with their peers (or when they believe they are being observed by peers) (Crone and Dahl 2012). In effect, adolescents are hugely swayed by their age peers (Patton et al. 2016).

Health and psychology research has long explored the links between peer influence and adolescent sexual behaviour specifically, though with a heavy focus on risky sexual behaviour (Victor and Harari 2015). Extensive research in high-income settings has found that peer sexual behaviours, and perceptions about peer sexual behaviours, are related to an individual adolescents own behaviours and attitudes (Dilorio et al. 2001; East, Felice, and Morgan 1993; Prinstein, Meade, and Cohen 2003). In fact, aspects of peer pressure and peer conformity more generally, which incidentally are distinct from a broader tendency to conform, are strong predictors of sexual behaviour and attitudes in adolescence (Santor, Messervey, and Kusumakar 2000).

A handful of studies in low- and middle-income settings yield similar results (Babalola 2004; Magnani et al. 2001). A study in Peru found peer effects for sexual activity (adolescents were significantly more likely to have had sex if they perceived their friends were sexually experienced), but, incidentally, found no relationship between having knowledge of how to avoid pregnancy and sexually transmitted infections and taking steps to avoid those risks (Magnani et al. 2001). This inconsistency between knowledge and action in sexual behaviour is found repeatedly in adolescent research (Dwing, Ryman, and Gillman 2016; Steinberg 2008; Suleiman and Brindis 2014), and can be related to the trajectory that adolescent cognitive development follows—a so-called dual systems model (Icenogle et al. 2019; Steinberg et al. 2018).

In essence, descriptions of the dual systems model of adolescent neural development trajectories speak to a dominating influence of the approach system, which relates to reward behaviours, and a weaker influence of the regulatory system, which relates to behavioural control, particularly in emotionally charged situations (Casey, Jones, and Somerville 2011; United Nations International Children's Emergency Fund 2017a). However, the degree of dominance of one system over the other, as well as the robustness and capacity of the systems, changes over the course of early, middle and late adolescence. Several other developmental factors also come into play, which together strongly suggest that the influence of context is likely to differ considerably across the adolescent age schedule. The following paragraphs review developmental differences that have relevance for this study's interest in contextual effects in adolescent fertility patterns before turning to issues of power and gender norms that also influence adolescents' sexual socialisation in Mexico.

4.2.3 Early adolescence

Early adolescence marks a dramatic re-orientation of the brain towards social and emotional information processing streams, with particular capacity and motivation for learning that is relevant to the two social realms already named: social relationships as well as individual identity and ones place in social hierarchies (United Nations International Children's Emergency Fund 2017a). This re-orientation appears to have a fairly abrupt onset and is linked directly to puberty (Suleiman and Dahl 2017). Early adolescence also sees development in the area of the brain responsible for reward processing, pleasure seeking and emotional response (Baird et al. 2021). Consistent with a heightened sensitivity to rewards, a preference for short-term rewards appears to be greatest in early adolescence (Steinberg 2008).

In contrast, improvements in cognitive control, self-regulation and the ability to align behaviours toward longer-term goals sees a more gradual onset that appears rather independent of puberty (and will be reviewed in more detail under the sections on mid and late adolescence) (Suleiman and Dahl 2017). In effect, the dual systems model, or the asynchronous development between an easily aroused reward system and a still-maturing self-regulatory system, has been described as akin to "starting a car's engines before a well-functioning braking system is in place" (Steinberg et al. 2018).

Gender roles and norms form an important part of the process of identity formation and the navigation of social hierarchies. Research argues that gender norms and role expectations, which are largely determined by social influences (think household dynamics and norms in the wider community), are both solidified and become more salient in adolescence (Baird et al. 2021; Banati and Lansford 2018). Nevertheless, because early adolescence is a particularly dynamic time of neural flexibility (United Nations International Children's Emergency Fund 2017a), it also appears to provide a unique window of opportunity for interventions that disrupt negative and inequitable attitudes. Longitudinal research in a wide range of low- and middle-income countries finds that girls who regularly questioned gendered inequities in early adolescence saw that questioning cut short or disappear in later adolescence, by which time they framed their futures through the lens of marriage and motherhood only (Baird et al. 2021; Rivett, Loveday, and Lerner 2021).

Sexual behaviours of the youngest adolescents do regularly, but not always, appear to be influenced by peer behaviour. For example, a study in Rwanda found that the perception that all or most of one's friends were sexually active was associated with sexual activity at later adolescent ages, but not to sexual activity prior to age 15. Additionally, the strength of the association increased over the adolescent age schedule (Babalola 2004). Note however that the authors speculate whether a possible under-reporting of sexual activity in early adolescence in their study sample is responsible for the result. In contrast, other research in the United States and Peru has found peer effects in sexual behaviour among early adolescents, though differences across the age schedule were not examined (Dilorio et al. 2001; East, Felice, and Morgan 1993; Magnani et al. 2001).

4.2.4 Mid adolescence

Mid adolescence marks the peak of several neural milestones. Cognitive capacity, which increases dramatically over the early adolescent years, plateaus at about age 16 (Icenogle et al. 2019). Reward sensitivity, sensation seeking, and risk propensity also increase over early adolescence, reaching their peak in mid adolescence and declining thereafter (Steinberg 2008; Steinberg et al. 2008). Indeed, all affective processing—which comprises the positive and negative feelings, responses and motivations related to emotion-laden behaviour, knowledge or beliefs and which is so salient in social domains—peaks in mid adolescence (Crone and Dahl 2012). Mid adolescence also marks a turning point at which other-oriented thoughts dominate over self-oriented thoughts, where adolescents are increasingly capable of taking the perspective of others into account (early adolescents have less of an understanding of others' intentions when making or judging decisions) (Crone and Dahl 2012).

Nevertheless, while cognitive capacity appears to reach its peak in mid adolescence, there is a gap between the age when adolescents have the ability to engage in complex reasoning in controlled settings and the age when they are able to exercise restraint in emotional situations, particularly in social situations (Landsford et al. 2021). That is, mid-adolescents have the ability to reason as adults but their cognitive control and regulation remain highly dependent on external context, and as such mid-adolescents cannot yet apply their capabilities consistently across a wide range of settings (United Nations International Children's Emergency Fund 2017a). Where previous conceptualisations of adolescent development emphasised that the adolescent propensity for risk taking is based on cognitive immaturity, more recent emphasis is now given to how social contexts, particularly the presence of peers, influence adolescents' decision processes (Crone and Dahl 2012). For example, in laboratory settings, there is no difference between the risk taking of mid-adolescents and adults when they are alone, but when in the presence of peers (or in situations marked by emotional arousal), adolescents' risk taking increases while adults' risk taking shows no change (Steinberg 2008). Other evidence indicates that fear of peer rejection also peaks in mid adolescence (Gullotta, Adams, and Markstrom 2000).

Here again, research indicates that sexual behaviour in mid adolescence is influenced by peers (Dilorio et al. 2001; Magnani et al. 2001), though one American study suggests that certain types of sexual behaviours are more amenable to peer influence than others in mid adolescence (Prinstein, Meade, and Cohen 2003).

4.2.5 Late adolescence

Late adolescence heralds a developmental focus on areas of the brain responsible for decision making, future planning, organisation and impulse control (Baird et al. 2021). The concept of locus of control, or the belief that outcomes are caused by ones personal actions, increases steadily over the adolescent years, as does the ability to use cognitive control over ones thoughts and actions (that is, self-regulation) (Crone and Dahl 2012; Gullotta, Adams, and Markstrom 2000; Landsford et al. 2021; United Nations International Children's Emergency Fund 2017a). Indeed, the ability to think in the abstract about long-term goals and distinguish between the observable world and a world of possibilities is an important marker of adolescent development and contrasts sharply with the thinking processes of young children that emphasize the here and now (Gullotta, Adams, and Markstrom 2000). Similarly, resistance to peer influence increases steadily over adolescence (Icenogle et al. 2019; Steinberg 2008).

While cognitive capacity in late adolescence appears to be no greater than mid adolescence, self regulation in the face of emotional, exciting, or risky stimuli increases linearly over the adolescent years (and beyond adolescence) (Icenogle et al. 2019; Steinberg et al. 2018). Interestingly, while multi-country comparisons find relatively little variation in the developmental trajectory of cognitive capacity, some argue that self-regulation skills see considerable diversity due to contextual norms across countries (Icenogle et al. 2019), while others see little cross-country variation (Steinberg et al. 2018).

Despite considerable gains in capacity for self regulation and future orientation seen in late adolescence, the life stage still presents challenges. For example, sensation seeking appears to increase steadily over adolescence and peaks at age 19, after which it declines (Landsford et al. 2021; Steinberg et al. 2018). Perhaps most important, there are considerable discrepancies in the age trends of behavioural propensities as measured in controlled laboratory settings, and the manifestation of those behaviours in real life (and across cultures) (Landsford et al. 2021). Essentially, even though mid adolescence may be characterised by a higher propensity for risky behaviour, as well as a heightened sensitivity toward social rewards and a lower resistance to peer influence, later adolescence sees comparatively more risk taking in real-world settings (Duell et al. 2018; Steinberg 2008). There is also a considerable degree of variation in real-world risk taking across cultural settings (Steinberg 2008). In other worlds, inclinations to behave recklessly appear to be strongest in mid adolescence, but opportunities to realize those inclinations become more plentiful after mid adolescence and depend on cultural norms and practices. Equally important, it appears that there are no gender-based neural differences in adolescent propensity for risk taking. However, there are dramatic gender differences in real world risk taking, which suggests the gender differences come down to differences in opportunity, norms and context (Duell et al. 2018).

Taken together, this evidence suggests that context should indeed matter for adolescent fertility patterns. Additionally, context may well be defined most directly by the situation prevailing among an adolescent's peers as opposed to the broader population. Importantly, given the complex array of developmental transitions described in the neuroscience and psychology literature, the salience of context is likely to differ across the adolescent age schedule, though competing considerations make it impossible to predict at what ages context might matter most.

Nevertheless, when considering aspects of sexual activity and childbearing patterns, particularly in the adolescent years, it is imperative to emphasize that it is a powerfully gendered experience, often shaped by aspects that are outside of the adolescent's control and dramatically influenced by highly gendered social norms.

4.2.6 Coerced sex and restricted agency

No discussion of social influence on adolescent sexual behaviour, pregnancy, and childbearing is complete without acknowledging the considerable role of coercion and restricted agency. Indeed, adolescent sexual socialisation in Mexico—like many places—includes issues of sexual coercion that can take many forms. Sexual coercion encompasses overt issues of forced sex as well as issues of gender norms that limit a girl's ability to be a full and positive agent in the exercise of her sexual and reproductive health and rights.

Adolescent health experts emphasize that the most considerable obstacle to protecting adolescents from non-consensual sex are double standards regarding men and women's sexual behaviour that hinder communication and negotiation on sexual matters (Jejeebhoy and Bott 2003; Levin, Ward, and Neilson 2012). Gender scripts, or internalised notions of gender-differentiated expectations and norms are pivotal, and many contribute to a dual sexuality regime full of mixed messages and gender bias (Summit et al. 2016). Findings from Mexico and elsewhere, describe how much of sexual socialisation privileges male decision-making and normalises non-consensual sexual behaviour (Espinosa-Hernández, Vasilenko, and Bámaca-Colbert 2016; Moore et al. 2007).

Cultural values that are particularly salient in Mexico's sexual socialisation processes include *marianismo*, *vergüenza* and *machimso*, and are closely tied to religious and traditional role ideologies (Espinosa-Hernández, Vasilenko, and Bámaca-Colbert 2016; Gutiérrez Domínguez 2015; Villarruel et al. 2007). *Marianismo* (from the Virgin Mary) prescribes an ideal of purity, asexuality, abstinence until marriage, and devotion to the family and to bearing children. *Vergüenza* (from shame) stipulates that women should be sexually inexperienced, unknowledgeable and unwilling, and fosters feelings of sexual guilt and shame. For males, *machismo* (from masculine) supports early sexual activity and promotes displays of strength, aggression and virility among males (Villarruel et al. 2007). All prescribe the surrendering of decisions about sexuality, contraception and reproduction to men while emphasising women's subordinate and passive role (Espinosa-Hernández, Vasilenko, and Bámaca-Colbert 2016; Pick, Givaudan, and Poortinga 2003; Villarruel et al. 2007).

Together, the impact on adolescent sexual behaviour is profound because these cultural norms create gender scripts wherein females accept male dominance in sexual encounters, while also requiring that females exhibit sexual unwillingness to maintain respectability, thereby conditioning both males and females to perceive coercive sexual behaviour and gender-based violence as socially acceptable (Fawcett et al. 1999; Jejeebhoy and Bott 2003; Moore et al. 2007; Shafer et al. 2018). Women in Mexico and elsewhere emphasise that, to protect their reputation, women must say no to sex under all circumstances, though they will often acquiesce out of fear of violence and abandonment if they refuse, or because of flattery and pestering or passive acceptance; meanwhile, to show trust and commitment to their partner and demonstrate sexual inexperience, women cannot request their partner use a condom (Lenkiewicz 2013; Moore 2006; Moore et al. 2007).

In surveys in low- and middle-income countries, typically 15% to 30% of first sexual experiences of adolescents are reported as forced—though with considerable variation depending on question wording and sampling procedure (Jejeebhoy and Bott 2003; Jejeebhoy, Shah, and Shyam n.d.; Pan American Health Organization 2012). Surveys in Mexico generally report similar prevalence, again with considerable variation, and additional evidence suggests that between 3% and 8% of women experience sexual violence or forced sex before the age of 15 (National System of Statistical and Geographic Information 2016; Olaiz et al. 2006; United Nations International Children's Emergency Fund 2017b). Husbands, partners and boyfriends are identified as the most common perpetrators of sexual violence, but friends, acquaintances, and family members comprise a nontrivial portion as well (Frías and Erviti 2014; Jejeebhoy and Bott 2003; National System of Statistical and Geographic Information 2016; Pan American Health Organization 2012). Measuring the prevalence of sexual coercion is complicated by issues of expansive underreporting, sensitivity to question wording, and differences in the way individual women interpret and process their experiences (Jejeebhoy, Shah, and Shyam n.d.; Martínez n.d.; Moore et al. 2007). One telling example is a survey conducted in Haiti that included distinct questions about forced and unwanted sex. Less than 5% of respondents said their sexual debut was forced, but nearly half (45%) of respondents said their first sexual experience was unwanted (Pan American Health Organization 2012).

Adolescents appear to be at heightened risk of sexual coercion and gender-based violence compared to other women, and the experiences can leave lifelong marks of reduced sexual agency. The youngest adolescents appear to have the highest risk. For example, many studies find that the earlier the sexual debut, the more likely the sex was to be forced (Jejeebhoy and Bott 2003; Koenig et al. 2004; Moore 2006). Sexual debut and pregnancy before the age of 15 (but not from ages 15 to 19) is related to a higher likelihood of HIV acquisition, even after adjusting for the younger adolescents' longer time of risk exposure. Early sexual debut is also more often characterised by forced sex, sex with a higher number of partners, and greater age differences between partners (Christofides et al. 2014; Pettifor et al. 2009, 2021). In Zimbabwe, however, higher risk of HIV acquisition and higher incidence of other sexual behaviours that come with health risks was found not just for those with sexual debut before the age of 15, but also for those aged 15 to 17 (Pettifor et al. 2004). Note that while HIV incidence peaked for young women after age 18 in these contexts, sexual debut and pregnancy in early adolescence (rather than later in adolescence) was associated with increased sexual health risks. Coerced sex at an early age reduces a woman's ability to see her sexuality as something over which she has control (Krug et al. 2002). Sexual debut in early adolescence is found to be associated with lower use of protection and contraception, higher odds of pregnancy, and/or higher number of sexual partners (Brahmbhatt et al. 2014; Koenig et al. 2004; Pradhan, Wynter, and Fisher 2015; Uchudi, Mostazir, and Magadi 2012). Usually, these riskier sexual behaviours persist into adulthood among those with early sexual debut and experiences of sexual coercion (Pan American Health Organization 2012).

Though older women will have higher rates of ever having experienced intimate partner violence (because of longer exposure to risk), adolescents consistently see the highest prevalence of recent violence, often with rates that are twice as high as those reported among older age groups (Pan American Health Organization 2012). Not only is sexual abuse in early adolescence related to higher risk of pregnancy (Saewyc, Magee, and Pettingell 2004; Stewart et al. 1996)—note that the average age at first occurrence of sexual abuse among adolescents is usually reported to be 12 to 13 years old (Moore 2006)—but those with a first birth in early and middle adolescence face particularly high risk of intimate partner violence (Pan American Health Organization 2012). Evidence from Latin America and Asia finds that motherhood and marriage in early adolescence leads to more intense intimate partner violence as well as higher maternal and child mortality and morbidity (Conde-Agudelo, Belizán, and Lammers 2005; Neal, Channon, and Chintsanya 2018; Urdinola and Ospino 2015; Yount et al. 2016).

In Mexico, as elsewhere in the region, adolescents in a union are at heightened risk of coerced sex, severe acts of violence and partnership instability (Castro Martin 2002; Catro and Casique 2009; Friedemann-Sánchez and Lovatón 2012; García and Olivera 2011; Jejeebhoy, Shah, and Shyam n.d.; Pan American Health Organization 2012; United Nations International Children's Emergency Fund 2017b). In fact, the earlier the age at first union, the higher the risk of violence, with the highest prevalence being found among those whose first union occurred in early adolescence (Pan American Health Organization 2012).

In Mexico, the age of legal consent to sex varies from state to state, ranging from 12 to 15 years old (Petroni, Das, and Sawyer 2019), which means that in some states, until recently, the legal age of marriage was lower than the legal age of sexual consent. In 2019, the federal government amended the civil code to raise the age of marriage to 18 years, up from the previous stipulation of 14 years for females and 16 years for males, though some individual states had enacted similar laws in prior years. The amendment also removed exceptions permitted to the previous and new age benchmark, such as underage marriage with parental consent (Gobierno de México 2019). During the period of this study, laws in some states depenalised rape if the adolescent married her abuser or if she had not lead an "honest" and "chaste" life (Frías and Erviti 2014). Though Mexican law prohibits forced and child marriages, the practice, including instances where rape survivors are forced to marry their abusers, still occurs in some communities. Usually, the unions are not formalised legally (Domínguez Riquelme and Alvarado León 2019; Luna Pérez et al. 2020).

While violence and forced sex are obvious restrictions on adolescents' agency, there exist less overt and malignant constraints. Issues of agency, whether it is rational and deliberative or emotional and subconscious, along a variety of dimensions permeate qualitative research on reproductive behaviours and fertility decisions (Guzzo et al. 2019). On the one hand, many adolescent mothers in Latin America and the Caribbean lack other life plans and aspirations (such as further education) that would conflict with motherhood, and as such, they do not feel their fertility interrupts anything (Azevedo et al. 2012). There is evidence linking female's limited prospects and low expectation for labour force participation directly to early childbearing (Azevedo et al. 2012; Ibarraran et al. 2014; Novella and Ripani 2016). In Mexico, female labour force participation, particularly among adolescents, is low, and adolescent employment appears to be declining (Centro de Estudios de las Finanzas Públicas 2018).

Additionally, though adolescents affirm they know about contraception, they will express uncertainty or passivity about how they became pregnant — it was something that happened to them, not something that was the result of their (lack of) decision-making (De Rosa, Doyenart, and Lara 2016; Lenkiewicz 2013). Similarly, large numbers of adolescents report not using contraception simply because they had not planned on having sex (Rodríguez Vignoli 2014a). Low self-esteem, fear of rejection, and a dependence on snap decisions arising from emotions of the moment also characterize adolescent discussions of sexual agency in Latin America and the Caribbean (Flórez 2005; Lipovsek et al. 2002). Research from United States affirms that ambivalence about adolescent pregnancy increases its probability of occurring while strong desires to explicitly avoid pregnancy consistently predict lower risk (Miller, Barber, and Gatny 2013; Rocca et al. 2010).

Traces of other aspects of sexual socialisation or contextual effects that influence the patterns of adolescent sexual behaviour, pregnancy, and pregnancy termination—all part of a broad process leading to adolescent childbearing—find support in a variety of settings. For example, evidence from Colombia finds that a woman's likelihood of experiencing coerced sex is associated with the prevalence of the experience among women in her same neighbourhood, with the magnitude of the contextual effect being as large or larger than other individual characteristics (McQuestion 2003). Research in sub-Saharan Africa indicates that adolescents that ascribe to the dual sexuality regime (that emphasises women's submissiveness), see an earlier onset of transitions to sexual debut, marriage and pregnancy than adolescents with lower gender bias (Magadi and Agwanda 2009). Additionally, there is strong evidence for the geographic clustering in patterns of timing of first sex wherein adolescents in certain regions have much higher levels of sexual activity at earlier ages than others, even after accounting for other individual and household factors that are predictive of adolescent sexual debut (Magadi et al. 2021; Magadi and Agwanda 2009; Magadi and Uchudi 2015; South and Baumer 2001). In a study in Kenya where adolescents were asked to identify the factors they thought most led to adolescent pregnancy, peer pressure to have sex was the most cited factor, and the adolescents noted that pressure came from both female and male friends, not just romantic partners (Were n.d.). A study in the US found that while neighbourhood of residence was not necessarily related to pregnancy risk, adolescents in more disadvantaged neighbourhoods were less likely to terminate their pregnancies than adolescents in wealthier neighbourhoods (South and Baumer 2001). Similar findings in Nigeria identified that individuals living in communities with a higher prevalence of contraception also had higher odds of pregnancy termination. Furthermore, adolescents whose sexual debut occurred before age 15 also had higher probabilities of having experienced a pregnancy termination than others with a later sexual debut (Onukwugha et al. 2020).

All this to say that the contextual influences that underpin adolescent childbearing are many. This study examines municipal contextual effects generally, as well as the contextual effects of the childbearing rates of an adolescent's peers specifically, and when this study refers to these trends as the peer influence of fertility, it does so with the recognition that 'peer influence' encompasses a broad array of socialisation processes. The processes extend from neurological and developmental differences in aspects of social learning and social influence in adolescence, to broader gender norms and more diffuse community structures that shape adolescent girls' autonomy and power in sexual and reproductive behaviours. It must be emphasised that underlying the rates of live births are a host of proximate determinants of fertility that are critical determinants of the trends (and thereby the context) but unavailable in municipal data. Differences in the timing of sexual debut, in trends of union formation, in patterns of sexual activity, in the rates of pregnancy, in the levels of intendedness of births and in the incidence of pregnancy termination all vary considerably across Mexican municipalities, and each municipalities' unique combination of these determinants culminate in its childbearing rates. Ultimately, the goal of this study is not to describe the mechanisms of municipal contextual effects but instead to explore whether the importance of municipal context differs across the adolescent age schedule, as well as whether it differs for a particularly salient distal determinant of fertility: namely, schooling status.

4.3 Data

Data for this analysis come from a 2015 inter-census survey in Mexico, which was designed to sample 20% of the country's population (Instituto Nacional de Estadística y Geografía 2015). Sample selection includes all adolescents aged 12 to 19 years as those aged 10 and 11 were not asked fertility questions. In total, the data include 1,762,920 adolescent females aged 12-19, resident in 2,457 municipalities in Mexico in 2015.

The median size of a municipal adolescent female population in the 2015 data was about 1,500 girls, though with considerable variation. Half of all municipalities saw populations of between about 500 to 4,000 females aged 10 to 19, but with as few as 14 girls (in Onavas, Sonora) and up to 82,000 girls (in Iztapalapa, Mexico City) in municipalities (Consejo Nacional de Población 2020). Given these differences in size, and the heterogeneity they represent, it is likely that Mexico's municipal landscape may not operate as strongly as community-level context on adolescent fertility. In other words, this study's results may only be capturing an echo of the contextual influences that operate more directly at a more local scale. Nevertheless, the geographic delimitation is valuable given that municipalities are relevant for several practical reasons. First, municipalities are the geography of focus for implementation of the country's recent national strategy to reduce adolescent childbearing (Gobierno de la República 2015). Second, municipalities are the country's smallest fiscally independent administrative units. Without funding and administrative leeway, new directions in policy and programming are difficult. And third, municipalities are the smallest geographic units available in open-access census and survey data and as such are the smallest geographic unit for which representative demographic research is consistently conducted in Mexico, meaning that analysis at the municipal level can speak to other subnational research as well.

4.3.1 Variables

This research takes a parity-specific approach to adolescent fertility. That means that first and second births are examined separately in distinct regression models. As such, there are two outcome variables of interest. For first births, the outcome variable identifies first births that occurred within the last 15 months, or births in 2014 and 2015 given the survey was conducted in March 2015. The fifteen-month cut-off is intended to better focus the analysis on the more immediate circumstances surrounding fertility at specific ages. When looking at all adolescent births instead of births within previous 15 months (see Appendix D), the differences in likelihoods by age tell a slightly different story and differences by relative schooling position are not quite as extreme. Additionally, the predicted probabilities become much higher at older ages because they are about the cumulative incidence of adolescent fertility. The less-marked schooling differences are positive on the one hand because they suggest that adolescent mothers eventually return to school more often in settings where school enrolment is high, but they are unhelpful on the other hand because, overall, they dilute the analytical focus and interpretation away from the true scale of age-related differences in context of adolescent fertility.

Adolescents for whom no fertility information was reported were considered to not have a first birth in the last 15 months. Additionally, because the data only provide the date of the most recent birth, both adolescents with more than one birth and those with first births with missing birth years were considered to not have had a first birth in the last 15 months. Of the 153,768 adolescents with one or more births, 71,007 (46%) are reported to have occurred within the 15 months preceding the survey.

For higher-order births, the sample of interest is restricted to only those adolescents at risk of an additional birth—or the 153,768 adolescents with one or more reported births. The outcome variable of interest in this data subset sample identifies second and higher-order births that occurred within the last 15 months, or all non-first births that occurred in 2014 and 2015. Most (89%) of these births were second births. For simplicity, the remainder of the paper refers to these higher-order adolescent births as second births. Again, cases with missing birth years were considered to not have a second birth in the last 15 months. Of the 23,675 adolescents with two or more births, 15,161 (64%) are reported to have occurred within the last 15 months.

Several individual covariates are included in the models. These characteristics were chosen based on theoretical considerations, their importance in other research on adolescent fertility, initial exploratory work and their availability in the data. These variables include the adolescents' reported age (*age*); whether the adolescent is currently studying (*school*); a poverty indicator based on whether the adolescent lives in a dwelling with overcrowding (*poverty*), defined by instances where the household's dwelling has more than 2.5 occupants per room (Consejo Nacional de Evaluación de la Política de Desarrollo Social 2010); whether the adolescent identifies as indigenous (*indigenous*), defined as those who report speaking an indigenous language as well as consider themselves culturally indigenous in whole or in part; whether the adolescent is a migrant (*migrant*), defined by instances where the 2010 and 2015 municipality of residence were not the same; whether the adolescent is currently working (*works*), no matter if the work is remunerated or not; whether the adolescent is affiliated with a healthcare provider (*healthcare*), no matter if the provider is public or private; and finally, an indicator of rural residency (*rural*), identified as localities with fewer than 2,500 inhabitants, which aligns with official definitions in Mexico (Consejo Nacional de Evaluación de la Política de Desarrollo Social 2010). See the following section's disucssion of centring and Table 4.1 for how the variables are ultimately coded in the models.

In this research, age and school enrolment are of central interest because, as already discussed above, the likelihood of childbearing differs dramatically at different ages and among girls with different schooling profiles—with older adolescents and those who are not in school experiencing a higher incidence of fertility. Nevertheless, in many countries in the region, rates of fertility have increased among the youngest adolescents while they have declined among older adolescents (Álvarez Castaño 2015; Berquó and Cavenaghi 2005; Neal et al. 2018; Rodríguez Vignoli 2014b; Rodríguez Vignoli and Cavenaghi 2014). Unique to this study is the exploration of how an adolescent's relative position of deprivation or privilege matters. For school enrolment, this means that the regression models simultaneously consider whether a girl is enrolled or not enrolled in school and the proportion of peers in her municipality that are enrolled in school.

Extensive research finds that poverty is associated with higher incidence of adolescent fertility, as is indigenous identity and rural residence in Latin America and the Caribbean (Berquó and Cavenaghi 2005; Gomes 2012; Neal et al. 2018; Rodríguez Vignoli 2014b). Here again, trends in change over time are not always straightforward with urban areas seeing greater increase in adolescent fertility than rural areas in many cases (Berquó and Cavenaghi 2005; Neal et al. 2018; Rodríguez Vignoli 2014b).

While indigenous populations tend to have higher adolescent fertility (as well as total fertility), the populations also see much higher levels of poverty and lower levels of schooling, characteristics which are also associated with higher fertility. Literature examining fertility among indigenous populations in Mexico does not always make comparisons that account for the lower socioeconomic status of the indigenous women, and as such it is often unclear whether the high rates of fertility examined in the studies are related to women's ethnic identity independent of their poorer socioeconomic status. Tellingly, one study looking at adolescent fertility in Mexico did not find a higher likelihood for indigenous adolescents to have experienced pregnancy than their non-adolescent peers when controlling for other socioeconomic characteristics (though indigenous adolescents did have a higher likelihood of having formed a union) (Sosa-Sanchez and Menkes Bancet 2019).

Migration's association with adolescent fertility is not often studied. Some research finds that migration is associated with higher levels of adolescent fertility (Arriaga-Romero et al. 2010; Sintonen, Bonilla-Carrión, and Ashorn 2013), while other research has found migration is associated with lower levels of adolescent fertility (Flórez and Soto 2013). Migratory patterns are important to consider for theoretical reasons as well. That is, migrants will have been subject to the contextual influence of their origin municipality, not just their current municipality, making it important to account for this in the regression analysis.

Evidence on the association between work and adolescent fertility is mixed. On the one hand, some research finds that adolescent fertility, including in Mexico, is related to an increase in the probability of employment in adolescence, likely because of the new financial pressures parenthood brings (Azevedo et al. 2012). However, both adolescent and female employment in Mexico is quite low, meaning that work could be a marker for adolescents with less traditional gender norms living in areas that are more economically robust (López-Acevedo et al. 2021; World Bank 2019c). In some cases, employment might reasonably have similar effects as schooling, with adolescents who are employed having less free time available for social and romantic interactions.

Finally, evidence on the association between healthcare access and adolescent fertility in Mexico is sparse. However, it may well be that the indicator mirrors what is most often seen in the relationship between contraception and adolescent fertility in the region. That is, in cross-sectional analysis, the use of contraception is associated with a higher incidence of adolescent fertility, simply because so many adolescents do not use any contraception until after the birth of a child (Rodríguez Vignoli 2014a). In any case, the variable is of interest because current policy strategies prioritize the expansion of youth access to healthcare services for reducing adolescent fertility in Mexico (Gobierno de la República 2015). Additionally, even if healthcare access is associated with higher incidence of adolescent first births, the relationship could be different for second births. Current policy strategies aim to introduce adolescent first-time mothers to contraception through their obstetric and postnatal care providers (Gobierno de la República 2015).

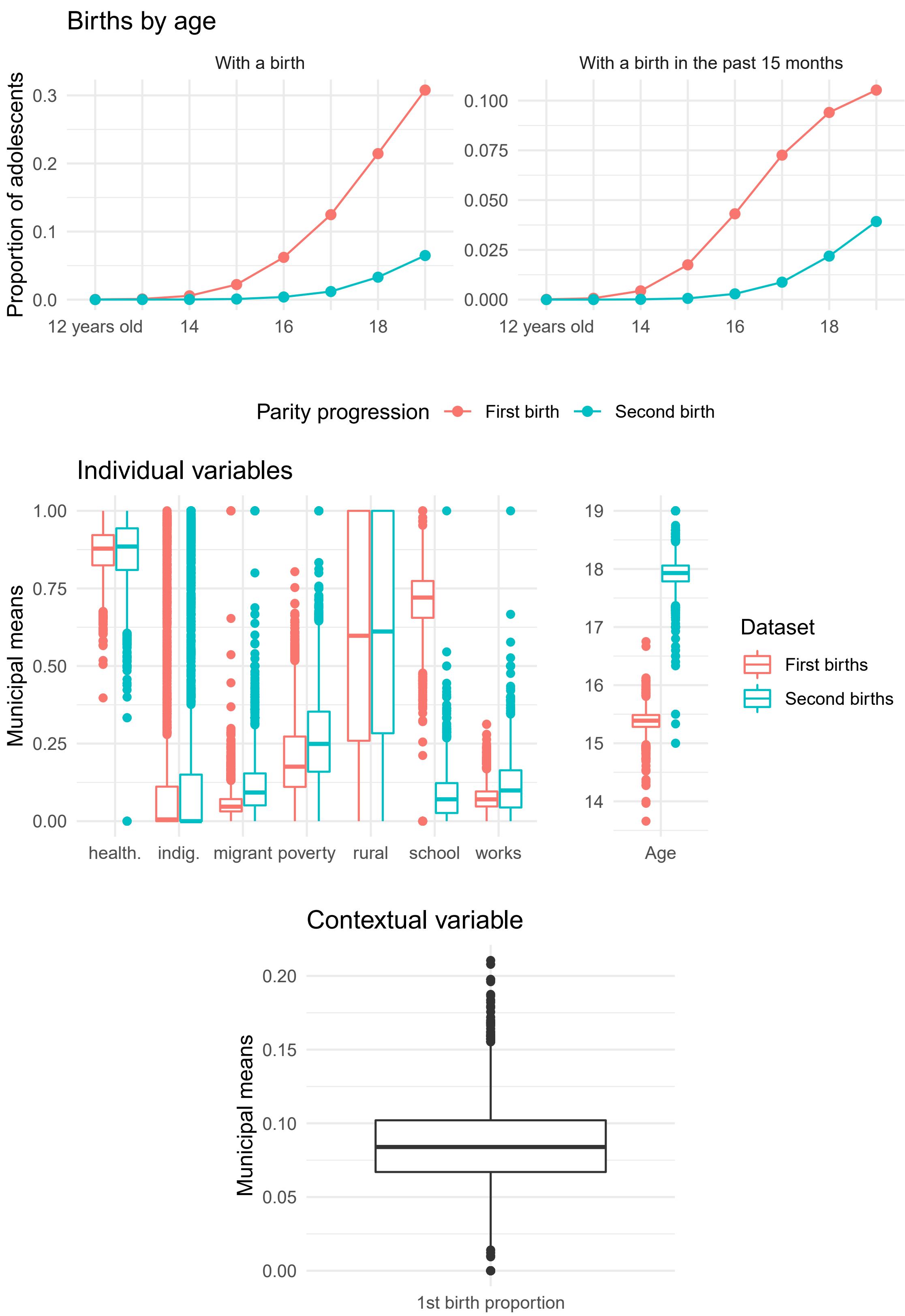
The analysis also examines adolescent fertility as a contextual variable. The proportion of adolescents with a first birth within each municipality is meant to describe the adolescent fertility context. This contextual variable is powerful for its ability to approximate important but unmeasured cultural and behavioural aspects that influence adolescent fertility. For example, broader social norms for adolescent sexual activity, use of contraception, partnership formation and early childbearing, all have bearing on the likelihood of an individual girl experiencing motherhood in adolescence, and these norms manifest as higher or lower fertility within Mexican municipalities.

Figure 4.1 presents several boxplots to show how the population composition of these individual characteristics varies across municipalities. The figure also depicts how adolescent fertility changes across the age schedule. The two plots on the top row, subplots “Birth by age”, depict the proportion of adolescents with first and second births. The plot on the left shows cumulative births. That is, the proportion of adolescents with a first or second birth by each age, no matter when those births occurred. The plot on the right shows the proportion of adolescents at each age who had a birth in the past 15 months. This right-hand plot (births in the past 15 months) depicts the outcome variables of interest in this study’s regression analyses while the cumulative plot is for reference purposes to better understand the prevalence of adolescent fertility in Mexico. For instance, while about a third of 19-year-old adolescents have given birth, only 10% of 19-year-olds experienced a first birth within the past 15 months. Just over 6% of 19-year-olds have two births with 4% of 19-year-olds having experienced their second birth within the past 15 months.

The second row of subplots depict the population composition of municipalities with respect to the makeup of their adolescent population’s characteristics of healthcare access, indigenous identity, migration status, poverty, rural residence, school enrolment and employment. The figure depicts boxplots, which show municipal medians (centre horizontal line within the boxes), municipal second and third quartiles (top and bottom horizontal lines of the boxes), municipal proportions within 1.5 times the interquartile range (vertical lines extending from the boxes), and any remaining outliers (points at the ends of the lines) for all of the individual variables included in the analysis. For instance, healthcare access is very similar among all adolescents and adolescent mothers. The middle half of municipalities see between 82% and 92% of all adolescents affiliated with a healthcare provider (first births), while between 81% and 94% of adolescent mothers have healthcare access (second births) in the middle half of municipalities. The municipal composition is also fairly similar between the first and second birth analyses for indigenous identity and rural residence. In contrast, more adolescents in the second birth analysis are migrants, are poor, are working and are not in school. For example, while the middle half of municipalities see between 66% and 77% of all adolescents currently enrolled in school, among adolescent mothers, only 3% to 12% are in school in the middle half of municipalities. There is also a large difference in the average age in the two datasets. What is important is that these figures reveal that municipalities differ in the composition of their adolescent populations.

The third row of subplots presents the distribution of the contextual variable, which is the proportion of adolescents in each respective municipality with a first birth. In the middle half of municipalities, between 7% and 10% of adolescents have experienced a birth, but the proportions range from as low as 0% up to 21% of adolescents with a first birth. The contextual variable is used in both first and second birth analyses. This point is important to emphasize. While the individual cases included in the analysis on second births only consider those with first births, the contextual fertility

Figure 4.1: Descriptive statistics of adolescent fertility in Mexican municipalities in 2015



variable is meant to describe fertility landscape experienced by all adolescents. The idea is that adolescents at risk of a second birth are not solely influenced by other adolescent mothers but by the broader adolescent landscape within her municipality. Again, this contextual variable is the proportion of all adolescents with a first birth.

4.3.2 Centring

Appropriately centring Level 1 variables in multilevel models is vital to the interpretation of the estimated parameters. In the case of this research, Level 1 refers to individual girls while Level 2 is the municipality in which she lives. At Level 1 are the covariates describing each girl's individual characteristics. These individual covariates can either be centred at the grand mean or they can be centred around the cluster mean. That is, either deviated around the national mean for all of Mexico or around the mean of municipality *j* to which adolescent *i* belongs. These two centring options produce estimates that differ in value and meaning, but not statistical correctness. That is, centring decisions are pivotal for adequately addressing the substantive questions of interest, but one is not more statistically correct than the other in and of itself (Kreft 1995).

Consider the covariate *school*, a dichotomous variable indicating that the adolescent is currently studying, for example. Centring of individual dichotomous variables, as opposed to continuous variables, can be more difficult to grasp conceptually, but the impact of centring for the interpretation of the models parameters remains unchanged. If no centring were undertaken, the covariate *school* would take the value of 1 for a girl who is currently studying and the value of 0 for a girl who is not.

Under grand mean centring, the schooling status of each individual would be deviated around the grand mean. In the dataset, 71% of all adolescents are currently enrolled in school, so the individual girl who is currently in school would be assigned the value of 0.29 (1.00-0.71=0.29) and the girl who is not in school would be assigned the value of -0.71 (0.00-0.71=-0.71). This type of centring makes the interpretation of the intercept quite convenient, in that it becomes the municipal mean that would result had the proportion of girls who are studying been identical (at 71%) across municipalities.

However, the interpretation of a model's variance components under grand mean centring (and models without any centring) can be problematic and potentially biased toward zero because there is a dependency between intercepts and slopes. Remember that variance is an important measure of possible contextual phenomena. The dependency between intercepts and slopes can thus artificially compress the variation under the shrinkage process that occurs in multilevel modelling. In effect, under grand mean centring, the variance estimates become an ambiguous mixture of individual and contextual phenomena (Enders and Tofighi 2007). Given this study's interest in exploring the importance of context, grand mean centring (as well as uncentred variables) would be a problematic choice because of the ambiguously-measured variance the models produce.

Centring within cluster, in contrast, completely removes the dependency between intercepts and slopes so that estimates of variance unambiguously measure variation at Level 2 without potential confounding from variation at Level 1. Under centring within cluster, the schooling status of each individual, for example, is deviated around the cluster mean. In the dataset, half of municipalities see between 66% and 77% of all adolescent girls currently studying. As such, the variable becomes indicative of individual girl's schooling status as well as how widespread schooling is among her peers. For instance, an individual girl who is currently in school in one of these middle 50% of municipalities, would have the schooling value from 0.34 (1.00-0.66=0.34) to 0.23 (1.00-0.77=0.23) and the girls who are not currently in school are assigned values from -0.65 (0.00-0.65=-0.65) to -0.77 (0.00-0.77=-0.77). With this type of centring, the interpretation of the intercept becomes the predicted score for a case where the variable in question is at the cluster mean. With dichotomous variables, an equivalent interpretation for the intercept is the unadjusted municipal mean, or the municipal mean given the proportion of girls in school in the municipality are at the value indicated in the data rather than an adjusted proportion identical across all municipalities (Enders and Tofighi 2007).

Additionally, under centring within cluster, the estimated slope coefficient for *school* no longer mixes within-municipality and between-municipality associations in schooling status and adolescent fertility. Instead, it exclusively estimates the association across individuals within municipalities. This implies that the models investigate whether an individual girl's relative schooling position within her municipality is an important determinant of her behaviour (and risk of adolescent fertility), and whether there are variations in this relationship (be they in its magnitude or direction). This yields slope estimates that can, for example, say whether a girl who is out of school in a municipality where it is non-normative to be out of school has higher risk of adolescent fertility than does a girl who is out of school in a municipality where it is common to be out of school. Additionally, centring within cluster is particularly beneficial for examining cross-level interactions. For instance, whether aggregate fertility behaviours have a different association with individual fertility risk depending on how old the individual girl is. Grand mean centring risks producing significant cross-level interaction effects when no such effect exists in the population simply because within- and between-cluster relationships are not disentangled (Hofmann and Gavin 1998).

Centring for Level 2 variables is far less complex as it is only possible to centre around the grand mean given that every member of a given cluster shares the same value for the Level 2 variable. That is, there is no within-municipality differences, only differences across municipalities. In this research, the contextual variable is grand mean centred to ease interpretation of the regression coefficients.

Table 4.1 presents a range of summary statistics for the variables after centring within cluster for Level 1 variables and grand mean centring of the Level 2 variable both for the first and second

		Original variable	Centred variable				
Variable	Type	Value	Minimum value	1st Quartile	Mean	3rd Quartile	Maximum value
First birth analysis							
Age	individual	12 to 19	-4.1250	-2.1738	0.0	1.7557	5.3409
School	individual	0 or 1	-0.9787	-0.5727	0.0	0.3007	0.7883
Poverty	individual	0 or 1	-0.8040	-0.2190	0.0	-0.0566	0.9893
Indigenous	individual	0 or 1	-0.9944	-0.0121	0.0	0.0000	0.9997
Migrant	individual	0 or 1	-0.6533	-0.0641	0.0	-0.0262	0.9982
Works	individual	0 or 1	-0.3126	-0.0978	0.0	-0.0464	0.9941
Healthcare	individual	0 or 1	-0.9956	0.0644	0.0	0.1728	0.6027
Rural	individual	0 or 1	-0.9842	-0.2027	0.0	0.2155	0.9995
1st birth proportion	contextual	0.0 to 0.2	-0.0872	-0.0163	0.0	0.0149	0.1233
Second birth analysis							
Age	individual	12 to 19	-6.2353	-0.8036	0.0	1.0127	3.6667
School	individual	0 or 1	-0.5455	-0.1094	0.0	-0.0270	0.9955
Poverty	individual	0 or 1	-0.8333	-0.2973	0.0	0.4737	0.9756
Indigenous	individual	0 or 1	-0.9915	-0.0227	0.0	0.0000	0.9973
Migrant	individual	0 or 1	-0.8000	-0.1111	0.0	-0.0357	0.9966
Works	individual	0 or 1	-0.6667	-0.1546	0.0	-0.0349	0.9961
Healthcare	individual	0 or 1	-0.9889	0.0448	0.0	0.1791	0.6667
Rural	individual	0 or 1	-0.9877	-0.2174	0.0	0.2258	0.9933
1st birth proportion	contextual	0.0 to 0.2	-0.0778	-0.0098	0.0	0.0213	0.1233

Note:
Individual variables are centred within cluster and contextual variables are grand mean centred

Table 4.1: Summary statistics of centred variables

birth regression models. The relative position of an adolescent can be easily read from the centred individual variables. Take *poverty* for example. The minimum value observed in the first birth analysis is -0.80, which describes a girl who does not experience overcrowding in her household dwelling in a municipality where 80% of her peers experience overcrowding. On the other end of the spectrum, the maximum value observed is 0.99, describing a girl experiencing overcrowding in a municipality where only 1% of her peers live in overcrowded dwellings as well. These cases are the extremes, but it is reasonable to imagine that these relative positions might matter. That is, a girl in poverty in a municipality where only 1% of her peers are poor may have very different adolescent fertility probabilities than a girl in poverty in a municipality where 90% of her peers are as well, but it is not immediately clear what direction the influence will take. The regression analysis will help indicate whether deprivation in a context of surrounding affluence creates a 'desperation effect' whereby it is associated with higher chances of adolescent fertility (for the girl experiencing poverty) or a 'protective effect' whereby it is associated with lower chances of adolescent fertility.

4.4 Analytical strategy

The multilevel models are carried out in R using the package lme4 (Bates et al. 2015), which uses an estimation procedure that optimizes a function of the log-likelihood using penalised iteratively re-weighted least squares. The log-likelihood is evaluated using the Laplacian approximation.

4.4.1 Model 1 (null model)

As a starting point, I fit a null model with only an intercept and random effects for each parity separately. Recall that the population sample for the first birth analysis is all adolescents while the population for progression to second births is adolescents with one or more births. The null model is a first step in identifying clustering in adolescent parity-specific fertility within municipalities. The presence of clustering, quantified by the random components of the model, is indicative of a possible contextual phenomenon. The null model for first births does not include any explanatory variables but simply estimates the average probability that an adolescent has had a first birth in the past 15 months, as well as estimates municipal differences in the average probability. In this case the probability is the same as the proportion of adolescent with a first birth in the past 15 months in each municipality. The model looking at second births in adolescence estimates the municipal-specific probability that an adolescent with one birth has progressed to a second birth within the last 15 months and before reaching her twentieth birthday. Here again, the individual probabilities can be equivalently interpreted as the municipal proportions of adolescent mothers progressing to second birth. In summary, the null model simply aims to identify the existence of possible contextual phenomena through the quantification of municipal clustering in adolescent fertility. The null model can be written as:

$$\text{log}(\frac{\pi_{ij}}{1-\pi_{ij}}) = \beta_0 + u_{0j}$$

In this model, the intercept β_0 is shared by all municipalities while the random effect u_{0j} is specific to municipality *j*. Random effects are assumed to follow a normal distribution with variance σ^2_{u0}. The presence of municipal residuals or random effects, u_{0j}, in the model reflects that the probability of adolescent fertility may vary at the individual and municipal level. Municipal differences in the predicted outcome correspond to the municipal variance of the intercept. The variance is a summary of the differences. In linear multilevel models, total variance can be partitioned neatly into individual- and contextual-level variance in what is often called the variance partition coefficient (VPC). In linear multilevel model, the variance partition coefficient describes the proportion of the total variance in the outcome that is attributable to the cluster level. That is, the proportion of the residual variation in the propensity to have a birth in adolescence that is attributable to unobserved municipal characteristics—or a quantification of the importance of possible contextual phenomena in adolescent fertility probabilities. In the case of the null model, the VPC can be expressed as follows:

$$\text{VPC} = \frac{\sigma^2_u}{\sigma^2_u + \sigma^2_e}$$

Where σ^2_u is the Level 2 residual variance and σ^2_e is the Level 1 residual variance, and both are parameters estimated by the linear multilevel model regression.

The partitioning is not as clear cut in logistic models because Level 1 and Level 2 variance are on different scales—the probability and logistic scales respectively. Also, the Level 1 variance depends on the prevalence of the outcome. Additionally, the Level 1 variance, σ_e^2, is not an estimated output of multilevel logistic regressions. Nevertheless, several approximations of the variance partition component have been proposed, including a normal response approximation and simulation methods (Austin and Merlo 2017). One approach, called the latent variable method, converts the variance at both levels to the same scale before computing the variance partition coefficient to be able to translate it to the logistic context (Snijders and Bosker 2012). The latent response formulation has become the most widely used (Austin and Merlo 2017) and is deemed adequate for this study because the method assumes that, in this study's case, the propensity for having a birth in adolescence is a continuous latent variable underlying the dichotomous response of having a birth in the past 15 months or not. In other words, every girl has a certain propensity for having a birth but only girls whose propensity crosses a certain threshold actually do. Here, the variance in the unobserved individual propensity follows a logistic distribution equal to $\pi^2/3$ (i.e., 3.29), meaning that the equation for the variation partition coefficient of the null logistic model can be expressed as follows:

$$\text{VPC} = \frac{\sigma_u^2}{\sigma_u^2 + 3.29}$$

This study also uses the median odds ratio (MOR) to quantify the magnitude of possible contextual phenomena. In this study, the median odds ratio describes the difference in adolescent fertility probability between two subjects with identical individual characteristics but living in different municipalities, repeatedly sampled at random. That is, the difference in fertility risk between the two as quantified by the municipal-specific random effects. The median odds ratio can be evaluated as:

$$\text{MOR} = \text{exp}(\sqrt{2\sigma_u^2} * 0.6745)$$

Again, Where σ_u^2 is variance of the distribution of the random effects and 0.6745 represents $\phi^{-1}(0.75)$ or the 75th percentile of a standard normal distribution (Austin and Merlo 2017). The advantage of using median odds ratio for quantifying the effect of clustering is that it is on the same scale as individual-level covariates so the magnitudes can be compared. Also, unlike the variance, it is statistically independent of the prevalence of the phenomenon (Austin and Merlo 2017).

4.4.2 Model 2

As a second step, the analysis investigates whether an individual girl's relative position within her municipality is associated with differentiated risk of adolescent fertility. This step expands on the null model by including the individual variables of interest, each centred within their cluster. These variables are the characteristics of age, schooling status, poverty, indigenous identity, migration status, employment, healthcare access and rural residency. Additionally, an interaction effect between age and schooling status explores whether the association between schooling status and adolescent fertility differs across the adolescent age schedule. For instance, most 19-year-old adolescents are out of school anyway so being out of school may not have as strong an association with adolescent fertility as might be the case for a 14-year-old who is out of school given that most 14-year-olds are still in school.

This second model also explores the extent to which municipal differences are explained by the composition of adolescents in municipalities. While grand-mean centred individual variables produce estimates that already 'equalize' the population composition across clusters, the same adjustment can be achieved with models with cluster-centred variables. To produce equalised estimates across municipalities, the cluster-centred variables simply need to be set at values that equalize them across municipalities. For example, setting all covariates so they represent a municipal population that is the same as the national average by using an adjustment that is equal to the difference between each municipal-specific mean and the national mean.

The Model 2 equation for first births, which also shows in detail the centring process used in this study for clarity, can be represented as:

$$
\begin{aligned}
\text{log}(\frac{\pi_{ij}}{1-\pi_{ij}}) =& \beta_0 + \beta_1(\text{age}_{ij} - \overline{x}_{\text{age}_j}) + \beta_2(\text{school}_{ij} - \overline{x}_{\text{school}_j}) \\
&+ \beta_3(\text{poverty}_{ij} - \overline{x}_{\text{poverty}_j}) + \beta_4(\text{indigenous}_{ij} - \overline{x}_{\text{indigenous}_j}) \\
&+ \beta_5(\text{migrant}_{ij} - \overline{x}_{\text{migrant}_j}) + \beta_6(\text{works}_{ij} - \overline{x}_{\text{works}_j}) \\
&+ \beta_7(\text{healthcare}_{ij} - \overline{x}_{\text{healthcare}_j}) + \beta_9(\text{rural}_{ij} - \overline{x}_{\text{rural}_j}) \\
&+ \beta_{10}(\text{age}_{ij} - \overline{x}_{\text{age}_j})(\text{school}_{ij} - \overline{x}_{\text{school}_j}) \\
&+ u_{0j}
\end{aligned}
$$

In this model, the β_0 to β_{10} coefficients are shared by all municipalities while the random effect u_{0j} is specific to the intercept of municipality *j*. Individuals *i* in their respective municipalities *j* have individual characteristics a_{ij}, which are relative the municipal mean of that characteristic $\overline{x}_{a_j}$.

The Model 2 equation for progression to second births is identical to that shown above except that there is no interaction between *age* and *school*. A Likelihood Ratio Test indicated that an interaction term did not offer a significant improvement to the model fit, which implies the association between schooling status and second birth probabilities remains the same at all adolescent ages.

The variance partition coefficient is derived in the same way as under the null model, but it now looks at the proportion of the residual variation in the propensity to have a birth in adolescence that is attributable to unobserved municipal characteristics after accounting for differences in the composition and relative position of the adolescent populations in municipalities of the characteristics included in the regressions. A note of caution is necessary here. The variance partition coefficients are not necessarily directly comparable between the null model and Model 2. Because the individual level variance is fixed at $\pi^2/3$ (i.e., 3.29), each time a variable is added to the model, the underlying latent variable and the cluster-level variation are rescaled (Austin and Merlo 2017). That is, as a consequence of the individual-level residual variance being fixed, all other parameters in the model change to accommodate the change introduced by the addition of any individual-level explanatory variable(s) (Weinmayr et al. 2017).

4.4.3 Model 3

The third step is pivotal. It investigates whether possible contextual phenomena differ in magnitude for different groups of adolescents. That is, whether context matters differently at different ages and by relative schooling status. This model no longer assumes that the magnitude of the association between schooling or age and the risk of adolescent fertility is the same in all municipalities. Rather, it explores whether the patterns vary depending on the municipality's context. For example, it is possible that contextual factors have higher impact on adolescents out of school than those in school, or higher impact on younger adolescents than older adolescents. The model is extended to allow the regression coefficients of *age* and *school* to vary randomly at the municipal level:

$$
\begin{aligned}
\text{log}(\frac{\pi_{ij}}{1-\pi_{ij}}) =& \beta_0 + \beta_1(\text{age}_{ij} - \overline{x}_{\text{age}_j}) + \beta_2(\text{school}_{ij} - \overline{x}_{\text{school}_j}) \\
&+ \beta_3(\text{poverty}_{ij} - \overline{x}_{\text{poverty}_j}) + \beta_4(\text{indigenous}_{ij} - \overline{x}_{\text{indigenous}_j}) \\
&+ \beta_5(\text{migrant}_{ij} - \overline{x}_{\text{migrant}_j}) + \beta_6(\text{works}_{ij} - \overline{x}_{\text{works}_j}) \\
&+ \beta_7(\text{healthcare}_{ij} - \overline{x}_{\text{healthcare}_j}) + \beta_9(\text{rural}_{ij} - \overline{x}_{\text{rural}_j}) \\
&+ \beta_{10}(\text{age}_{ij} - \overline{x}_{\text{age}_j})(\text{school}_{ij} - \overline{x}_{\text{school}_j}) \\
&+ u_{0j} + u_{1j}(\text{age}_{ij} - \overline{x}_{\text{age}_j}) + u_{2j}(\text{school}_{ij} - \overline{x}_{\text{school}_j})
\end{aligned}
$$

In this model, aside from representing the municipal differences in the proportion of adolescents with a first birth, the intercept variance u_{0j}, each municipality has its own regression coefficient for the association between *school* and adolescent fertility, as well as *age* and adolescent fertility. The municipal coefficients deviate from the overall fixed effects for *age* (β_1) and *school* (β_{10}) by a residual amount, u_{1j} and u_{2j} respectively. The slope variability for these random effects is assumed to follow a normal distribution with variance σ^2_{u1} for *age* and σ^2_{u2} for *school*. Again, these variables suggest that municipal context modifies the individual level association between adolescent fertility and age and schooling status.

In this case, the Level 2 variance is no longer a function of the intercept variance (σ^2_{u0}) alone, but also depends on the slope variances (σ^2_{u1} and σ^2_{u2}), the *age* and *school* variables, and the covariances between them. That is, the Level 2 variance becomes a function of age and schooling status and can be represented by the following equation:

$$\begin{aligned}\text{var}[u_{0j} + u_{1j}(\text{age}_{ij} - \overline{x}_{\text{age}_j}) + u_{2j}(\text{school}_{ij} - \overline{x}_{\text{school}_j})] = \\ \sigma^2_{u0} + \sigma^2_{u1}(\text{age}_{ij} - \overline{x}_{\text{age}_j})^2 + \sigma^2_{u2}(\text{school}_{ij} - \overline{x}_{\text{school}_j})^2 + \\ 2\sigma_{u01}(\text{age}_{ij} - \overline{x}_{\text{age}_j}) + 2\sigma_{u02}(\text{school}_{ij} - \overline{x}_{\text{school}_j}) + \\ 2\sigma_{u12}(\text{age}_{ij} - \overline{x}_{\text{age}_j})(\text{school}_{ij} - \overline{x}_{\text{school}_j})\end{aligned}$$

where σ^2_{u0} represents the variance in u_{0j}, and the slope variances σ^2_{u1} and σ^2_{u2} depend on the value of the variable *age* and *school* respectively. The covariance between u_{0j} and u_{1j} is represented by σ_{u01}, and also depends on the value of the variable *age*. The covariance between u_{0j} and u_{2j} is represented by σ_{u02} and the covariance between u_{1j} and u_{2j} is σ_{u12}. In calculating the variance partition coefficient, the variance from the equation above takes the place of σ^2_u in the equation already seen (VPC=$\sigma^2_u/(\sigma^2_u + 3.29)$).

In the case of second birth progression, likelihood ratio tests indicated that random effects for *age* and *school*, whether alone or in combination, did not offer a better fit to the data. This suggests that there was no detectable difference in the association between the progression to second adolescent births and age and schooling status in the various municipalities of residence. Recall that the sample size of this dataset is limited, and few second births occur at the younger ages, so there could be variance by age or schooling status in the population but its was undetectable in the regression models. As such the regression results for Model 3 are presented for illustrative purposes only.

4.4.4 Model 4

After investigating whether possible contextual phenomena differ in magnitude for girls at different ages and by schooling status, a final step looks at whether aggregate levels of adolescent childbearing form a quantifiable part of the contextual phenomena that matter for individual childbearing probabilities. That is, whether the fertility patterns of an adolescent's peers have an independent association with a girl's own individual likelihood of giving birth in adolescence. Additionally, the model explores whether the contextual influence of aggregate fertility patterns differs in magnitude at different adolescent ages. That is, whether there is an interaction between age and municipal adolescent fertility levels. The parity-specific models are extended to include the grand mean centred municipal variable of the proportion of all adolescents with a first birth. Additionally, this new municipal-level variable is interacted with age in the regression model looking at first adolescent births. Note that the centring decision for a municipal-level predictor is far less complex than it is for individual-level predictors because it is only possible to use the raw metric or the grand mean centred metric. The choice only affects the estimation of the intercept coefficient. Centring within cluster is not possible because every observation in the same cluster has the same value for municipal-level predictors. In this case, grand mean centring is preferable as it is consistent with standard practice and facilitates the interpretation of the regression results (Enders and Tofighi 2007).

The equation for Model 4 of first births can be expressed as:

$$
\begin{aligned}
\text{log}(\frac{\pi_{ij}}{1-\pi_{ij}}) =& \beta_0 + \beta_1(\text{age}_{ij} - \overline{x}_{\text{age}_j}) + \beta_2(\text{school}_{ij} - \overline{x}_{\text{school}_j}) \\
& + \beta_3(\text{poverty}_{ij} - \overline{x}_{\text{poverty}_j}) + \beta_4(\text{indigenous}_{ij} - \overline{x}_{\text{indigenous}_j}) \\
& + \beta_5(\text{migrant}_{ij} - \overline{x}_{\text{migrant}_j}) + \beta_6(\text{works}_{ij} - \overline{x}_{\text{works}_j}) \\
& + \beta_7(\text{healthcare}_{ij} - \overline{x}_{\text{healthcare}_j}) + \beta_9(\text{rural}_{ij} - \overline{x}_{\text{rural}_j}) \\
& + \beta_{10}(\text{age}_{ij} - \overline{x}_{\text{age}_j})(\text{school}_{ij} - \overline{x}_{\text{school}_j}) \\
& + \beta_{11}(\overline{x}_{\text{birth1}_j} - \overline{x}_{\text{birth1}}) + \beta_{15}(\overline{x}_{\text{birth1}_j})(\text{age}_{ij} - \overline{x}_{\text{age}_j}) \\
& + u_{0j} + u_{1j}(\text{age}_{ij} - \overline{x}_{\text{age}_j}) + u_{2j}(\text{school}_{ij} - \overline{x}_{\text{school}_j})
\end{aligned}
$$

The equation for progression to second births in adolescence is the same as that above, except it does not include the age and school interaction fixed effect or age and school random effects.

The variance partition coefficient is derived using the same equation as described under Model 2. Whereas the variance partition coefficients under the null model and models 2 and 3 are not directly comparable to each other, the variance partition coefficients in Model 4 can be compared more reliably to those in Model 3 (in the case of first births) and Model 2 (in the case of progression to second births) because the only change is the addition of a contextual variable. Because cluster-level variables do not explain individual-level variation, any rescaling of other parameters that occurs to keep individual-level residual variance fixed at 3.29 will be minute, and will remain within the range of imprecision resulting from model estimation (Weinmayr et al. 2017). As such, the reduction in unexplained variance from previous models to Model 4 speaks to the explanatory power of the peer influence of adolescent fertility as a contextual phenomenon on individual fertility likelihoods.

	Model 1			
	First births		Second birth Progression	
	Regression Coefficeint	(standard error)	Regression Coefficeint	(standard error)
Fixed part				
Intercept	-3.195	(0.007)***	-2.305	(0.012)***
	Variance	(standard deviation)	Variance	(standard deviation)
Random part				
Intercept	0.055	(0.23)	0.093	(0.31)
Observations	1,762,920		153,768	
Log Likelihood	-296,824		-49,197	

Note:
*** p-value < 0.0001

Table 4.2: Model 1 Regression Results

4.5 Results

4.5.1 Model 1: Municipal clustering

The null model does not include any explanatory variables but only estimates the proportion of adolescents in municipalities with a first birth in the previous 15 months. In the model, variation between municipalities are assumed to be of similar magnitude for every girl—no matter her age or schooling status. This aim of this model is to identify the existence of possible contextual phenomena, which can be quantified by clustering of adolescent fertility within municipalities. Table 4.2 presents the regression results, which estimate that a municipality with $u_{0j} = 0$ has -3.195 log odds of adolescent first birth within the last 15 months. This converts to 3.9% of all adolescents having a first birth in the last 15 months (exp(-3.195)/(1+exp(-3.195))=0.039). For second births, a municipality with $u_{0j} = 0$ has -2.305 log odds of second birth progression, which converts to 9.1% of all adolescent mothers having progressed to an additional birth in the last 15 months. The municipal residuals indicate that these proportions vary across municipalities such that the middle half of municipalities see their predicted proportion for first births range from 3.6% to 4.4% and for second births from 8.3% to 9.8%.

The model also indicates that there is municipal clustering, or that girls living in the same municipality share a common likelihood of adolescent fertility that differs from the overall likelihood by an amount that corresponds to the municipal residual. Total differences in first and second birth proportions can be attributable to both individual and municipal differences in the likelihood of adolescent fertility, and these total differences are quantified by the variance components. The portion of the difference that is at the municipal level is indicated by the variance partition coefficient. The variance partition coefficient for first births is 0.016 and for second births is 0.028. That is, 1.6% of the total individual differences in the likelihood of a first birth in the past 15 months are at the municipal level, and 2.8% of the total individual differences in the likelihood of progressing to a second birth in the last 15 months are at the municipal level. Or, put differently, 1.6% of total differences in likelihood of adolescent fertility is due to between-municipality differences in adolescent fertility (whether through different population compositions or contextual phenomena).

Another way to conceptualize the variance partition coefficient is that if it were 0.0, then the likelihood of first birth in adolescence for girls in the same municipality would be no more similar than the likelihood for a random sample of girls from all of Mexico. On the other hand, if the variance partition coefficient were 1.0, then all girls in the same municipality would have exactly the same adolescent fertility outcome.

At first blush, the variance of only a few percentage points appears inconsequential, but when examined in terms of median odds ratios, the clustering takes on much more meaning. The estimated median odds ratio is 1.25 for first births and 1.34 for second births. Conceptually, this implies that if any girl were to move from one random area to another random area with higher risk, her odds of an adolescent first birth would increase by 25% simply by virtue of the place she is living and no other change in her personal characteristics. For progression to second births, her odds would increase by 34%.

The variance could be the result of different population compositions in municipalities or it could be the result of contextual phenomena that shape a common fertility likelihood among adolescents in the same municipality. The next models explore these questions.

4.5.2 Model 2: Individual characteristics and population composition

This model introduces individual characteristics to fine tune the predicted probabilities and differences across municipalities. Table 4.3 presents the regression results. The variance suggests that, even after accounting for the individual characteristics included in the model, there remains differences in adolescent fertility probabilities that are attributable to municipal-level context. For first births, the variance partition coefficient indicates that 1.6% of the total individual differences in likelihood are at the municipal level, and for second births, that 3.0% are. Note that Model 2 assumes that the variance partition coefficient, or the importance of context, is the same for all girls, no matter where she lives, how old she is or whether she is in school or not. When translated to median odds ratio, the model implies that if any two girls with identical individual characteristics from two random municipalities, the girl in the municipality with higher risk would see her odds of an adolescent first birth be 24% greater than the girl's in the municipality with lower risk simply by virtue of the context of the place she is living and no other difference in her personal characteristics. For second births, her odds would increase by 35% due to the change in municipality.

Because Model 2 includes individual characteristics, it can be used to adjust the predicted probabilities to account for disparate population compositions across municipalities. It is plausible that adolescent fertility probabilities would be more similar across municipalities if every municipality saw the same proportion of girls who were poor, were out of school, were indigenous, were working, were migrants, had healthcare access and had the same age distribution. Figure 4.2

	Model 2			
	First births		Second birth Progression	
	Regression Coefficeint	(standard error)	Regression Coefficeint	(standard error)
Fixed part				
Intercept	-4.807	(0.014)***	-2.416	(0.013)***
age	0.538	(0.005)***	0.368	(0.009)***
school	-3.577	(0.020)***	-0.838	(0.046)***
poverty	0.248	(0.010)***	0.409	(0.019)***
indigenous	-0.143	(0.018)***	0.269	(0.038)***
migrant	0.354	(0.014)***	-0.048	(0.031)
works	-1.256	(0.014)***	-0.527	(0.031)***
healthcare	0.546	(0.012)***	0.158	(0.026)***
rural	-0.204	(0.011)***	-0.004	(0.023)
age_school	0.430	(0.008)***		
	Variance	(standard deviation)	Variance	(standard deviation)
Random part				
Intercept	0.053	(0.23)	0.101	(0.32)
Observations	1,762,920		153,768	
Log Likelihood	-218,689		-47,624	

Note:
*** p-value < 0.0001

Table 4.3: Model 2 Regression Results

looks at this possibility by comparing unadjusted municipal predictions to the adjusted municipal predictions. The unadjusted municipal predictions are simply the predicted probabilities when all individual covariates are at their municipal mean (all covariates are given the value of 0), whereas the adjusted predicted probabilities are derived from adjusting all covariates for each specific municipality to be at the national average. In the figure, municipalities are ordered from those with the highest predicted probabilities to the lowest, according to their adjusted means. Importantly, the adjusted means differ considerably across municipalities, suggesting that the differing risk of adolescent fertility across municipalities is not simply the result of differences in the composition of municipal adolescent populations—at least with respect to the variables examined in the model.

The model also yields a number of noteworthy findings for how individual characteristics are related to the probability of adolescent fertility. As expected, the likelihood of having given birth increases with age, and girls who are in school have a lower incidence of fertility than girls who are not in school. However, there is an interaction between age and schooling status for first births that suggests that the likelihood of having given birth among younger girls who are out of school is actually higher than what would be predicted without the interaction. Conversely, the likelihood among the oldest girls is lower than what would otherwise be predicted. This intensification of the risk among out-of-school girls at younger ages is likely a reflection of how uncommon it is to be out of school in Mexico in 2015 at the youngest adolescent ages and, possibly, childbirth could be more commonly connected to dropout at these young ages than at older ages where many more girls are out of school for a variety of reasons.

The model also predicts a fascinating relationship between adolescent fertility and relative schooling position, which is depicted in Figure 4.3. As shown in the figure, if a girl's relative schooling

Figure 4.2: Predicted parity-specific municipal fertility probabilities according to actual municipal composition (unadjusted means) compared to equalised municipal composition (adjusted means)

position were to change while everything else about her remained unchanged (and was adjusted to the national average to equalize the population composition in municipalities), her likelihood of having experienced a birth would increase as the schooling profile of her peers improved.

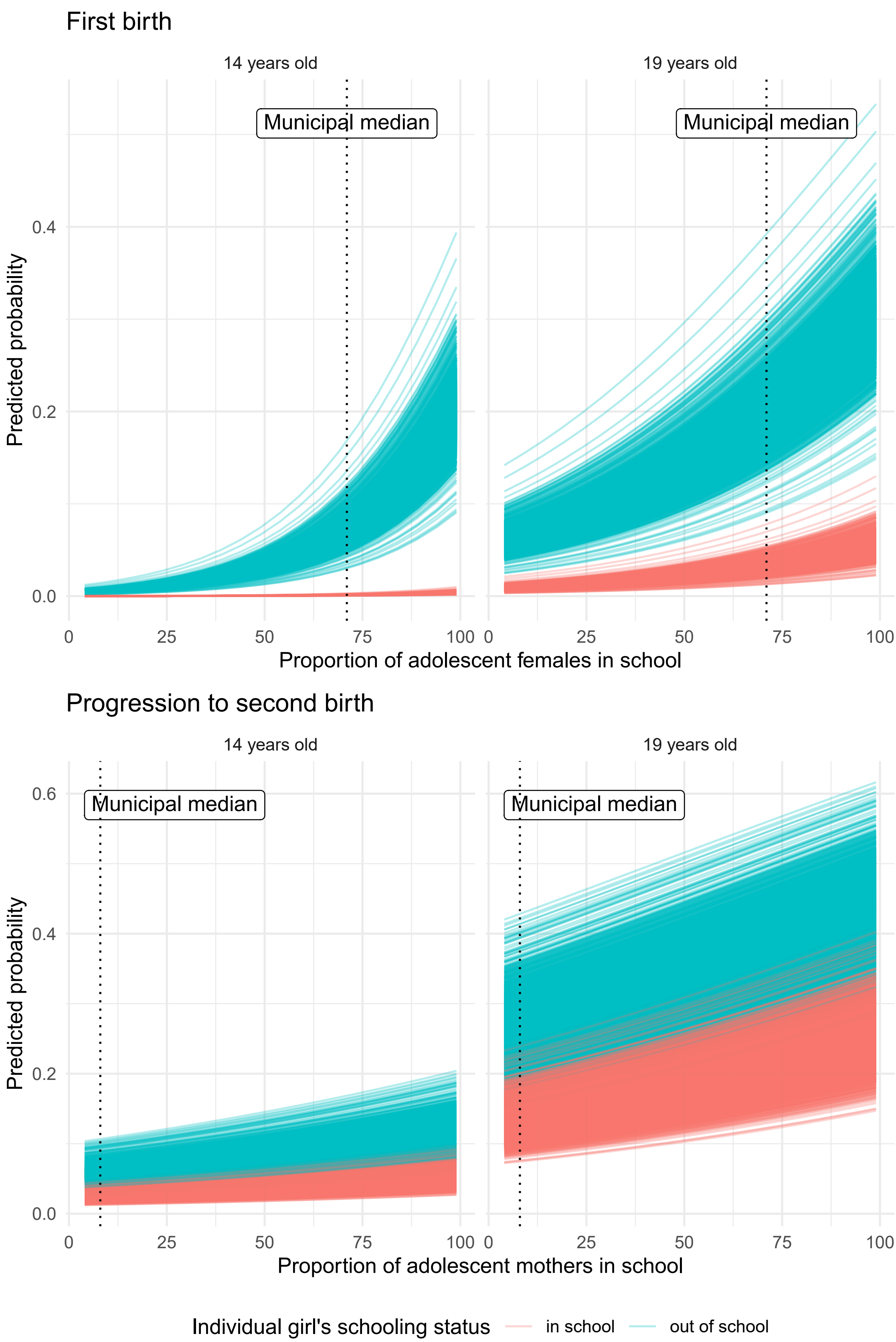
Additionally, relative schooling position matters much more for girls who are out of school than for girls who are in school. That is, the increase in the probability of adolescent fertility in moving from low levels of school enrolment to widespread school enrolment is greater for girls who are out of school than for girls who are in school. For example, a 19-year-old girl who is out of school when most other adolescent girls are also out of school—for example, when only a quarter of adolescents in her municipality are in school, all else remaining unchanged—would see a predicted probability of having experienced a birth in the last 15 months of between 0.04 and 0.20. If the same girl were to instead be out of school in when it is common to be in school—for example, when three quarters of her peers are in school, which is near the median for municipalities—her predicted probability would more than double, ranging between 0.10 and 0.41. Equivalently, a predicted 10% to 41% of 19-year-olds who are out of school, depending on the municipality, would have had a first birth in the past 15 months when three quarters of their peers were in school whereas a predicted 4% to 20% would have had a first birth when only a quarter of their peers were in school.

Even though a birth in early adolescence is very rare in the population as a whole, between 3% to 19% of 14-year-olds who are out of school in places where three quarters of adolescents are in school are predicted to have experienced an adolescent birth in the past 15 months. In places with lower enrolment, where only a quarter of adolescents are in school for example, between 0.4% to 3% of 14-year-olds who are out of school are predicted to have experienced a birth. Notice that the increase in probabilities for 19-year-olds doubled in moving from low enrolment to high enrolment positions while the same change for 14-year-olds saw a more than six-fold increase, all else remaining unchanged.

Conversely, both the probabilities and the increase in probabilities for girls who are in school is much less pronounced. For example, 0.5% to 3% of 19-year-olds who are in school when only a quarter of other adolescents in her municipality are in school would be predicted to have experienced a birth in the last 15 months. If the same girls were to instead be in school when three quarters of their peers are in school, between 1% and 8% of them would be predicted to have experienced a birth. Among 14-year-olds who are in school, a maximum of 0.04% are predicted to have given birth in contexts where a quarter of adolescents are in school, which increases to a maximum of 0.4% in contexts where three quarters of adolescents are in school, all else remaining unchanged.

The two subplots on the bottom row of Figure 4.3 depict the association between relative schooling position and probability of having progressed to a second birth in the previous 15 months among 14- and 19-year-old mothers, considering all else about her remains unchanged and municipal population compositions are equalised across all other characteristics. The probability of

Figure 4.3: Individual fertility probabilities for 14- and 19-year-olds by parity, individual schooling status and relative schooling position among peers



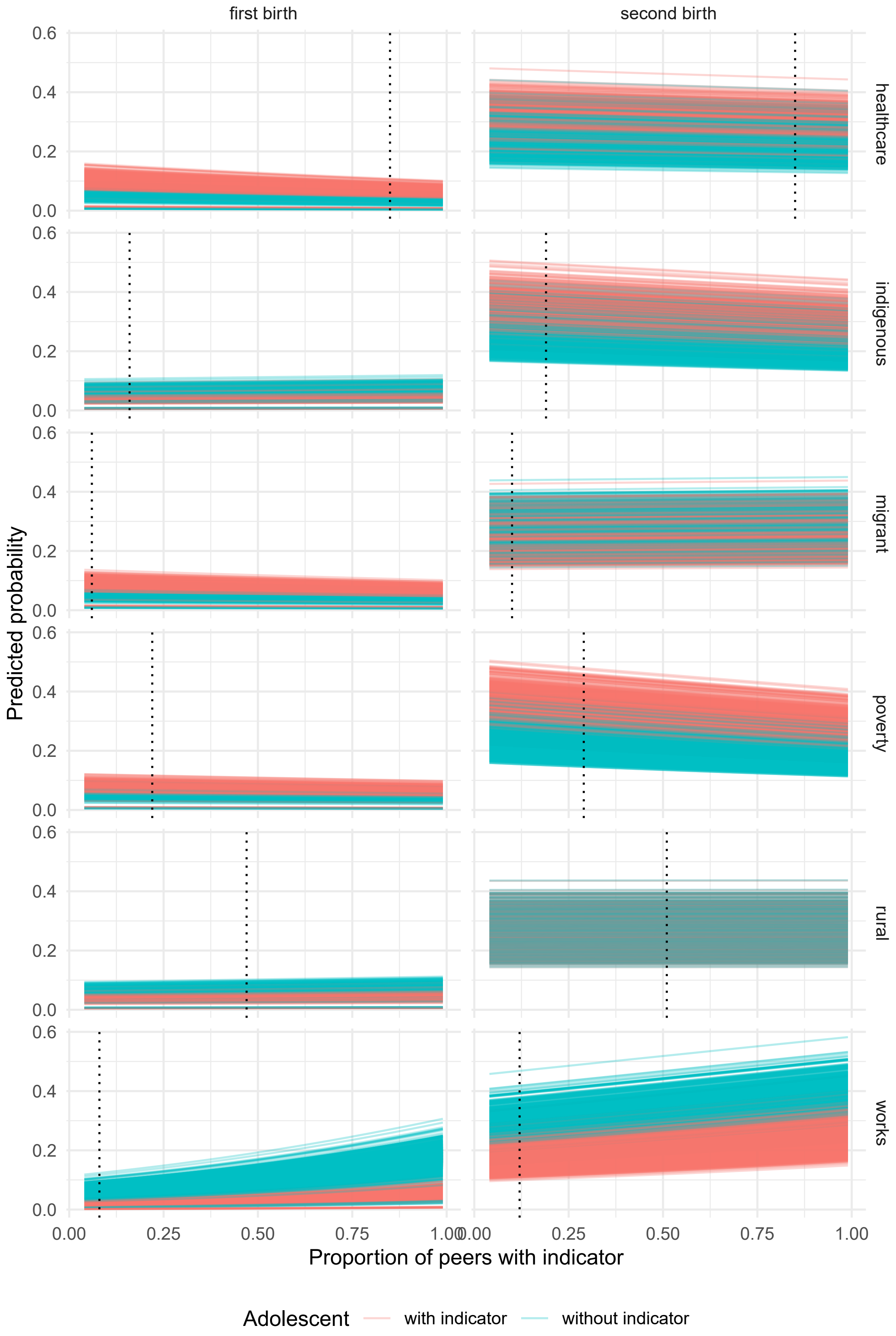
a second birth is higher at older ages in adolescence than it is at younger ages, as is seen in the higher intercepts for 19-year-olds than for 14-year-olds. Recall that an interaction between age and schooling status in the regressions for second births was estimated with too much uncertainty to justify its inclusion in the model. As such, the negative association between schooling status and fertility likelihood is estimated to be the same at all ages (has the same slope), rather than intensifying at younger ages as it did with first births. Additionally, the distinction between those in school and out of school is less pronounced than it was with first births, and the municipal differences are such that girls who are in school in a few municipalities see higher predicted probabilities than girls who are out of school in a handful of other municipalities, which was not the case for first births. Nevertheless, second births see the same curious pattern of increasing probabilities as the schooling profile of peers improves—just as was seen with first births. In this case, peers refers to adolescent mothers rather than all adolescents as it did for first births.

The figure is also important for depicting the considerable range in predicted probabilities across municipalities even when adjusted to equalize population composition, and, not least, how alarmingly high the probabilities of progression to second births among adolescent mothers can be in many municipalities. For example, the model predicts that between 5% and up to 17% of out-of-school 14-year-old mothers will have progressed to a second birth (if three quarters of her peers are in school), just as between 24% to 57% of out-of-school 19-year-old mothers would with three quarters of her peers in school. Otherwise, when one quarter of adolescent mothers are in school, between 3% and 12% of out-of-school 14-year-olds and 18% to 46% of out-of-school 19-year-old mothers are predicted to have progressed to a second birth in the previous 15 months.

For adolescent mothers in school, predicted probabilities are lower and the difference by relative schooling position is less extreme. The results suggest that between 1% and 6% of 14-year-olds are predicted to have progressed to second births when a quarter of their peers are in school while a slightly higher 2% to 8% are predicted to have done so in when three quarters of their peers are in school. For 19-year-old mothers, between 8% and 27% are predicted to have progressed to second births when a quarter of their peers are in school while 12% and 36% are predicted to have done so in when three quarters of their peers are in school, all else remaining unchanged. Note that it is actually quite uncommon for adolescent mothers to be in school: the municipal median is 8% of adolescent mothers of all adolescent ages are currently studying.

The other individual characteristics included in the models also produce noteworthy results. Figure 4.4 depicts the association of each characteristic with adolescent fertility among 19-year-olds. It shows the predicted probabilities of a first birth among a 19-year-old adolescent or progression to a second birth among a 19-year-old adolescent mother in the last 15 months when she has or does not have the specific characteristic while her relative position within her municipality changes, and considering all else about her remains unchanged and municipal population compositions are adjusted to equalize across all other characteristics. Each plot brings out two distinct

Figure 4.4: Individual fertility probabilities for 19-year-olds by parity, individual characteristics and relative position among peers



features of the association. First, whether having the characteristic is associated with a higher or lower likelihood of adolescent fertility for individual girls compared to not having the indicator. Put differently, whether a characteristic has a positive or negative relationship with adolescent fertility. Second, whether an individual adolescent's relative position matters. That is, whether individual probabilities would be predicted to change if more or fewer of the adolescent's peers also had the characteristic, all else remaining unchanged.

In looking at healthcare affiliation, the results suggest that adolescents who are affiliated with healthcare providers generally have higher probabilities of adolescent fertility than adolescents without healthcare affiliation. This is the case for both first births and progression to second births. The relative position of an adolescent's healthcare status matters only very slightly, but is interesting nonetheless. That is, if the prevalence of healthcare access among an adolescent's peers were to increase while all else remained unchanged, individual fertility likelihoods would diminish.

In looking at indigenous identity, the results indicate that the relationship is different at each parity. For first births, indigenous identity is generally associated with lower first birth probabilities than non-indigenous identity. However, if the proportion of peers in the municipality who are indigenous were to increase and all else remained unchanged, individual predicted probabilities would also increase, though the change is exceptionally slight. In contrast, for second births in adolescence, indigenous identity is associated with higher probabilities than non-indigenous identity. Meanwhile, if the concentration of indigenous peers in the municipality were to increase and all else remained unchanged, individual predicted probabilities for second births would decrease, which is also the opposite of what was seen with first births.

In looking at migrants, the results indicate that migration is associated with higher probabilities of a first birth in adolescence, but not higher probabilities of second births in adolescence. There is no statistical difference between migrant and non-migrant adolescents in their probabilities of second birth progression. However, the relative importance of migration suggests that if the proportions of migrants were to increase and all else remained the same, individual probabilities would diminish slightly for first births.

For poverty, the results indicate that poverty is associated with higher probabilities of adolescent fertility, for both first and second births. Additionally, the relative positioning suggests that as poverty becomes more prevalent, all else remaining unchanged, adolescent fertility probabilities diminish. The decrease is very slight for first births but is considerable for second births.

Rural residency is associated with lower first birth probabilities but there is no relationship between rural residency and second birth probabilities that can be measured with any certainty. Additionally, the relative concentration of rural residents in municipalities does not appear to matter for second birth probabilities, though it does for first births. As the proportion of the adolescent population that is rural increases, all else remaining unchanged, individual probabilities of first births in adolescence increases very slightly.

Finally, adolescents who work have lower fertility probabilities than adolescents who do not work, and this applies to both first births and second births. Additionally, the relative composition appears to make a comparatively large difference. For both first and second births, if the proportion of adolescents who work were to increase, all else remaining unchanged, fertility probabilities would also increase.

Importantly, none of these characteristics have as dramatic a relationship with adolescent fertility as does schooling—both in terms of higher or lower probabilities and change across relative position. Also, the salience of the characteristics are different for different parities. Apart from schooling, working status is most salient for first births while for second births, working status and poverty are most salient.

4.5.3 Model 3: Variation by age and schooling status

The previous model assumed that the magnitude of the association between *age* and *school* and adolescent fertility is similar in all municipalities. That is, the slope coefficient for *age* and *school* characterizes the relationship between adolescent fertility and age or schooling status in every municipality. However, this next step explores whether the association can differ across municipalities. It is possible that municipal context can modify the individual level association between *age* and *school* and adolescent fertility probabilities, resulting in different municipal slope coefficientss. For example, it is possible that contextual factors in some municipalities are such that the difference in probabilities of adolescent fertility is more similar across all adolescent ages than what has been estimated heretofore. In other words, probabilities at younger ages are higher in some municipalities than what would otherwise be predicted. It is also possible that municipal differences in adolescent fertility could see starker contrasts between those in and out of school or there could be greater municipal variability in adolescent fertility probabilities among very young adolescents. Importantly, these differences could exist even after equalising across observed characteristics (i.e., poverty, indigenous identity, migrant status, employment, healthcare access and rural residence) as a result of other unobserved characteristics.

A model that allows the regression coefficients for *age* and *school* to vary randomly at the municipal level explores these possibilities. It estimates whether there is a modification in individual level associations in age and schooling status, as well as differences in variability of adolescent fertility probabilities in these characteristics in municipalities. Table 4.3 presents the regression results. Likelihood ratio tests confirm that the model with random slopes for *age* and *school* offers a better fit for first births but not for second births.

The second-birth regression with random slopes is shown for illustrative purposes only and Model 2 remains the preferred model over Model 3. According to Model 2, the estimated variance partition coefficient for progression to second births remains at 0.03 (or 3% of the individual differences in

	Model 3			
	First births		Second birth Progression	
	Regression Coefficeint	(standard error)	Regression Coefficeint	(standard error)
Fixed part				
Intercept	-4.860	(0.017)***	-2.419	(0.014)***
age	0.549	(0.005)***	0.369	(0.011)***
school	-3.638	(0.023)***	-0.872	(0.059)***
poverty	0.248	(0.010)***	0.409	(0.019)***
indigenous	-0.148	(0.018)***	0.270	(0.038)***
migrant	0.354	(0.014)***	-0.048	(0.031)
works	-1.261	(0.014)***	-0.528	(0.031)***
healthcare	0.547	(0.012)***	0.159	(0.026)***
rural	-0.205	(0.011)***	-0.004	(0.023)
age_school	0.439	(0.008)***		
	Variance	(standard deviation)	Variance	(standard deviation)
Random part				
Intercept	0.171	(0.41)	0.103	(0.321)
age	0.0006	(0.02)	0.002	(0.041)
school	0.107	(0.33)	0.027	(0.016)
Observations	1,762,920		153,768	
Log Likelihood	-218,571		-47,623	

Note:
Model 3 for second birth progression is shown for illustrative purposes only as testing indicates that Model 2 is preferred.
*** p-value < 0.0001

Table 4.4: Model 3 Regression Results

the progression likelihood are at the municipal level), no matter where an adolescent lives, how old she is, or whether she is in school or not. Again, when translated to median odds ratio, the model implies that if any girl were to move from one random area to another random area with higher risk, her odds of progressing to a second adolescent birth would increase by 35% simply by virtue of the context of the place she is living and no other change in her personal characteristics.

In looking at first births, the regression coefficients for the fixed effects remain almost unchanged, but the new coefficients for the random variables mean that the relationship between *age* and *school* and adolescent first births is not identical across all municipalities but varies. In contrast to second births, for first births, the results indicate that contextual influence differs dramatically in magnitude depending on how old a girl is and whether she is in school or not.

Figure 4.5 depicts how the estimated variance partition coefficient and median odds ratio differ across the age schedule and according to schooling status and relative schooling position. Recall that Model 2 indicated that only 1.6% of individual differences in adolescent first birth probabilities were at the municipal level and her odds of experiencing an adolescent birth increasing by 24% in moving from one random area to another with higher risk. Under Model 3, the importance of context is different for all three conditions (that is, her age, her schooling status and her relative schooling position). Under Model 3, context matters more at younger ages than it does at older ages, it matters more for girls who are in school than it does for girls who are out of school, and it matters more in contexts with lower levels of school enrolment than in contexts with higher levels of school enrolment. For example, up to a predicted 14% of individual differences in adolescent fertility risk are due to municipal context for girls among whom context matters most: 12-year-olds that are in school in municipalities where few adolescents are in school. This translates to her odds of fertility nearly doubling if she were to move from any random municipality to another random municipality with higher risk. In contrast, for the girls for whom context matters least (19-year-olds that are out of school in municipalities where most adolescents are in school), only 1% of individual differences in adolescent fertility risk are due to municipal context. This translates to her odds of fertility increasing by 18% if she were to move from one random municipality to another with higher risk.

Figure 4.5: Estimated variance partition coefficients and median odds ratios (measures of the importance of contextual phenomena), as predicted under Model 3

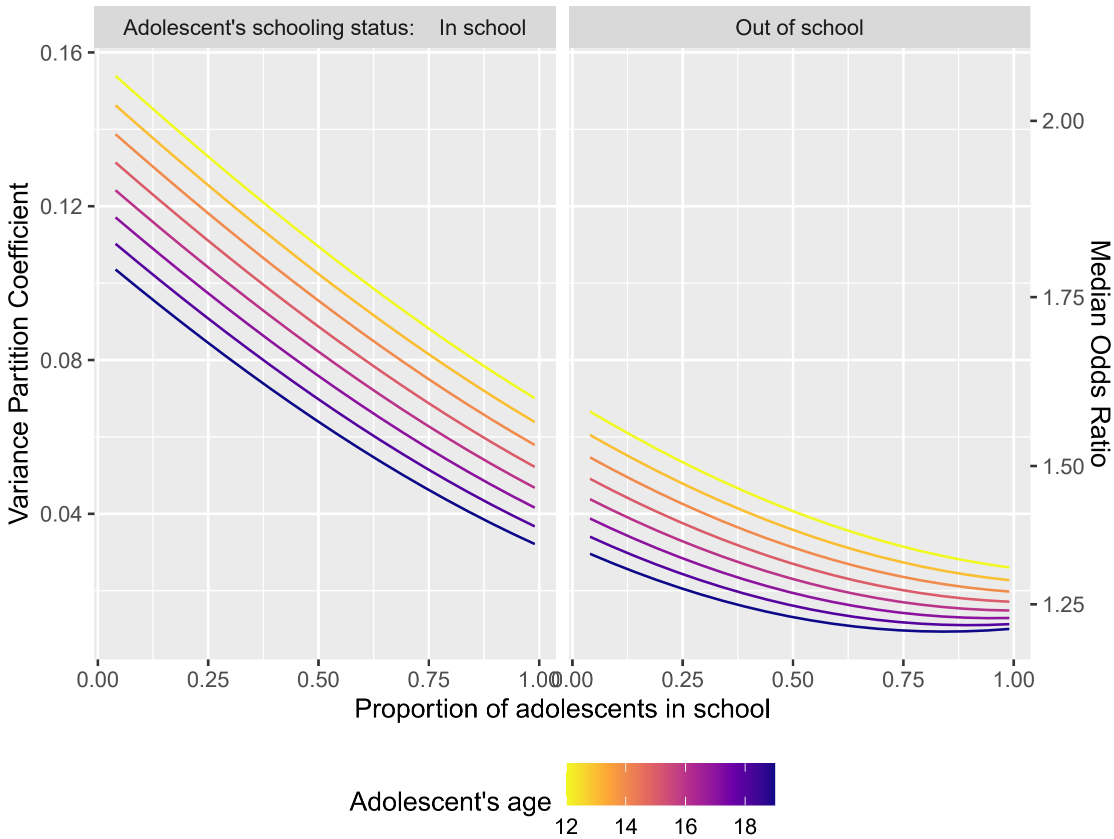


Figure 4.6 updates the predicted probabilities of a first adolescent birth to better show how the variance plays out in the model estimates. The lines in colour are the predicted probabilities under Model 3 while the black lines depict the maximum and minimum values from Model 2 (a repeat of the estimates shown in Figure 4.2). Note that under Model 2, the slopes across all municipalities are identical so that the maximum values come from one single municipality while the minimum values come from another single municipality. Under model 3, municipal slopes are distinct and as such, a collection of different municipalities see the highest and lowest values at the different ages, among those in and out of school, and across relative schooling positions.

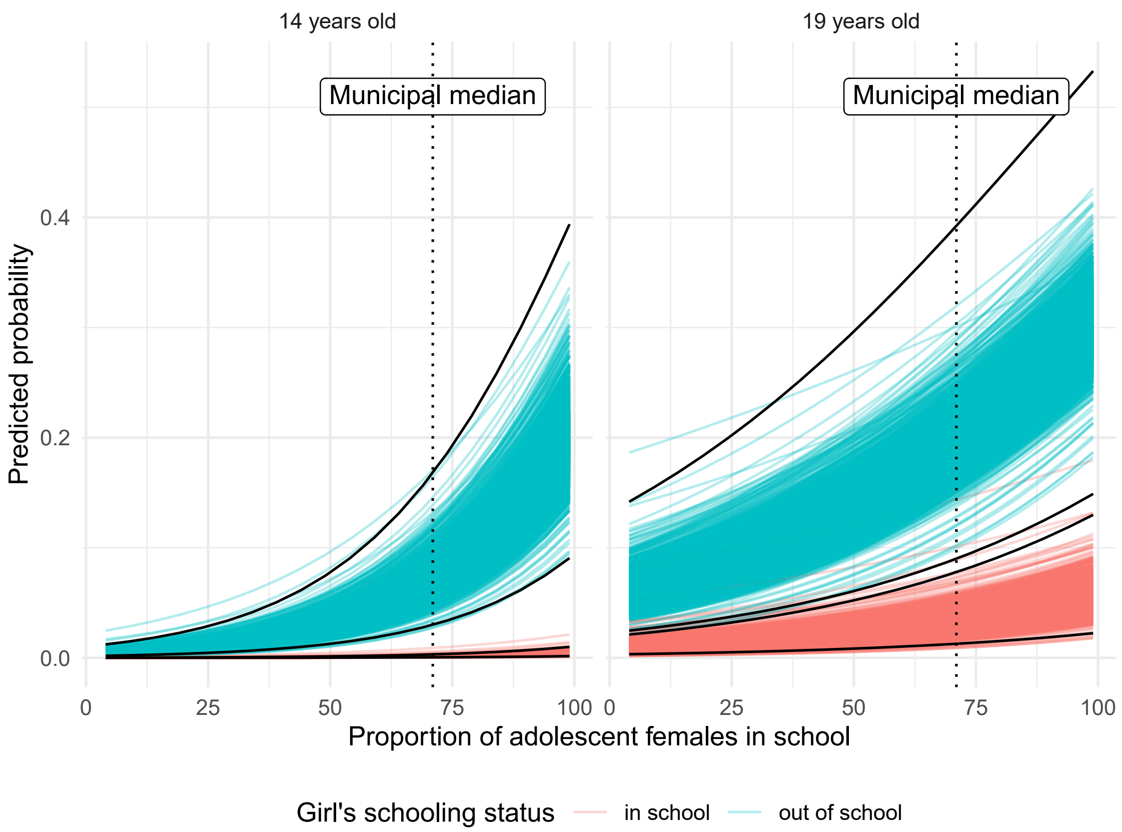
In essence, Model 3 updates the range in predicted probabilities over what was estimated under Model 2. There is generally little change in the estimated range of the predicted probabilities for the middle half of municipalities (as well as the median values), but predicted probabilities in municipalities at the extremes do change. For the most part, the range in predicted probabilities increases under Model 3 as compared to Model 2, increasing by between 5% (among older adolescents who are out of school in low enrolment settings who see a maximum predicted probability of 0.20 in Model 2 and 0.21 in Model 3) and up to 500% higher (among younger adolescents who are in school in low enrolment settings who see a maximum predicted probability of 0.004 in model 2 and 0.02 in model 3). The increase in the range of predicted probabilities is greater at younger ages than at older ages, greater among girls who are in school compared to girls who are out of school, and greater in settings with low enrolment compared to settings with widespread enrolment, which corresponds with where context matters most.

Nevertheless, the range in predicted probability actually diminished for girls who are out of school in high enrolment settings, particularly at older ages. For example, under Model 2, up to 41% of 19-year-olds who are out of school when three quarters of their peers are in school have had a first birth in the previous 15 months. Under Model 3, this is lower, with up to 33% of girls with similar profiles being predicted to have experienced a first birth. For 14-year-olds, the proportion becomes 18% under Model 3 instead of 19% seen under Model 2.

Ultimately, to understand the substantive importance of the updated predicted probabilities from Model 3, it is critical to relate them to the findings about the differentiated relevance of context. Under Model 3, context matters more at younger ages than it does at older ages, it matters more for girls who are in school than it does for girls who are out of school, and it matters more in contexts with limited school enrolment compared to contexts with widespread enrolment. However, the predicted probabilities are lower at younger ages than at older ages, for girls who are in school compared to girls who are out of school, and in contexts with more limited school enrolment. As such, the changes must be understood in relative terms. For example, fertility probabilities are lowest at the youngest adolescent ages but because context matters most at the youngest ages, the proportional change (but not absolute change) in probabilities resulting from the updated variance estimates is greater than that at older ages.

Importantly, the overarching trends already seen in Model 2 remain unchanged. That is, the likelihood of having had a first birth in adolescence increases with age, and girls who are in school have a lower incidence of fertility than girls who have left school. Additionally, if a girl's relative schooling position were to change while everything else about her remained unchanged (and was adjusted to the national average to equalize the population composition in municipalities), her likelihood of having experienced a birth would increase as the schooling profile of her peers improved.

Figure 4.6: First birth fertility probabilities for 14- and 19-year-olds by schooling status, as predicted under Model 3 (in color) compared to Model 2 (black lines)



4.5.4 Model 4: Influence of peers' adolescent fertility across the adolescent age schedule

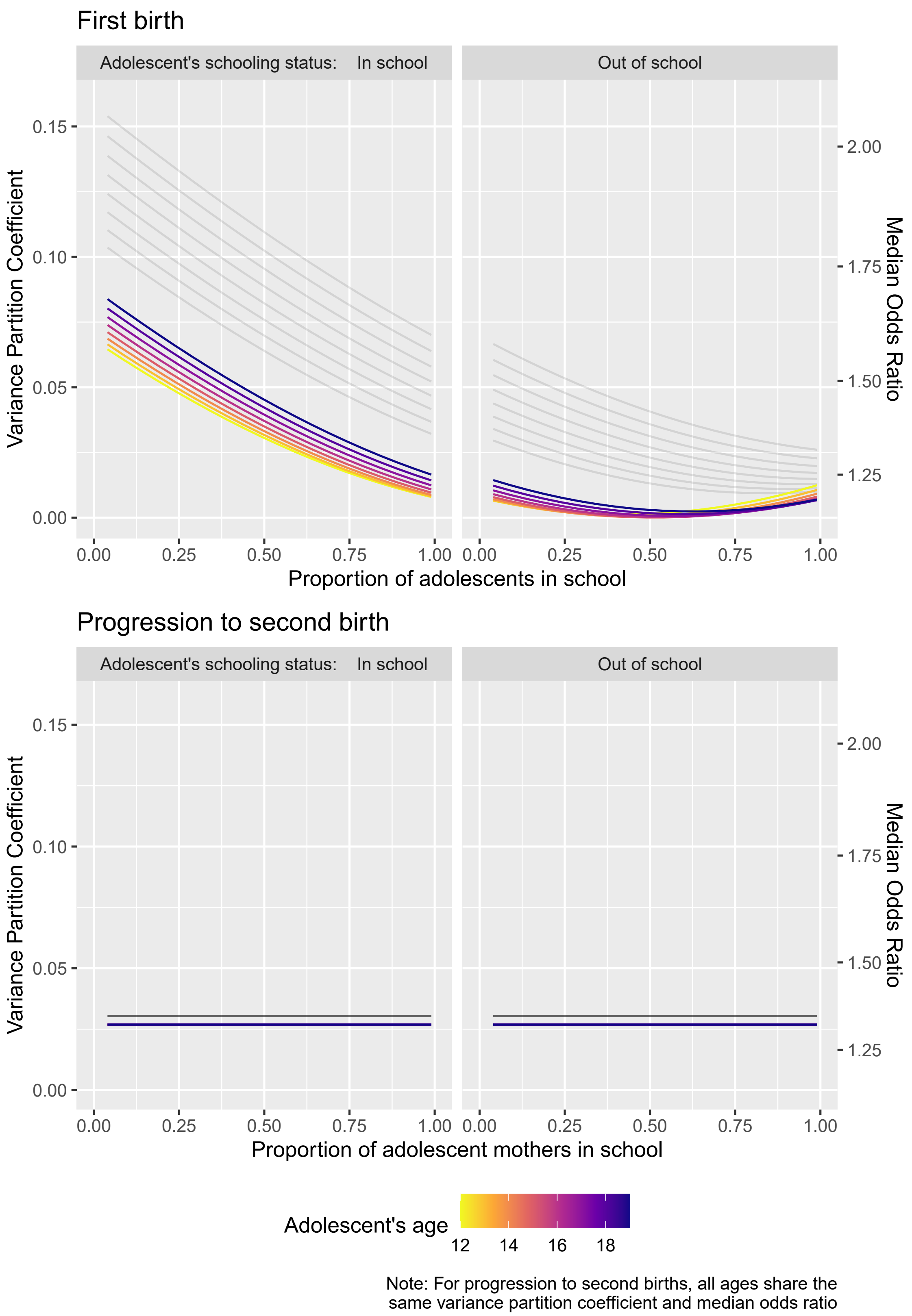
After finding that the influence of contextual phenomena differs for girls at different ages and by schooling status in individual childbearing probabilities for first births (but not necessarily for progression to second births), a final step of the study is to explore whether aggregate levels of adolescent childbearing form a quantifiable part of municipalities' contextual phenomena. That is, whether the fertility patterns of an adolescent's peers have an independent association with a girl's own individual likelihood of giving birth in adolescence. Additionally, it is worth exploring whether the influence of aggregate adolescent fertility patterns differ in magnitude at different adolescent ages.

A model that includes a measure of the proportion of adolescents with a first birth in each municipality *birth1* and an interaction between age and municipal first adolescent birth proportions *age_birth1* explores these possibilities. Table 4.5 presents the regression results. Likelihood ratio tests confirm that the model with peer fertility context, *birth1*, offers a better fit for both first and second birth regressions, while the interaction effect *age_birth1* offers a better fit for first births but not second births. That is, there is indeed an independent association between the adolescent fertility of a girl's peers and her own individual likelihood of giving birth in adolescence. For first births, the magnitude of the association differs across the adolescent age schedule with the model's negative coefficient for *age_birth1* implying that the importance of fertility context attenuates somewhat more at the oldest adolescent ages than what would otherwise be predicted.

The inclusion of the municipal-level adolescent fertility measure yields very little change in the coefficients for the fixed effects of the individual factors, which means that their interpretation, as seen in previous models, remains effectively unchanged. However, two dramatic changes arise related to the coefficients for the variance components and the municipal levels of adolescent childbearing. First, the unexplained variance is reduced compared to previous models and second, individual fertility likelihoods change dramatically depending on the prevalence of adolescent childbearing in municipalities. Figure 4.7 shows the change in variance in terms of the variance partition coefficients and median odds ratios.

The change in the variance for second births is straightforward and fairly limited. Recall that for progression to second births, the importance of context is the same for all girls, no matter her age or schooling status. In previous models without the municipal levels of adolescent first births, the variance partition coefficient indicated that 3.0% of the total individual differences in likelihood of progressing to a second adolescent birth was at the municipal level. Equivalently, an adolescent mother's odds of progressing to a second birth would increase by 35% if she were to move from one random municipality to another random municipality with no other change in her individual characteristics. After accounting for municipal levels of adolescent fertility, total

Figure 4.7: Estimated variance partition coefficients and median odds ratios (measures of the importance of contextual phenomena), as predicted under Model 4 (in color) as compared to Model 3 (in grey)



	Model 4			
	First births		Progression to second birth	
	Regression Coefficeint	(standard error)	Regression Coefficeint	(standard error)
Fixed part: Individual factors				
Intercept	-4.856	(0.015)***	-2.431	(0.013)***
age	0.549	(0.005)***	0.368	(0.009)***
school	-3.617	(0.023)***	-0.844	(0.046)***
poverty	0.248	(0.010)***	0.407	(0.019)***
indigenous	-0.143	(0.018)***	0.270	(0.038)***
migrant	0.360	(0.014)***	-0.047	(0.038)
works	-1.245	(0.014)***	-0.530	(0.031)***
healthcare	0.548	(0.012)***	0.159	(0.026)***
rural	-0.201	(0.011)***	-0.004	(0.023)
age_school	0.435	(0.008)***		
Fixed part: Municipal factors				
birth1	12.017	(0.145)***	3.688	(0.457)***
age_birth1	-1.170	(0.076)***		
	Variance	(standard deviation)	Variance	(standard deviation)
Random part				
Intercept	0.032	(0.18)	0.091	(0.30)
age	0.0006	(0.02)		
school	0.116	(0.34)		
Observations	1,762,920		153,768	
Log Likelihood	-217,486		-47,595	

Note:
*** p-value < 0.0001

Table 4.5: Model 4 Regression Results

individual difference in the likelihood of progressing to second births reduces to 2.7% and the median odds ratio reduces to 33%. The reduction in variance that occurs after accounting for municipal levels of first adolescent births suggests that the fertility patterns (at least the levels of first births) of an adolescent mother's peers has an independent, albeit limited, association with a girl's own individual likelihood of progressing to a second birth in adolescence. The influence is constant across all adolescent ages.

In contrast, the change in the variance for first adolescent births is considerable and quite dynamic. Recall that for first births in adolescence, contextual phenomena matter more at younger ages than at older ages and matter more for girls who are in school compared to girls who are out of school, with, depending on the girls' age and schooling status, between 1% and 14% of individual differences in fertility risk being due to municipal context. After accounting for municipal levels of adolescent first births, the importance of context reduces substantially, with, depending on the girls' age and schooling status, between 0% and 7% of individual differences in fertility risk being due to the remaining unexplained aspects of municipal context.

Interestingly, the reduction in the importance of context is greater the younger the age to such an extent that, at least among girls in school, trends completely reverse. That is, after accounting for the influence of the broader fertility trends of an adolescent's peers, the remaining unexplained contextual phenomena matter more at older ages than at younger ages. Put differently, among girls in school, the fertility context of a municipality matters more for the individual fertility likelihoods of the youngest girls compared to the oldest girls. For example, before accounting for the peer influence of fertility, the individual fertility likelihood of a 12-year-old girl in school in a place where almost none of her peers were in school would nearly double if she were to move from one random municipality to another with no other change to her personal characteristics. After accounting for the peer influence of fertility, the 12-year-old student's likelihood would instead increase by a little more than 50% in moving to a place with similar fertility context. For a 19-year-old in the same situation, the increase in her likelihood with such a move between random municipalities changes from 71% (before accounting for the peer influence of fertility) to 69% (after accounting for the peer influence of fertility)—a much more modest adjustment. Otherwise, among girls in school, the pattern seen earlier with regard to a girl's relative schooling position repeats itself. That is, the remaining unexplained contextual phenomena matter most in situations where a smaller proportion of a girl's peers are in school and context diminishes progressively in importance as the proportion of a girl's peers who are in school increases.

Among girls who are out of school, the picture changes yet again. The reversal in the importance of context by age seen among girls enrolled in school holds only in situations where a lower proportion of a girl's peers are in school. However, as the proportion of adolescents who are in school improves, peer fertility influence matters most among the oldest out-of-school adolescents while other unexplained contextual phenomena matter more among the youngest out-of-school adolescents. Importantly, the influence of peer fertility patterns accounts for nearly all of the contextual phenomena among out-of-school adolescents in situations where between a third to two thirds of all adolescents are in school.

For example, whereas under previous models that did not account for the influence of peer fertility, a girl's individual likelihood of having had a first birth would increase by between 22% to 43% (depending on her age) if she were to move from one random municipality to another in situations where a girl is out of school while half of all her peers are in school. In contrast, after accounting for the influence of peer fertility, the same girls' individual likelihoods would increase by, at a maximum, 0.3%. In essence, the pattern seen earlier with regard to a girl's relative schooling position does not repeat itself. That is, there is not necessarily a decline in importance of context as the proportion of girls who are enrolled in school improves. After accounting for peer fertility influence, at least among the youngest adolescents, the influence of remaining unexplained contextual phenomena matters more in situations with high peer enrolment than it does in situations with low levels of school enrolment. After accounting for peer fertility influence among the oldest adolescents, unexplained contextual phenomena remain more important in lower enrolment situations.

Not only does the variance change with the inclusion of the municipal-level adolescent fertility measure, but individual fertility likelihoods change dramatically depending on the levels of aggregate adolescent childbearing in municipalities. Figure 4.8 shows the individual age-specific fertility likelihoods with and without fertility context for a municipality at the national average (with intercept β_0 and without any municipal-specific random effect u_{0j}). The age-specific likelihoods without fertility context are those predicted under Model 2 and those with fertility context are those predicted the current Model 4. In the figure, fertility context is shown up to a maximum of 20% of peers with a first birth because no municipalities in the data saw a higher proportion of adolescents with a first birth.

According to the figure, after taking fertility context into account, an adolescent's individual likelihood of having given birth increases as the proportion of her peers with a birth increases. For instance, two 19-year-olds with identical individual characteristics but one living in a context where no adolescents have given birth and another living in a context where 20% of adolescent have given see a nearly five-fold difference in their probabilities of having experienced a first birth. (In the no-fertility context, a 19-year-old has a predicted probability of 0.027 and in the high-fertility context, a 19-year-old has a predicted probability of 0.125 of having had a first birth.) Although predicted probabilities are lower at younger ages than they are at higher ages, the difference by context is greater among younger adolescents than among older adolescents. For two 14-year-olds, there would be an eighteen-fold different in their fertility probabilities in no-fertility context compared to high-fertility contexts. (In a context where no adolescents have given birth, a 14-year-old has a predicted probability of 0.001 while in a context where 20% of adolescent have given birth, a 14-year-old has a 0.018 predicted probability of a first birth.)

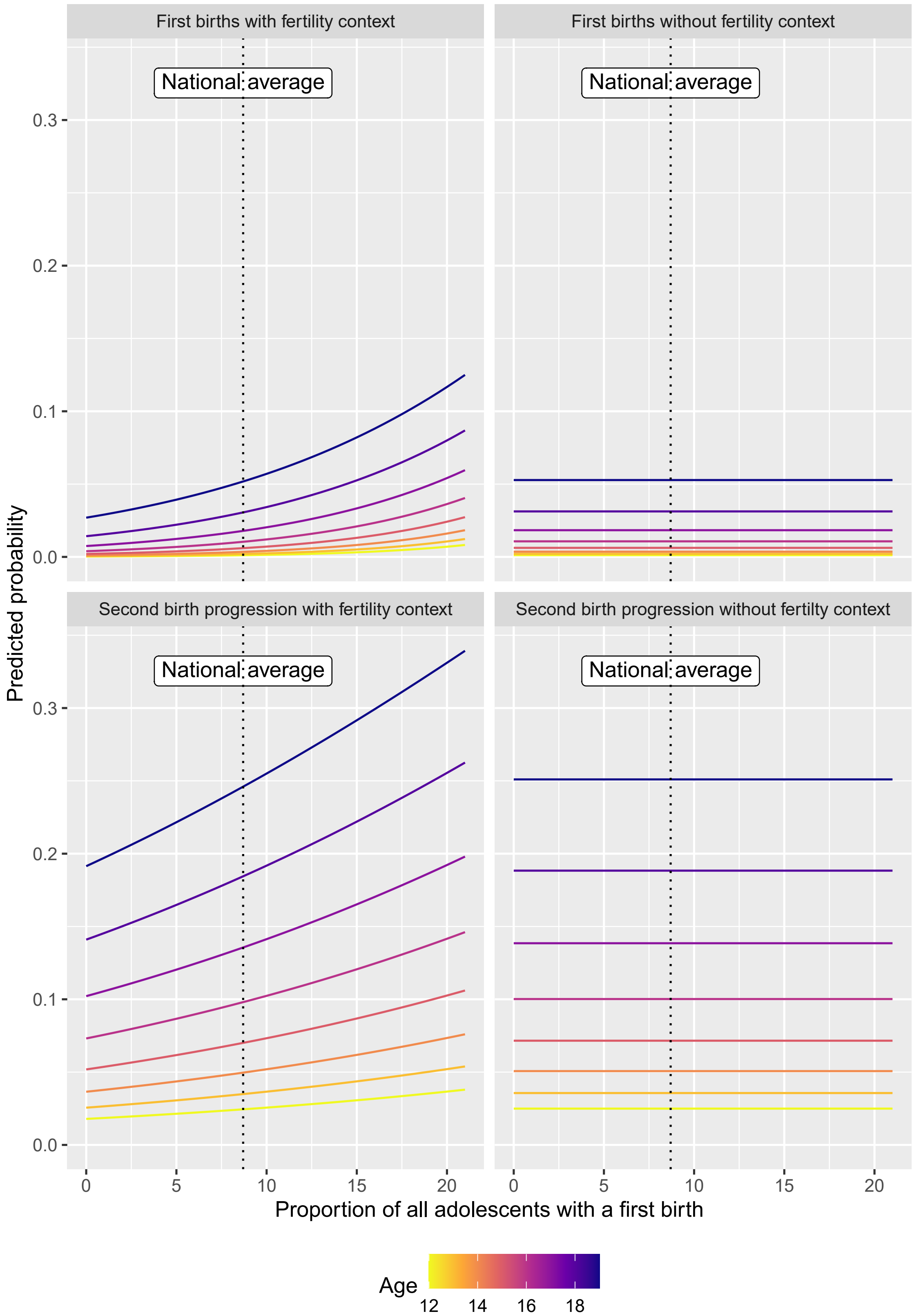
The importance of context for progression to second births as also dramatic. Because the age-specific predicted probabilities are higher for progression to second births than they are for first births, the change across fertility context is greater in absolute terms, but not relative terms. For example, a 19-year-old mother in a no-fertility context, has a predicted probability of progressing to a second birth of 0.191 while in a high-fertility context she has a probability of 0.339, which represents a nearly two-fold increase. Meanwhile, a 14-year-old mother in a no-fertility context has a predicted probability of having progressed to a second birth of 0.037 while in a high-fertility context she has a probability of 0.076, which represents a slightly more than two-fold increase.

Ultimately, the influence of the fertility patterns of peers on an individual girl's likelihood of adolescent childbearing cannot be overstated. A high proportion of adolescents who have entered motherhood in municipalities makes a multiplicative difference in the risk of individual girls experiencing motherhood before the age of twenty.

4.6 Discussion

The multilevel regression models have revealed considerable nuance in the ways that individual characteristics and contextual phenomena are related to adolescent fertility in Mexico. The following paragraphs summarize the most noteworthy lessons as well as connect the findings to the

Figure 4.8: Individual adolescent fertility probabilities by age and municipal fertility context, as predicted under Model 4 compared to Model 3



Note: Probabilities with fertility context are those as predicted under Model 4 and those without fertility context are those as predicted under Model 3 broader picture of developmental differences and issues of restricted agency across the adolescent age schedule.

While individual factors consistently account for the bulk of adolescent fertility risk, the findings reveal that the magnitude of contextual influence varies dramatically among different groups of girls. That is, the findings reveal that the key to context is understanding that context matters differently for different groups of girls. For example, initial models suggest that only about 2% to 3% of individual differences in the likelihood of adolescent first and second births, respectively, are at the municipal level. However, subsequent models finds that the influence of context differs dramatically across the age schedule and by schooling status. For example, context accounts for 14% of the difference in individual first birth risk among the youngest adolescents who are in school while it accounts for only 1% of the difference among the oldest adolescents who are out of school.

For a girl's likelihood of both entering motherhood in adolescence and progressing to a second birth in adolescence, school enrolment status emerged as the far most salient individual characteristic analysed. While it was expected that girls who were out of school had higher likelihoods of adolescent fertility than girls who were in school, the degree of the difference by schooling status was impressive. In the first birth analysis particularly, the magnitude of the coefficient was dramatically larger than any other characteristic, meaning that the differences in fertility probabilities between girls who were and were not in school were far more extreme than differences in any other variable. Specifically, controlling for all other variables, a girl in school was 97% less likely to have experienced a first adolescent birth compared to being out of school. For second births, the differences were less extreme but schooling status still saw larger differences than any other characteristic. Specifically, an adolescent mother in school was 57% less likely to have progressed to a second birth compared to being out of school.

Work activity emerged as the second most salient characteristic for adolescent fertility probabilities, both for first and second births. Existing research offered mixed predictions for how labour force participation might be related to adolescent fertility, but this study saw a strong and clear association: like school enrolment, girls who were not working had higher likelihoods of adolescent fertility than girls who were working. For first births, a girl who was working was 72% less likely to have experienced an adolescent birth, and for second births, an adolescent mother who was working was 41% less likely to have experienced a second adolescent birth compared to not working. This aligns well with the theoretical underpinnings of the enrolment and aspirational effects of schooling in causal-effect literature. For enrolment, the time girls spend enrolled and present in school reduces the time they have available for social and romantic interactions (Angrist et al. 2002; Baird et al. 2010; Duflo, Dupas, and Kremer 2015; Geruso and Royer 2018; Grönqvist and Hall 2013; Gulemetova-Swan 2009; Ibarraran et al. 2014; Kalamar, Lee-Rife, and Hindin 2016; Kruger and Berthelon 2009, 2009; Monstad, Propper, and Salvanes 2008; Novella and Ripani 2016; Silles 2011). Regarding aspirations, schooling seems to induce life aspirations that extend beyond motherhood alone and thus delay childbearing (Baird et al. 2010; Black, Devereux, and Salvanes 2008; Cygan-Rehm and Maeder 2013; Duflo, Dupas, and Kremer 2015; Kalamar, Lee-Rife, and Hindin 2016; Mason-Jones et al. 2016; Monstad, Propper, and Salvanes 2008).

It is not possible for this regression analysis to speak to causal effects, but only associative patterns, because the timing of events is not disentangled. Nevertheless, the association between work and adolescent fertility in this study is similar to the association between schooling and adolescent fertility—those who work have lower adolescent fertility probabilities. Like girls who are in school, girls who work may well see similar limits to their time for romantic relationships or parenting of a second child. The association also speaks to potential aspirational differences. Girls who pursue work activity once they have left school likely aspire to different life trajectories than girls who do not pursue employment after school. Because work status is comparatively more salient for second births than it is for first births—in that the magnitude of the association between work status is closer to that of school enrolment—and slightly more adolescent mothers work than are in school, the aspirational differences may be particularly important for second births. That is, strong gender norms in Mexico contribute to low female labour force participation (Safa 1995), and as such, employment among adolescent mothers goes against prevailing attitudes. Because employment among adolescents and adolescent mothers is related to lower fertility probabilities, it possible that labour force participation reflects life aspirations beyond motherhood whereas the opposite (higher fertility probabilities among girls who work) might be more indicative of heightened financial pressures from motherhood.

While poverty was also salient for the occurrence of second births, it was much less important for the occurrence of first births in adolescence. Nevertheless, in both cases, it demonstrated the expected association: girls who were poor had higher likelihoods of adolescent fertility than girls who were not poor.

To summarize, for first births, school enrolment and work status were definitive for a girl's probability of entering motherhood—school enrolment more so than work status, but the two operated in the same direction. Being in school or working was related to much lower likelihoods of adolescent fertility across the age schedule. In the population, many more girls are in school than are working, meaning that there is much more room for expanding labour force participation than there is school enrolment. Because there are many more long-standing national programs that exist to keep girls in school than exist to encourage their employment, expanding appropriate adolescent employment opportunities in the country could bring comparatively easy gains. Of course, it is vital that adolescent employment is not exploitative but rather builds skills, capacities and experience in safe and empowering environments.

For second births, the defining characteristics are school enrolment, work status and poverty.

While first births saw a considerable gulf between the magnitude of the associations between enrolment and work, and the three defining variables for second births are much closer in the magnitude of their association (though school enrolment still dominates). Additionally, in the population, a much higher proportion of adolescent mothers are poor than are working or in school. This speaks to other literature that finds that adolescent mothers from low socio-economic strata, who also have smaller financial and emotional support networks, are more likely to be in a union than girls from better-off strata whose larger support networks make it easier for them to work or return to school (Esteve, García-Román, and Lesthaeghe 2012).

Not only did the direction of the association between adolescent fertility and school enrolment, work status and poverty matter, but a girl's position relative to her peers also made a dramatic difference for her fertility likelihood. In all three characteristics, the models suggested there existed something of a desperation effect or increasing marginalisation. Disadvantage, as manifest by higher adolescent fertility probabilities, became more extreme when it was comparatively uncommon for a girl to experience deprivation. That is, when a girl was in a position of deprivation in a place where most of her peers were not similarly disadvantaged, the underprivileged girl's predicted likelihood of adolescent fertility was higher than if she lived in a place where most of her peers were like her. For instance, the likelihood of fertility for a girl who was out of school in places where most girls were in school was multiplicatively higher than for a girl who was out of school in places where most other girls were also out of school. Girls who do not work in places where lots of girls work also have higher adolescent fertility than girls who do not work in places where few girls work. Likewise, girls in poverty in places where there is little poverty see much higher fertility likelihoods than poor girls in places with widespread poverty, all else equal.

On the other hand, however, the desperation metaphor is inadequate because the converse of the patterns are also true. That is, privilege also becomes less advantageous in situations where deprivation is uncommon. For example, girls who are in school in places where most adolescents are also in school, have higher probabilities of fertility than girls who are in school in places where it is uncommon. Likewise, girls who work in places where it is common to work have higher adolescent fertility than girls who work in places where it is uncommon. And girls who are not poor in places where most adolescents are also not poor have higher fertility than girls who are not poor in places where most adolescents are poor. Here again, it is critical to emphasize that this analysis cannot disentangle the timing of events, so a wide variety of explanations could be responsible for the patterns. For instance, rather than high-enrolment contexts leading to more adolescent births among in-school youth, it may simply be that it is easier for adolescent mothers to stay in school or return to studying in places where it is more normative for girls to stay in school longer. The same for labour force participation. In places where it is more normative for an adolescent to work, or perhaps where employment opportunities are more abundant, it is easier for adolescent mothers to work.

The other individual characteristics explored were rather less salient for differences in adolescent fertility likelihoods, but produced a number of interesting findings nevertheless. Previous research offered mixed messages about what the direction of the association might be for healthcare access, indigenous identity, migrant status and rural residency. In this study, those with access to healthcare had higher probabilities of first and second births, which is ultimately not surprising given that underage mothers qualify for free public healthcare simply because of their pregnancy status (Gobierno de México 2022)—though it is unclear how many adolescent mothers in the country have access directly because of their maternity. Critically, more expansive healthcare access in the population was associated with slightly lower adolescent fertility probabilities. This is encouraging for the strategies that argue for the expansion of healthcare access among adolescents. Additionally, healthcare was the only variable of those studied that speaks to the idea of a protective effect where adolescents, whether they have access individually or not, had slightly lower fertility probabilities in areas where healthcare access was widespread compared to areas where healthcare was more limited.

Indigenous identity is particularly interesting because the direction of the association differs for first and second births. When controlling for other socio-economic characteristics, girls who identified as ethnically or linguistically indigenous had lower probabilities of entering motherhood in adolescence than girls who were not indigenous. In contrast, indigenous girls had higher probabilities of progressing to second adolescent births than non-indigenous girls with equivalent socio-economic profiles. It is possible that indigenous populations have stronger cultural proscriptions against sex outside of unions (leading to a slightly lower incidence of first births than among comparable non-indigenous populations), while a higher incidence of more formal unions among indigenous youth increases the risk of addition childbearing in adolescence among indigenous adolescent mothers than non-indigenous adolescent mothers.

Finally, the analysis found that migratory history and rural residency mattered for patterns of first births but not for second births. Specifically, migrant adolescents had higher probabilities of adolescent fertility than non-migrants while rural adolescents had lower probabilities of adolescent fertility than urban residents when controlling for the other socio-economic characteristics (such as school enrolment, work status and poverty levels). Additionally, the concentration of migrant, rural, and indigenous populations matters very little for adolescent fertility likelihoods. That is, one's relative position in the population in terms of migration, rurality, and indigenous identity hardly mattered.

Now, to turn to the findings about the presence of contextual phenomena in adolescent fertility patterns. Neuroscience and psychology find considerable evidence that peer influence and context matter for adolescent behaviour (Baird et al. 2021). Importantly, research finds considerable age differences that suggest that the impact of peer influence and context is likely to differ across the age schedule. For example, early adolescence marks an abrupt reorientation of the brain to social and emotional development, with a preference for short-term rewards being greatest at this stage (Steinberg 2008). Mid adolescence sees life peaks in aspects such as reward sensitivity, sensation seeking and risk propensity (Steinberg 2008; Steinberg et al. 2008). While cognitive capacity is also highly developed by mid adolescence, the decision-making process is highly contingent on context, particularly the presence of peers (Crone and Dahl 2012; Landsford et al. 2021). Finally, while late adolescence sees greater skill in future planning, impulse control and self-regulation alongside a slight reduction in risk propensity, real world opportunities for risky behaviour increase (Baird et al. 2021; Icenogle et al. 2019). As such, late adolescents generally see higher real world risk-taking than younger adolescents who have higher propensities for risky behaviour (Duell et al. 2018; Steinberg 2008). Additionally, health and demographic literature suggest that issues of coerced sex and restricted agency play a significant role in adolescents' sexual behaviours. Adolescents appear to experience higher rates of unwanted and forced sex than adults, and the youngest adolescents appear to be most vulnerable to limits on their agency and power (Jejeebhoy and Bott 2003; Pan American Health Organization 2012). A the core of the issue is a sexual socialisation that privileges male decision-making and dominance and conditions both males and females to perceive coercive sexual behaviour and gender-based violence as socially acceptable (Fawcett et al. 1999; Jejeebhoy and Bott 2003; Moore et al. 2007; Shafer et al. 2018). In this sense, the peer influence of fertility within municipalities encompasses a broad array of socialisation processes that are not just restricted to social learning of sexual behaviours and gender roles (such as timing of sexual debut and union formation, or use of contraception) but also more malign influences, for example, of communities and institutions that turn a blind eye to abuse and coercion or do too little to safeguard the health and rights of adolescent girls.

Not only has this study found evidence that context matters for individual adolescent fertility probabilities, but it found that the magnitude of the influence of context differs across the adolescent age schedule for first adolescent births. The study explored the importance of context generally before examining the influence of peer fertility influence specifically. Peer fertility context is strongly related to individual fertility patterns in that individual fertility probabilities (for both first and second births) are higher in contexts where a larger portion of the adolescent population has experienced a first birth than in contexts where fewer adolescents are mothers. Importantly, both for general context and peer fertility context, differences by age showed distinct and fascinating trends. The following paragraphs summarize the age and schooling status differences for first births. Recall that while context did matter for the individual probabilities of progression to second births, there were no differences across the age schedule or schooling status. This could very well be a reflection of the limited data for studying birth progression, wherein most second adolescent births occurred at similar ages (in late adolescence) and where very few adolescent mothers were in school. It could also reflect greater access to and use of contraception among adolescents after experiencing a birth.

In looking at the impact of context generally on individual first birth probabilities, the research found that the importance of context increases progressively from the oldest to the youngest ages such that overall municipal context matters most at the youngest ages. Additionally, the general context of the municipality also matters more for the individual fertility probabilities of girls who are in school than for girls who are out of school, and more in situations where less of the population is enrolled than in situations where more of the population is enrolled in school. Recall that younger girls have lower fertility likelihoods than older girls, and girls who are in school have lower fertility probabilities than girls who are out of school—so the point is not about their probabilities but rather the degree to which to probabilities vary by municipal context, or the environment of a girl's municipality of residence independent of her own individual characteristics. The data used in this study cannot say why these trends exist, but the literature already reviewed provides some plausible connections. That is, though the occurrence of fertility in early adolescence is comparatively rare in the population, the propensity for the youngest adolescents to be influenced by social forces and the surrounding milieu is higher than in later adolescent years possibly because the development of cognitive control lags so far behind aspects of social orientation in early adolescence, also because youngest adolescent seem particularly at risk of sexual coercion. Evidence that can speak to why context matters more for in-school youth than out-of-school youth, and more in low-enrolment situations than high-enrolment situations is tenuous. It is possible that the individual circumstances that contribute to a girl's school leaving could contribute to her fertility propensity to a greater degree than her municipal setting given that she is not in school. In contrast, once accounting for the individual circumstance that contribute to a girl being able to stay in school (where causal evidence suggests schooling otherwise places strong restrictions on the time she has available for meeting and interacting with older males), the municipal setting contributes to her fertility propensity to a comparably greater degree.

In looking at difference in the importance of peer fertility influence specifically, the research found that a municipality's adolescent fertility context was most salient for the youngest adolescents. In fact, among girls in school, after accounting for fertility context, the remaining unexplained municipal contextual matters least at the youngest ages and most at the oldest ages. Among girls out of school, fertility context is still most salient for the youngest adolescents, but the remaining municipal context only matters least at the youngest ages in low-enrolment settings, whereas in high-enrolment settings, the remaining (unexplained) aspects of municipal context matter least among the oldest adolescents. Importantly, in settings where about a third to two thirds of girls are enrolled in school, the peer influence of fertility (especially among adolescents in mid and early adolescence) explains nearly all of the observed contextual phenomena in individual probabilities of experiencing an adolescent first birth.

Psychology and health research on peer influence in adolescent sexual behaviours do not often explore differences by age directly. One study in Rwanda that did so reported statistical conclusions that seem to contradict this study's findings that peer fertility influence is most salient at the youngest adolescent ages, the authors worried that under-reporting of sexual activity in early adolescence was responsible for their finding, which was that perception of friends' sexual activity was not related to individual sexual activity in early adolescence (though it was in later adolescence) (Babalola 2004). Other evidence from the US suggests peer influence on sexual behaviours does matter in early adolescence (as well ad mid adolescence), and, interestingly, the contextual influence of childbearing appeared to be stronger than that of sexual activity (East, Felice, and Morgan 1993). (Note that girls in late adolescence were not included in the study.) Lessons from this research suggest that the salience of contextual influence on adolescent childbearing is greatest at the youngest adolescent ages, not the oldest adolescent ages.

The finding that adolescent fertility context specifically matters most at the youngest ages has far-reaching significance. In Mexico, rates of childbearing among girls 14 years and younger has increased in recent decades (Meneses and Ramírez 2018). Similar patterns of stagnation or more limited decline for the youngest adolescents compared to older adolescents have also been found in other countries (Garbett, Perelli-Harris, and Neal 2021; Neal et al. 2018). Given that so little representative data exists on the childbearing patterns of the youngest adolescents, and that such early motherhood comes with strident health and human rights concerns, finding that patterns of childbearing among early adolescents are particularly influenced by the childbearing of their adolescent peers, breaks new ground and, most importantly, gives new impetus for the direction of Mexico's national strategy to reduce adolescent fertility. Declines in Mexico's adolescent fertility rates over the last half century have been driven almost exclusively by a declining incidence of higher-order births in adolescence. There has been very little change in the proportion of women who enter motherhood in adolescence, and this pattern is repeated in many other countries in Latin America and the Caribbean (Neal et al. 2018; United Nations Population Fund 2022). In order to accelerate the pace of decline in its adolescent fertility rate, Mexico must target first births. Without stronger reduction in first births in adolescence, future inroads into adolescent fertility reductions will be limited. Additionally, this study suggests that reducing the incidence of first births for all adolescents, could have particularly strong spill over effects for the youngest vulnerable girls who have otherwise not seen declines in their fertility rates.

Chapter 5

Concluding remarks

5.1 Summary, contribution and limitations

This thesis has explored the demographic puzzle of Latin America and the Caribbean's high levels of adolescent fertility. Its collection of three research papers make an important contribution to existing literature on several fronts—both in substance and methods. The papers' overarching interest in parity-specific trends and differences across the adolescent age schedule are particularly informative as fertility at different adolescent ages has vastly different implications. Childbearing at the youngest adolescent ages carries particularly strong health and human rights concerns.

The introduction set out to describe why adolescent fertility and schooling patterns in Latin America and the Caribbean are such an enigma, but other research has also found the region's fertility patterns puzzling. What is unique about the introduction is its innovative framing of the theoretical underpinnings of the connection between schooling and adolescent fertility. Considerable theoretical and empirical work looks at the relationship between schooling and total fertility, and plenty of empirical work has examined the connection between schooling and adolescent childbearing, and but there was no clearly articulated theory for why schooling matters for adolescent fertility specifically. Theoretical discussions of schooling and total fertility largely speak to issues of quantity, and while quantity still matters when examining adolescent fertility, the issue is more about the timing of entry into motherhood.

Indeed, a woman's schooling is one of the strongest predictors of how many children she will have. From the literature on the relationship between education and fertility, two overarching themes arise: (1) education and fertility have a negative relationship, or, on average, as a woman's years of schooling increase, the number of children she has decreases (Ainsworth, Beegle, and Nyamete 1996; Behrman 2015; Brand and Davis 2011; Diamond, Newby, and Varle 1999; Nisén et al. 2014; Sohn and Lee 2019); and (2) women at all education levels have experienced substantial declines in their total fertility over time, particularly over demographic transitions (Abbasi-Shavazi et al.

2008; Bongaarts 2003; Choe and Retherford 2009; Kravdal and Rindfuss 2008; Shapiro 2012; Yoo 2014).

Classical theories on the explanations for why schooling reduces fertility emphasise changing cost-benefit, quality-quantity trade-offs to the mother (LeVine et al. 1991). Research in low- and middle-income countries continues to find that the quantity-quality trade-off in family size and schooling persists (Duncan, Kalil, and Ziol-Guest 2017), and, importantly, there are two proximate determinants of fertility that education seems to consistently influence. First, schooling increases contraception use, resulting in fewer unwanted births; second, schooling delays the initiation of childbearing, also resulting in lower lifetime fertility (Cleland 2002). The robust positive relationship between schooling and contraception has been found worldwide, and higher levels of education are associated not only with higher levels of contraceptive use, but also with more effective use (Bongaarts 2003, 2010; Martin and Juarez 1995; Musick et al. 2009).

In contrast to schooling's negative association with the quantum, or quantity, of fertility, as discussed above, there is a positive association between schooling and the tempo, or timing, of fertility (Cleland 2002). The more schooling a woman has, the later she begins childbearing. While theoretical work on the relationship between education and the timing of fertility has been given comparatively less attention than the connection between education and the quantum of fertility, empirical work is widespread. Education-differentiated postponement patterns are not uniform, and first birth age dispersion has been seen in many high-income countries in variety of time periods (Andersson et al. 2009; Berrington, Stone, and Beaujouan 2015; Bloom and Trussell 1984; Lappegård and Rønsen 2005; Rendall et al. 2010; Rindfuss, Morgan, and Offutt 1996; Spéder 2006). Importantly, in research that makes the distinction, it has been found that childbearing postponement is more strongly related to time since leaving school than to calendar age; the increased time women spend in education can account for much of the postponement of first births (Neels et al. 2017; Ní Bhrolcháin and Beaujouan 2012).

Ultimately, the relationship between schooling and the tempo of adolescent fertility is much more immediate than the relationship between schooling and general fertility. Adolescent fertility and pre-tertiary schooling, by definition, both happen in adolescence. Strong evidence for a causal relationship between school and adolescent fertility comes from randomised control trial evaluations. Programs that encourage girls to stay in school, or to return to school after they have dropped out, significantly reduce adolescent marriage, fertility and sexual activity rates. This been found in trials in Latin America and the Caribbean, Africa and Asia (Baird et al. 2010; Duflo, Dupas, and Kremer 2015; Kalamar, Lee-Rife, and Hindin 2016). Evidence also comes from demographic research that look at the impact of school reforms on adolescent fertility. The research finds that changes in compulsory schooling requirements, which increase the age of school leaving, causally reduce adolescent fertility (Grönqvist and Hall 2013; Monstad, Propper, and Salvanes 2008; Silles 2011). However, these studies also find that additional schooling inspires changes in a girl's life goals and expectations and reduces adolescent fertility even after she leaves school (Black, Devereux, and Salvanes 2008; Cygan-Rehm and Maeder 2013; Monstad, Propper, and Salvanes 2008). The aspirational changes are usually framed in terms of changing economic expectations and trade-offs as well as the influence of changing social norms for life course event timing (Gustafsson 2001; Kohler, Billari, and Ortega 2002).

As such, the relationship can be framed into two fundamental actors: enrolment effects and aspirational effects. Enrolment relates to how being enrolled and present at school reduces adolescent childbearing risk while the girl remains in school, and aspiration relates to how schooling inspires changes in a girl's life goals and expectations that can reduce fertility even after she has left school. The applicability of this framework is universal, but its application to Latin America and the Caribbean is particularly interesting and is the focus of the first paper.

5.1.1 Paper 1

The first paper builds on the theoretical framework offered in the introduction to produce a comprehensive demographic accounting of how Latin America and the Caribbean has maintained such high levels of adolescent fertility in the face of dramatic schooling improvements over the course of its demographic transition. Demographic transitions and schooling expansions usually occur alongside postponements to entry into motherhood.

The small handful of previous studies that examined the puzzle gave mixed results: in some cases, women in all educational strata saw increasing levels of adolescent fertility in the region while in other cases, university-educated women were immune to increasing adolescent childbearing. What was missing was an analysis that could reconcile the mixed messages and place them within the bigger picture. For example, the Brazilian study (Cavenaghi and Diniz Alves 2011) found adolescent fertility rates increased both for women with 8 or fewer years of schooling and those with 9 or more years, but given that both of these categories contain the schooling levels that have seen some of the most dramatic increases in risk (lower secondary and upper secondary incomplete), the findings likely mask strong underlying differences between tertiary goers and upper secondary completers compared to schooling levels below. The analysis of both Rodriguéz Vignoli and Cavenaghi's (2014) and Esteve and Florez-Paredes (2014) offered important improvements by looking at first birth proportions rather than the adolescent birth rate, their schooling categories aligned school levels across countries by specific schooling years, rather than by certificate and non-certificate years. As such, they missed important nuance between schooling completers and incompleters across contexts. They both also covered more limited time periods. Finally, though Batyra (2020) explores the idea of differences between graduates and dropouts, the analysis does not distinguish between lower secondary and upper secondary. Critically, none of these studies looked at patterns of higher-order births.

As such, the first paper's contribution to demystifying the puzzle comes because it looks at what adolescent fertility patterns have been over the long term; what they have been for first as well as higher-order adolescent births; and what they have been for education divisions that distinguish between all relevant schooling levels, particularly upper- and lower-secondary education, as well as dropouts and graduates at each level. The study's accounting of the demographic changes was meant to speak to a broader theoretical question about the relationship between schooling and fertility timing.

The study is unique in its methods for its model-based estimation of patterns. The regression models improve the reliability and detail of the estimates and allow for statistical testing of differences between the many schooling levels examined. Importantly, the statistical testing takes account of the uncertainty introduced through the complex sampling designs of the data. Ultimately, the analysis revealed that in most, but not all, of the six countries analysed, only women who reached university had not seen long-term increases in adolescent first births. In contrast, schooling-specific rates of second and higher-order adolescent births had generally, but not universally, fallen. The findings also emphasised lower-secondary's diminishing returns and upper-secondary's distinctiveness in adolescent fertility patterns.

The study also related the findings back to the introduction's theoretical underpinnings by examining patterns in the timing of adolescent fertility for each schooling level. The findings suggest that over the long term, adolescent fertility's link with enrolment remained fairly unchanged while aspirational changes, in contrast, were considerable. In regards to constancy of the link with enrolment, recall that in spite of increasing proportions of women experiencing a first birth in adolescence (and at slightly younger mean ages) within most schooling strata, first births occurred, for the most part, after adolescents had already left school. Even first births that occurred to adolescents who reached upper secondary and tertiary schooling saw little effective change in the timing of those births with regards to school leaving. Tertiary schooling, which is the only educational trajectory that lasts through the entirety of adolescence, was the only schooling level that remained largely immune to increasing adolescent fertility. According to the imputations, the incidence of adolescent births that occurred while a girl was enrolled and present at school remained equally rare throughout the entire five decades analysed. Put differently, school enrolment's apparent ability to reduce fertility was as effective in the most recent cohorts as it was in the earliest cohorts. In contrast, the aspirational aspect of each schooling level in regards to the timing of fertility radically transformed. The middle schooling levels that were once fairly elite, lost their selectivity and became little different from the lowest schooling levels in terms of first births in adolescence. That is, the middle education strata saw the greatest increases in the incidence of first births in adolescence, so much so that they converged with lower schooling levels and effectively shared the same patterns as women with no formal schooling in the most recent cohorts in a repositioning of the social hierarchy. Other research has emphasised the constancy of relative, but not absolute, positions in fertility differences by social strata in the region (Batyra 2020; Esteve and Florez-Paredes 2014). Nevertheless, for second and third births in adolescence, aspirational differences meant that the middle education strata supplied important protection that the lowest schooling levels did not. Namely, secondary schooling saw much stronger declines in progression to higher-order adolescent births than did primary and no school, meaning that the cumulative adolescent childbearing of each educational strata remained distinct.

The strength the of the first paper is in its attention to detail—to long-term differences in patterns of first, second and third births to adolescents; and to differences among graduates and dropouts at all schooling levels; and to the statistical implications of complex survey design in the uncertainty of the estimates. Trends in first births are completely different to trends in second and third births, trends at almost every schooling level are distinct from each other, and aggregate trends differ from education-specific trends. Importantly, the schooling that occurs at different stages in adolescence are at the crux of the region's puzzling trends in adolescent fertility and schooling expansion. The schooling that occurs in early adolescence (lower secondary) has seen the most dramatic increase in adolescent first births, and the schooling that occurs in late adolescence (complete upper secondary and tertiary) shown stronger resistance than any other schooling levels to increasing adolescent first births. For second births, the most dramatic declines have been at the schooling levels that occur in late adolescence while less change has occurred at schooling that occurs in early adolescence—and the declines in second and third births are not due to changing timing of first births (such as increasing age on average at first birth that gives less time of subsequent childbearing in adolescence).

The impact of the study's findings are far reaching. First, the research agenda can take structure from the new theoretical underpinnings. In essence, education is connected to the timing of demographic phenomena through two separate pathways. That is, one pathway of enrolment and the restrictions schooling imposes on how young people spend their time, and the other pathway of aspirations, which shapes how adolescents come to envision their life course and whether they acquire the tools they need to follow their ambitions. Disentangling these pathways in future research could deepen the field's understanding of how education and fertility are connected, as well as how the links have or have not changed over time. In this study at least, over the long term, the relationship between specific schooling levels and adolescent fertility does indeed change dramatically. For the most part, it appears that only schooling careers that span the entire adolescence are associated with long-term resistance to increasing adolescent fertility. The stability of school enrolment's ability to reduce fertility appears to have persevered while schooling's aspirational influence has been modified under changing context and reorganised social hierarchies. Exploring this in other contexts promises a rich field of study. For example, levels of adolescent fertility are high in both Africa and Asia, and both regions see countries with strong declines alongside other countries with stagnation or even increase (United Nations Population Fund 2022). Connecting the changes in adolescent fertility to each country's respective schooling expansion would provide importance evidence on whether the enrolment and aspiration framework applies elsewhere.

Second, the findings give impetus to the research agenda to recognise the considerable differences in lower- and upper-secondary schooling. Most demographic research lumps all secondary schooling together, but this aggregation is missing important nuance. For example, this study's findings suggest refinement is needed in other research in other low- and middle-income countries where adolescent fertility is common and access to secondary schooling is still expanding. For example, research that finds that secondary schoolgoers have seen the greatest declines in mean ages at first sex and at first birth (Bongaarts, Mensch, and Blanc 2017), or the greatest increase in adolescent fertility (Grant 2015) could well be masking that the changes are happening at lower-secondary schooling but not in upper-secondary schooling.

Finally, from a policy perspective, the study pushes for the expansion of the compulsory schooling cycle to include upper secondary schooling. Initiatives seeking to reduce the Latin America and the Caribbean's high and stubborn levels of adolescent motherhood will find promising potential in focusing on the expansion of access to and completion of upper secondary and tertiary—as may other world regions. Primary and lower secondary simply do not occupy enough years in adolescence to conflict with early fertility. Enrolment appears to have remained a consistent check on adolescent childbearing even when schooling-inspired aspirations have not. The Millennium Development Goals created a global rallying point for universal primary schooling, and the Sustainable Development Goals expanded that to include universal lower secondary schooling. This study adds to the growing evidence that, for demographic and health purposes, the global goal should be further expanded to universal upper secondary schooling. Recall that health research is increasingly demonstrating that many of schooling's myriad benefits on health see threshold effects where the greatest benefits emerge at upper secondary schooling (Patton et al. 2016). Given that adolescent fertility remains so prevalent throughout the developing world (United Nations Population Fund 2022), expanding access to upper secondary schooling promises a way to accelerate declines in early childbearing. In this sense, the findings in the six countries analysed are relevant not just for Latin America and the Caribbean, but for all the world's lower- and middle-income countries where adolescent childbearing remains widespread despite dramatic fertility transitions and schooling expansions over the last half century.

Nevertheless, the paper is limited by its inability to authoritatively determine the sequence of fertility and school leaving. Demographic data in low- and middle-income countries that specifies the timing of school leaving and childbearing is scarce but would be exceptionally powerful. In the study, the population patterns of school attainment reflects a woman's educational qualifications at the time of the survey, which is not necessarily what they were at the time of an adolescent birth. Nevertheless, the paper tries to address this limitation by imputing whether there are changes in the timing of adolescent fertility as it relates to school leaving. The findings suggest that there does not appear to be any dramatic changes in school and fertility sequences over time. That is, almost all births to women who attained lower secondary or less occurred after she left school, while, for births occurring to those who reach upper secondary and tertiary, the proportion that occur before, after or coincide with school leaving has been fairly constant.

Additionally, the paper is limited in that it cannot speak to other underlying determinants of fertility and their schooling-specific changes, and which reflect critical aspects that remain unknown. In an ideal world, there would be data that allowed the study of schooling-specific changes in the proximate determinants of fertility to compliment this study's demographic accounting. For example, schooling-specific pregnancy rates, contraceptive use and pregnancy termination levels could tell a very different story and have important policy implications. It is possible that upper-secondary and tertiary school goers have seen their incidence of adolescent pregnancy increase in the region but that births rates have not changed because pregnancy terminations have also increased. Abortion is severely restricted in most of the region but remains widespread (Guttmacher Institute 2017). Alternatively, pregnancy rates at the higher schooling levels could have remained more constant over time even if sexual behaviours have changed (more sexual activity at younger ages) if there have been improvements in contraception uptake. For second births, it would be important to understand how much of declines are due to increases in contraceptive uptake after first births or how much of the declines are due to changes in partnership dynamics (such as fewer births being born within unions), and how these trends differ at specific schooling levels. Likewise, patterns of sexual debut, frequency of sexual activity, partnership dynamics, and fertility intentions would be important to understand—as would other more distal determinants such as wealth and urban or rural residence—as these have found strong educational gradation in adolescent fertility (Ali, Cleland, and Shah 2003; Bozon, Gayet, and Barrientos 2009; Di Cesare and Rodríguez Vignoli 2006; Esteve, García-Román, and Lesthaeghe 2012; Esteve, Lesthaeghe, and López-Gay 2012; Flórez 2005; Fussell and Palloni 2004; Glick, Handy, and Sahn 2015; Kravdal 2002; Kulczycki 2011; Vignoli 2017). However, data on the proximate determinants of adolescent fertility is sparse. What surveys I have seen that gather information on pregnancies (and not just live births), and especially pregnancy terminations, seem particularly prone to problems likely arising out of social desirability bias in reporting and poor question wording, as well as facing issues from small sample size and unrepresentative sampling procedures.

Also worth noting for this specific study is that it could benefit from including Brazil in the country comparison, as Brazil makes up nearly half of Latin America's population. Additionally, Brazil's adolescent birth rate trends are distinct from the countries included in the analysis—they started out at lower levels (similar to Haiti) before seeing increase in the 1980s and 1990s and declining again thereafter—and suggest an even stronger pattern of stagnation. Brazil was not included in this thesis' analysis because Brazil did not have enough demographic surveys to cover five decades of trends, but the country has a national demographic survey that is currently under way that would allow for replication of this study's analysis as soon as the data is released.

5.1.2 Paper 2

The second paper narrows the lens onto Mexico's subnational patterns of adolescent childbearing. Mexico's adolescent fertility rate has halved over the last fifty years and the country has set a goal to halve the rate again over the next decade. The goal is ambitious but severely off track. At the national level, the proportion of women entering motherhood in adolescence (one third of all women) has effectively stagnated since the 1990s, with declines in the adolescent fertility rate coming only from declines in second and third adolescent births. Strategy documents for the country's new initiative target implementation at the municipal level but no prior research had estimated parity-specific adolescent fertility at the municipal level. Furthermore, no prior research had estimated any kind of fertility estimates for adolescents 14 years and younger. The study set out to explore whether the patterns of first birth stagnation and second birth decline seen at the national level also define Mexico's subnational municipal trends. Specifically, it produced estimates of age- and parity-specific proportions and progression ratios in 2,457 Mexican municipalities over the last 25 years. Instead of finding uniformity, the estimates revealed a diverse array of trends in both first and second births in adolescence that have important policy and research implications.

The study indicated that the increasing incidence of first births in adolescence alongside a decreasing incidence of second adolescent births at the national level was not unequivocally repeated at the subnational level. At the subnational level, municipalities were split between those that saw increasing adolescent first births (56% of municipalities) and those that saw decreasing adolescent first births (44% of municipalities). As a general rule, municipalities with the lowest first birth proportions in 1990 saw the greatest increase over time while municipalities with the highest proportions in 1990 saw the greatest decline, which marked a convergence in patterns of first births. However, plenty of municipalities did not follow this generalisation. There were many municipalities, for instance, with high first birth proportions in 1990 that saw almost no change or even sharp increase over the last two and a half decades. Additionally, while the vast majority of municipalities (98%) saw a declining proportion of adolescents with second births, patterns of progression among adolescent mothers at risk of a second birth saw greater diversity and did not correspond tightly with levels or changes in first births.

The study's methodology relied on multilevel regression models for the estimates, and makes a unique contribution for how it incorporated design weights into the analysis. I find no other demographic research that addresses the issue of design weights, which is important because unlike OLS regressions, point estimates, and not just standard errors, will differ based on the chosen weighting procedure in multilevel models. Ultimately, the analysis revealed that underneath Mexico's rather stable aggregate fertility trends, municipalities see considerable diversity and change.

The policy implications of the findings are far-reaching. Not only did the estimates highlight priority municipalities that might otherwise be overlooked by the national strategy, but they emphasised the importance of tracking and targeting first and second adolescent births separately. Mexico's national strategy to reduce adolescent fertility recognizes the value of targeting interventions at the municipal level, but it prioritises municipalities with the highest $ASFR_{15\text{-}19}$ and largest populations (Gobierno de la República 2015). Rates of first births, instead of $ASFR_{15\text{-}19}$, saw very different municipal maps of high-fertility hotspots (see for comparison Ailines Genis 2018). Furthermore, $ASFR_{15\text{-}19}$ does not perfectly correspond with the incidence of parity-specific adolescent fertility, and there seemed to be more geographic heterogeneity in the incidence of parity-specific adolescent fertility than in $ASFR_{15\text{-}19}$. For example, the municipalities with the highest $ASFR_{15\text{-}19}$ were not always the same with the highest incidence of first births in adolescence, and municipalities with the highest risk of progression to second births were not always those with the highest proportion of first births. Additionally, neighbouring municipalities showed much more diversity in the incidence of parity-specific adolescent fertility than in $ASFR_{15\text{-}19}$ and, as such, many more states had municipalities with the highest incidence of first births than they had municipalities with the highest $ASFR_{15\text{-}19}$. Essentially, there appeared to be many municipalities with an above-average incidence of first births of above-average progression rate to second births that did not have an above-average incidence of $ASFR_{15\text{-}19}$ and would thus miss out in interventions that only target the highest $ASFR_{15\text{-}19}$.

In this sense, the study furthers the research and policy agenda both in Mexico and in adolescent fertility more generally on several fronts. Very little representative adolescent fertility research in low- and middle-income countries is done at the subnational scales, even though subnational trends will always be more diverse and dynamic than national and regional averages. Subnational analysis is also better poised for informing policy and programming. While some of the scarcity could be due to limited data, data limitations can be ameliorated to some extent with statistical modelling, and simply identifying and mapping fertility trends at smaller geographic areas can make a pivotal contribution to efforts to reduce adolescent fertility, as was the case in the United Kingdom (Hadley, Chandra-Mouli, and Ingham 2016). The study's strength is in its attention to detail regarding parity-specific differences in adolescent childbearing and, especially, to age-specific differences that bring out the patterns of the youngest vulnerable mothers. There is very little subnational adolescent fertility research in low- and middle-income countries that is representative, looks at parity-specific adolescent fertility, or looks at fertility among girls 14 years and younger. The additional insight provided by the parity- and age-specific estimates can make targeting particularly detailed, especially in Mexico's case, when the goal is to entirely eliminate childbearing in early adolescence, and when the incidence of early adolescent fertility has been increasing. Additionally, the study found that there are municipalities with above-average early adolescent fertility but average or below-average later adolescent fertility, which suggest they would likely otherwise be overlooked in initiatives that focus on targeting places with the highest $ASFR_{15\text{-}19}$. Fundamentally, reductions of first and second births require different strategies (as do births at different ages), and, critically, the analysis strongly suggests that the incidence of first or second births are not predetermined by each other. That is, a high incidence of second births to adolescent mothers is not exclusive to municipalities with high levels of first births in adolescence and neither are low levels of first births predictive of a low risk of second births. As such, the applications to policy and programming are abundant.

Nevertheless, the paper is limited in its examination of uncertainty in the estimated proportions. Bayesian methods would provide more robust picture of the of the reliability of the models. Additionally, the paper is limited in that it does not formally examine how underlying changes in the educational and socioeconomic landscape contribute to the subnational patterns of flux, nor what changes in the more proximate determinates of fertility might be contributing to changing patterns of births. Indeed, the convergence in levels of adolescent fertility across Mexican municipalities over time is remarkable and merits additional research. Given that other research in the region also hints of unexpected subnational complexity underlying national trends of stagnation or increasing adolescent fertility (see discussion in the second study for more detail), this line of subnational research would likely provide important insights that go well beyond their bounded geographic scope.

Some preliminary analysis done for the study, but not included in this dissertation, replicated the methods used in the first study to look at schooling-specific trends at the state level (not municipal level) in Mexico, and found very similar patterns to what was seen in the multi-country comparison. Trends and levels were not identical across Mexican states, but most states saw the strongest increase in risk at lower secondary schooling with more limited change at upper secondary schooling. It seems reasonable that the increasing risk in fertility at lower schooling levels alongside a resistance to increasing risk at higher schooling levels (a convergence across schooling domains) is related to the convergence in adolescent fertility levels across municipalities. In other words, the diversity in municipal trends could well be related to underlying differences in adolescent fertility risk at specific schooling levels. The interaction of changes in the composition of each municipal population's schooling profile, alongside changes in the intensity of risk at each schooling level could be producing the results. That is, there are differences across municipalities in what proportion of their adolescent populations attain lower secondary, upper secondary and tertiary schooling, and, simultaneously, there are likely to be differences in how much or little the risk of adolescent fertility has increased at each of these schooling levels. However, translating the complex underlying schooling-specific trends to regression analysis proved challenging. Models that examined the association between trends in schooling and fertility with more than one schooling specification ran into problems of multicollinearity, producing illogical and unstable results. Models that used only one schooling indicator (see Appendix C) were dissatisfying in that they suggested that the aggregate changes in adolescent fertility levels had only a weak connection to the dramatic aggregate changes in adolescent schooling and other socioeconomic conditions. Furthermore, the simpler models showed only limited distinctions between potential enrolment and aspirational effects. Future research could potentially explore the remaining questions using alternative variable specifications of the schooling levels that summarise highly correlated variables (principal component analysis, for example), or alternative regression techniques that can handle multicollinearity (Lasso and Ridge regression, for example).

Otherwise, additional research might look for a type of threshold effect in the association between schooling and adolescent fertility in the population. Recall that other Mexican studies have argued that high rates of adolescent fertility has persisted because the mass educational changes in birth cohorts from the 1930s to 1970s occurred at ages that were too young to conflict with the timing of transitions to motherhood and union formation. The studies concluded that aggregate postponement would not be visible until schooling expands to the point where enough women are still in school at the ages when they would otherwise begin childbearing (Kroeger, Frank, and Schmeer 2015; Lindstrom and Paz 2001). Though it appears that the bulk of educational changes have continued to occur at ages before motherhood entry, it could be that the subnational changes—given that there will be a greater diversity in schooling levels across municipalities—could find evidence of schooling-related postponement that is not yet visible at the national level.

Many other socioeconomic aspects are also relevant to the subnational trends and merit future exploration. For example, aspects of educational quality may be important. If schools are of insufficient quality to produce satisfactory economic returns to education, and female labour force participation remains limited, the aspirational effects of schooling may not be enough to induce changes to the norms of early childbearing. Similarly, drug-related and gender-based violence in Mexico as well as other countries in the region, is considerable but their connection to rates of adolescent fertility remains relatively unexplored (Berlanga Gayón 2015; Pan American Health Organization 2012; Rosen and Zepeda 2016). More broadly, shifting (converging?) socioeconomic characteristics are not well understood at the subnational level. Parity-specific adolescent fertility in Mexico has long been understood to differ considerably by socioeconomic and educational strata (Welti Chanes 2006), but it is not clear how much of the convergence in adolescent fertility subnationally might be due to diminishing cultural differences or shifting population composition. Mixed methods methodologies could be particularly beneficial here in that quantitative data would be important for looking at changes in the population composition while qualitative data would be needed for understanding adolescents' conceptualisations of motherhood entry and union formation and whether these are shifting across social strata. Any future analysis of shifting population composition must take into account the relevance of both absolute and relative shifts, in that other educational and economic literature points to diminishing marginal returns to education (Bol 2015; Urbina 2022). Fortunately, Mexico has abundant and frequent economic and labourforce data, as well as rigorous work on indicators of poverty and marginalisation that could be promising for such analysis.

As with the first study, examining changes in the proximate determinants of fertility—such as age at sexual debut, frequency of sexual activity, union formation (and whether it is consensual union or marriage), patterns in pregnancy intention, contraceptive prevalence, miscarriage, abortion—

would also be a critical next step. However, representative, subnational data on the proximate determinants of adolescent fertility in Mexico is exceptionally sparse and existing surveys are often not comparable over time (incongruent questions and population sampling, for example), making detailed analysis difficult. Existing state-level estimates confirm that subnational disparities in pregnancy rates and pregnancy terminations are considerable, but it is not clear what direction the associations of these proximate determinants might take with respect to changes in the trends of live births to adolescent mothers. Evidence suggests that sexual activity in adolescence is increasing, but so is the use of contraception, alongside a decline in the intendedness of adolescent pregnancies (Gutiérrez et al. 2012, 2012; Instituto Nacional de Estadística y Geografía 2014, 2018; Olaiz-Fernández et al. 2006). However, detailed disaggregation is lacking, both by geography and by population subgroups. As such, it is unclear if these changes are universal across scoioeconmic and education strata or confined to certain groups. Importantly, it is unclear what groups of adolescent girls are unable to prevent unintended pregnancies and births and why this is the case—why they are unable to realise their sexual and reproductive health and rights. In Mexico, knowledge of contraception is high among adolescents, but unmet need for contraception is higher in this age group than any other. As such, more needs to be done to understand what programs best improve access for adolescents and protect them from coercion. Given the biased gender norms for sexuality that prevail, it seems that what is urgently needed are innovative ways to reduce social stigma related to accessing contraception and innovative ways to transform the norms that perpetuate coercive sexual behaviours and prevent adolescents (both males and females) from communicating about and using contraception.

All this to say that the trends in convergence of levels of adolescent fertility across municipalities, as estimated in the second study, likely reflect dramatic shifts in the population—both in terms of scoioeconomic changes as well as in the proximate determinants of fertility—that have yet to be explored. A better understanding of this shifting landscape will be key to breaking the stalemate in Latin America and the Caribbean's persistence of high rates of motherhood entry in adolescence.

5.1.3 Paper 3

The third paper uses Mexico again as a case study to zoom further into the individual adolescent girl and a country's subnational patterns. Adolescence spans ten years of dramatic physical, emotional and cognitive change. Childbearing at different ages in adolescence underscores these considerable developmental differences. The study takes inspiration from neuroscience and psychology literature that finds considerable developmental differences across the age schedule in adolescents' propensity to be influenced by their broader social milieu. It also takes inspiration from health and demographic literature that raises concerns about heightened risk of coercion, violence and limited agency in adolescent sexual and reproductive issues, particularly among the youngest girls.

For example, early adolescence marks an abrupt reorientation of the brain to social and emotional development, with a preference for short-term rewards being greatest at this stage (Steinberg 2008). Mid adolescence sees life peaks in aspects such as reward sensitivity, sensation seeking and risk propensity (Steinberg 2008; Steinberg et al. 2008). While cognitive capacity is also highly developed by mid adolescence, the decision-making process is highly contingent on context, particularly the presence of peers (Crone and Dahl 2012; Landsford et al. 2021). Finally, while late adolescence sees greater skill in future planning, impulse control and self-regulation alongside a slight reduction in risk propensity, real world opportunities for risky behaviour increase (Baird et al. 2021; Icenogle et al. 2019). As such, late adolescents generally see higher real world risk-taking than younger adolescents who have higher propensities for risky behaviour (Duell et al. 2018; Steinberg 2008). Additionally, health and demographic literature suggest that issues of coerced sex and restricted agency play a significant role in adolescents' sexual behaviours. Adolescents appear to experience higher rates of unwanted and forced sex than adults, and the youngest adolescents appear to be most vulnerable to limits on their agency and power (Jejeebhoy and Bott 2003; Pan American Health Organization 2012).

The study's methodology is straightforward, but applied in an innovative way. That is, the methods rely on the ability of multilevel regression modelling to detect and quantify contextual phenomena. Importantly, the methods take up the issue of centring in multilevel models and what the choice implies for the interpretation of the results. I find no demographic analysis that addresses the important issue of centring in multilevel models, meaning that conclusions about contextual effects in other demographic research are difficult to interpret because they are based on an ambiguous mix of variance at the individual and cluster level. The format of the paper is also designed to present the methods so that the power of multilevel models is understandable to both specialist and non-specialist audiences. As such, the work could help take forward the methodological integrity of the research agenda in demographic studies of contextual effects.

While there is research that explores how broader cultural and socioeconomic contextual factors play a role in an individual girl's fertility risk, to the best of my knowledge, no research explores quantitatively how the importance of context changes over the adolescent age schedule and at different parities. This nuance is critical given how dramatic the study's findings are of the difference in magnitude of contextual influence at different adolescent ages. Not only does the study offer an important contribution to the field of demography through its innovative study of adolescent fertility among the youngest adolescents for whom so little research exists, but it also speaks to the neuroscience, psychology and health and rights research fields. Most neuroscience and psychology studies are small scale, and reliably extrapolating their implications to population-level patterns is impossible. To my knowledge, this study is the first of its kind to contribute quantifiable, representative demographic evidence that speaks to the dual systems model in adolescent development theory.

The study looks at context generally and the context of adolescent fertility specifically. It looks at the peer influence of fertility within municipalities (as measured by the proportion of adolescents with a first birth), but this measure represents a broad array of socialisation processes that are not just restricted to social learning of reproductive behaviours. Instead, they include social learning of sexual behaviours and gender roles (such as timing of sexual debut and union formation, or use of contraception) as well as more malign influences, for example, of communities and institutions that turn a blind eye to abuse and coercion or do too little to safeguard the health and rights of adolescent girls. Critically, at the core of the issue on Mexico's sexual socialisation—as in many other low- and middle-income countries—are norms that privilege male decision-making and dominance and condition both males and females to perceive coercive sexual behaviour and gender-based violence as socially acceptable (Fawcett et al. 1999; Jejeebhoy and Bott 2003; Moore et al. 2007; Shafer et al. 2018). Future research could explore how statistical measures of variance for contextual effects differ based on other potential indicators of these gender dynamics such as, where available, contextual measures of gender-based violence, unmet need for contraception, and rates of unintended pregnancy. Alternatively, contextual measures of schooling enrolment or attainment or female labour force participation could also provide indicators of changing gender dynamics that are related to sexual and reproductive behaviours as well. If all of these measures behave similarly to the peer fertility measure included in the study, it could be that they are all simply manifesting similarly broad and diffuse aspects of the influence of sexual socialisation. However, evidence from the US suggests that distinct sexual and reproductive behaviours have distinct influence. That is, the contextual influence of childbearing appeared to be stronger than that of sexual activity (East, Felice, and Morgan 1993). Future research could speak to this, though note that municipal indicators on adolescent sexual behaviours, contraceptive use, and pregnancy termination do not exist currently for Mexico.

This study also finds evidence that the importance of context differs dramatically not just by age, but by schooling status, and that a girls' relative schooling position matters. That is, there are differences in fertility risk for girls who are in school and out of school depending on how many of their peers are in school or out of school. Additionally, the study indicates that a girl's relative schooling position matters considerably more than her relative position for other socioeconomic characteristics analysed. However, work activity was also salient, both for first and second births. When tied with the conceptualisation of the enrolment and aspirational aspects of schooling on adolescent fertility, this finding opens the door to a research agenda that examines how work and training might operate similarly to schooling, and gives impetus to policy and programming that pushes more strongly for helping adolescent girls enter the labour force where there is arguably more room for improvement than in the expansion of schooling in Latin America and the Caribbean at least.

Longitudinal data, or cross-sectional data with sufficient detail on the sequencing of school leaving, employment and fertility initiation will be imperative for determining what underpins the findings on how one's relative position matters for fertility likelihoods. That is, not only did the direction of the association between adolescent fertility and school enrolment, work status and poverty matter, but a girl's position relative to her peers also made a dramatic difference for her fertility likelihood. In all three characteristics, the models suggested that higher adolescent fertility probabilities became more extreme when it was comparatively uncommon for a girl to experience deprivation. In some sense, this reflects a desperation effect, but in another sense, the metaphor is inadequate because the converse of the patterns were also true. That is, privilege also became less advantageous in situations where deprivation was uncommon. Data that can disentangle the timing of events, and help clarify whether high-enrolment contexts that have more adolescent births among in-school youth is a reflection of it being easier for adolescent mothers to stay in school or return to studying because it is more normative for girls to stay in school longer, or if it because underlying sexual and reproductive behaviours in these settings lead to higher adolescent fertility among the more advantaged. The same for labour force participation. Future research will want to determine whether higher adolescent fertility in places where it is more normative for an adolescent to work exists because employment opportunities are more abundant and it is easier for adolescent mothers to work, or some other explanation. Unfortunately, very little longitudinal data exists on adolescents in low- and middle-income countries. However, there is growing awareness that findings from high-income countries are not representative of the majority of the world's youth and do not often translate to other settings, and as such, interest in longitudinal studies in low- and middle-income settings is increasing (Henirch, Heine, and Norenzayan 2010; Landsford et al. 2021).

Note that in the study second births saw more limited contextual influence, which was in some sense surprising given how dramatically they have declined over the past decades. While the results could simply be a reflection of the small sample size rather than the absence of more dynamic contextual influence on second adolescent births, a more universal access to contraception among adolescents after a first birth could mean that context matters much less. Future research would do well to understand whether there are still groups of adolescent mothers who are experiencing unintended higher-order births or have an unmet need for contraception. Recall that the first and second studies in this thesis suggests that this might be the case. In the first study, women from the lowest schooling levels have seen much less decline in higher-order adolescent births. In the second study, municipalities with similar levels of first births in adolescence had very different levels of progression to second births. Identifying these groups could produce promising direction for future programming and policy in helping identify what adolescent mothers still need help spacing additional births.

Future research would also do well to replicate this third study's analysis in a setting where repeat adolescent childbearing is more common than it is in Mexico and where there are large datasets from which to conduct the analysis. Finding such a context might be challenging, given that there are few low- or middle-income countries that are larger than Mexico and have reliable census data with enough observations to surpass those available in the Mexican data. India offers a possibility. The paper is also limited in that it most likely undercounts the true magnitude of contextual influence in adolescent fertility risk because it examines municipalities, rather than smaller areas such as village or neighbourhoods where the influence is likely to be greater (as suggested by other research). Nevertheless, as described in the paper, the municipal delimitation has valuable policy and program justification.

Finally, there is a continued need to understand how much of adolescent reproductive outcomes are the result of coercion. In addition to the heightened health risks, much of the concern about adolescent fertility arises from the restrictions to adolescents' agency and rights that it can represent. Nevertheless, existing qualitative evidence speaks to an ambiguity here. Fertility can arise from social pressures and lack of other opportunities, but it also is framed as an overwhelmingly positive experience the brings important life meaning (Carvalho 2007; De Rosa, Doyenart, and Lara 2016; Neuhouser 1998; Steele 2011). Even when a pregnancy is not initially planned or wanted, adolescents usually describe how it brings meaning, emotional security, maturation and improved social standing. Motherhood in Latin America and the Caribbean, even adolescent motherhood, is reverenced. Likewise, motherhood is generally represented as the most valuable status a woman can achieve, and, particularly in situations of deprivation, it is often the only positive adult identity open to females in these settings (Lenkiewicz 2013; Steele 2011).

Ultimately, this thesis' exploration of the puzzle of continuity and change in Latin America and the Caribbean's patterns of adolescent fertility make an important contribution to knowledge about parity- and schooling-specific patterns in adolescent fertility as well as differences across the adolescent age schedule.

5.2 Policy Recommendations

To conclude this thesis, and to reiterate the applied value of the analysis, it is worth outlining the leading policy recommendations that are brought forward by this research.

1. Expand access to upper secondary schooling and improve education quality at all levels

The first study highlights the potential power of increasing access to upper secondary and tertiary schooling as a way to lower adolescent fertility. However, simply including upper secondary schooling in the obligatory schooling cycle is not necessarily enough to make it available to the most disadvantaged. Even when official school fees are eliminated, other significant financial barriers can include the cost of books and uniforms, transportation fares and extra-official or 'voluntary' school fees collected locally (Duflo, Dupas, and Kremer 2015). Additionally, exploratory work reviewed in Appendix C cautions against a hasty expansion of access to higher educational levels if it occurs at the expense of leaving the most vulnerable in lower levels of schooling behind.

For example, the distribution of Mexico's public spending on education at upper secondary and tertiary is in many ways contributing to greater inequality in the country whereby public investments in upper secondary and tertiary schooling have mainly benefited the middle and upper classes, primarily in urban areas (Carnoy 2011; Lopez-Acevedo and Salinas 2000).

Existing qualitative evidence suggests that issues of poor quality and disillusionment drive many adolescents out of school (McQueston, Silverman, and Glassman 2012; Näslund-Hadley and Binstock 2011; Sanchez et al. 2006). Additionally, the shifting aspirational power or diminishing marginal returns of education found in the first study suggest that it is imperative the schooling trajectories are able to translate to real world gains in employment and other life prospects if increasingly long schooling careers are going to be relevant for adolescents and their patterns of fertility.

2. Grow employment opportunities in addition to education

Work activity emerged as the second most salient characteristic for individual adolescent fertility probabilities, both for first and second births, in the third study in this thesis. This suggests that labour force participation may operate similarly to schooling in its enrolment (incarcerational) and aspirational links to fertility. Though the association between employment and adolescent fertility may be weaker than it is between schooling and fertility, expanding labour force participation among older adolescents who are out of school, as well as among adolescent mothers, may be highly cost-effective. Given that there is much more room for expansion in female employment than there is in schooling expansion, and that there are millions of out-of-school youth in Latin America who are likely more keen to work than they are to return to school (De Hoyos, Rogers, and Székely 2016), expanding adolescent employment has more low hanging fruit than does schooling where decades of expensive programs have been incentivising students to stay in school (Ordóñez-Barba and Silva-Hernández 2019; P. Schultz 2004). Recall that randomised control trial evidence from the Dominican Republic found that a program that provided training on life skills and employability to youth who had dropped out of school notably decreased adolescent fertility rates even when it had no discernible impact on the adolescent females' actual employment rates (Ibarraran et al. 2014; Novella and Ripani 2016).

3. Move beyond an over-reliance on the adolescent birth rate ($ASFR_{15\text{-}19}$) to more dynamic fertility measures

The adolescent birth rate can be a helpful summary measure of adolescent fertility trends. However, it conveys no parity- or age-specific information and completely ignores early adolescent fertility. Given the dramatic differences in the circumstances leading to births at different adolescent ages and to different birth parities, better targeting and more fully informed policy can best come from other dynamic demographic measures. The routine use of fertility data for girls under the age of 15 is particularly imperative. The second study in this thesis highlighted that Mexico has seen an increase in births in early adolescence, and while the country has set a goal to eliminate early adolescent fertility, no official measures exist to track it. Likewise, all three studies in this thesis have emphasised how trends for second and higher-order births are distinct from those of first births. The second paper brought out that rates of progression to second births among those at risk vary considerably across geographic locations with similar rates of first adolescent births. Very little is understood about the underlying mechanisms of declining repeat births in adolescence in the region.

More broadly, there is a paucity of rigorously evaluated programs that look to reduce repeat adolescent births or target childbearing among the youngest adolescents (Hindin, Michelle J et al. 2016; Igras et al. 2014). It is possible that an over-reliance on the adolescent birth rate as a measure of adolescent childbearing is partly to blame. Without more dynamic measures, the extent of repeat adolescent childbearing and fertility at different adolescent ages has remained largely hidden.

4. Carry out regular estimation of subnational adolescent fertility

In addition to using more dynamic fertility measures to track adolescent fertility, there is an urgent need for regular estimation of measures at the subnational scale to better direct resources. Broad brush rural and urban divisions or large region-level estimates are not enough for adequately directing national policy and programming. The second and third study in this thesis identified considerable geographic heterogeneity as well as specific localities with fertility trends that merit particular attention. Other research in the region indicates that subnational trends elsewhere are similarly complex. For example, adolescent fertility's association to poverty, schooling, socioeconomic status, and rural residence is not always uniform within country subregions (Berquó and Cavenaghi 2005; Flórez 2005; Neal et al. 2018; Núñez and Flórez 2001; Velarde and Zegers-Hochschild 2017).

Not only can subnational estimates identify poor performers in need of extra resources, but subnational estimates can also identify benchmark candidates. Comparing differences in underlying risk predictors between two locations with similar socioeconomic profiles but differing adolescent fertility can provide lessons for action, or at least motivation for action, as was the case in the United Kingdom (Hadley, Chandra-Mouli, and Ingham 2016).

5. Understand the role of context and peers in planning and implementing interventions

There is no silver bullet for eliminating adolescent childbearing, and while programs that keep girls in school have proven time and again to be effective (Baird et al. 2010; Duflo, Dupas, and Kremer 2015; Kalamar, Lee-Rife, and Hindin 2016), there is also an urgent need for the fostering of more productive norms around sexual and reproductive health and rights. Excluding men and boys from the conversation about agency and coercion in sexuality and reproduction leaves girls in an impossible situation: it perpetuates damaging gender bias by putting sole responsibility on adolescent girls for their reproductive outcomes without removing the severe restrictions on their agency that exist in the first place. Other contextual factors such as poverty, lack of employment, and violence, among many other things, also play their part in driving adolescent fertility.

Fortunately, the importance of context is widely acknowledged in adolescent fertility programming. Leading recommendations include addressing aspects of policy and community engagement, health service provision, comprehensive sexuality education, parental and family support as well as individual adolescent girl asset-building (United Nations Population Fund 2015). Evidence from this thesis, strengthens the case for addressing the role of context and peers in planning and implementing interventions, particularly for interventions among the youngest vulnerable mothers.

6. Focus on equity

A stronger approach to equity recognises that marginalised girls can remain at risk even when aggregate trends show considerable improvement. For example, the first paper suggests that adolescent mothers at the lowest schooling levels are not seeing declines in repeat childbearing like their better-educated peers. In the second paper, childbearing in early adolescence is found to be increasing, and this early motherhood carries particularly strong signals of violence, poverty and ill health that carry on through adulthood (Christofides et al. 2014; Jejeebhoy and Bott 2003; Koenig et al. 2004; Moore 2006; Pettifor et al. 2009, 2021). In the third paper, adolescents in situations of disadvantage seem to be at particularly high risk of fertility when they are excluded from surrounding affluence. In effect, more must be done to identify the girls who remain at the margins. More can be done to safeguard their rights and foster opportunities to enable them to eventually lead healthy and fulfilling adult lives and to pass those benefits on to the next generation.

7. Fund new data sources

Many of the outstanding questions regarding the changing relationship between adolescent fertility and schooling in Latin America — and, in particuarl, the underlying changes in the proximate determinants of adolescent fertility — exist because of data limitations. Most surveys that collect detailed fertility data do not provide small-scale subnational representation. As such, changes among adolescents in terms of their sexual debut, sexual activity, union formation patterns, and contraceptive habits, for example, are only understood in broad aggregate strokes. In an era of growing inequality and increasing demographic complexity such high-level overviews offer limited actionable knowledge. Demographic surveillance sites, which are more common in other low- and middle-income regions, could provide the needed deep dive in places where funding is not available for detailed national-scale surveys. Likewise, greater availability of longitudinal data will be critical for untangling the causal relationship between adolescent fertility and schooling, as well as the impact of childbearing on adolescent's life outcomes in the region. Large-scale longitudinal surveys do exist in Latin American countries, but these are almost exclusively focused on labour force participation and other economic measures. If such surveys were to incorporate fertility information, they could fill a sorely-needed data gap.

Appendix A

Appendix to Chapter 2

A.1 Case selection

The use of pooled surveys, or repeated cross-sectional data, extends the study's years of observation to span more than six decades of birth cohorts and increases the sample sizes of all schooling-specific sub-populations, some of which can be quite small in individual surveys. See Tables A.1, A.2, and A.3 below for the number of cases in each schooling level in each country by parity and decade.

School level	Ten-year birth cohorts 1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	Total cases
Colombia								
Some tertiary	2	157	1396	5687	8558	10086	2689	**28575**
Upper secondary complete	5	227	1603	6748	9519	9139	1595	**28836**
Upper secondary incomplete	3	31	224	755	824	904	223	**2964**
Lower secondary complete	1	132	779	1992	1546	1453	286	**6189**
Lower secondary incomplete	15	360	1953	5902	4947	3604	586	**17367**
Primary complete	35	590	2296	6410	5904	2966	319	**18520**
Primary incomplete	126	1238	3375	7005	5749	2659	218	**20370**
No school	50	283	876	1469	1079	451	39	**4247**
Dominican Republic								
Some tertiary	3	128	1131	3239	3961	2729	360	**11551**
Upper secondary complete	5	91	815	2697	2624	1877	263	**8372**
Upper secondary incomplete	10	99	883	2909	3295	2141	175	**9512**
Lower secondary complete	14	159	777	1738	1869	714	57	**5328**
Lower secondary incomplete	6	84	519	1310	1436	642	54	**4051**
Primary complete	8	167	695	1349	1157	411	32	**3819**
Primary incomplete	213	1583	4217	5798	4075	1384	60	**17330**
No school	40	266	1077	1545	918	308	11	**4165**
Guatemala								
Some tertiary	0	16	86	227	409	713	427	**1878**
Upper secondary complete	0	47	163	366	494	860	711	**2641**
Upper secondary incomplete	0	27	88	201	314	487	436	**1553**
Lower secondary complete	0	27	72	170	329	455	425	**1478**
Lower secondary incomplete	0	24	49	166	230	313	268	**1050**
Primary complete	0	131	345	758	1125	1229	789	**4377**
Primary incomplete	0	487	1337	2460	3004	2366	1086	**10740**
No school	0	835	2069	2503	1876	1142	303	**8728**
Haiti								
Some tertiary	0	3	38	172	488	865	343	**1909**
Upper secondary complete	0	0	15	86	237	362	248	**948**
Upper secondary incomplete	0	9	123	673	1992	2218	1234	**6249**
Lower secondary complete	0	7	59	248	663	813	443	**2233**
Lower secondary incomplete	0	7	100	469	1181	1494	844	**4095**
Primary complete	0	11	134	524	856	810	340	**2675**
Primary incomplete	0	97	1076	2708	4043	2888	899	**11711**
No school	0	266	2552	4166	3359	1274	265	**11882**
Mexico								
Some tertiary	25	705	4246	15330	17747	21466	11067	**70586**
Upper secondary complete	10	298	2870	12255	16198	15467	7800	**54898**
Upper secondary incomplete	9	140	1102	4280	5555	5259	2310	**18655**
Lower secondary complete	69	1443	6305	25124	34069	24112	8893	**100015**
Lower secondary incomplete	21	302	1157	3979	4253	2649	1057	**13418**
Primary complete	269	3590	11270	23039	20223	9788	2084	**70263**
Primary incomplete	688	7358	14334	19607	11555	4288	696	**58526**
No school	341	3578	4837	5919	2945	1292	226	**19138**
Peru								
Some tertiary	9	539	3204	11960	15103	12104	772	**43691**
Upper secondary complete	15	509	3145	9248	11686	9231	605	**34439**
Upper secondary incomplete	4	38	270	1043	1383	1206	89	**4033**
Lower secondary complete	7	128	851	2506	2777	1861	112	**8242**
Lower secondary incomplete	9	185	1032	3582	3827	2453	142	**11230**
Primary complete	0	95	1069	2824	6613	4054	188	**14843**
Primary incomplete	118	1946	6824	16757	10611	3904	126	**40286**
No school	55	924	2572	3726	1945	493	6	**9721**

Table A.1: Cases by schooling level: in models of average adolescent births and progression to first birth in adolescence

School level	Ten-year birth cohorts 1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	Total cases
Colombia								
Some tertiary	0	16	126	604	1332	1777	473	**4328**
Upper secondary complete	0	43	261	1347	2765	3315	673	**8404**
Upper secondary incomplete	0	9	54	187	380	501	139	**1270**
Lower secondary complete	1	26	175	598	749	903	192	**2644**
Lower secondary incomplete	1	111	671	2246	2729	2476	450	**8684**
Primary complete	12	211	903	2862	3274	2015	241	**9518**
Primary incomplete	60	528	1627	3750	3668	1982	173	**11788**
No school	31	148	502	903	716	295	29	**2624**
Dominican Republic								
Some tertiary	1	12	129	398	696	501	65	**1802**
Upper secondary complete	1	27	131	529	759	637	95	**2179**
Upper secondary incomplete	4	35	253	949	1547	1110	99	**3997**
Lower secondary complete	2	74	344	810	1115	500	45	**2890**
Lower secondary incomplete	2	41	282	721	953	494	38	**2531**
Primary complete	3	92	359	765	760	318	26	**2323**
Primary incomplete	118	927	2654	3761	2890	1076	43	**11469**
No school	31	175	679	1024	669	221	8	**2807**
Guatemala								
Some tertiary	0	2	9	20	45	70	24	**170**
Upper secondary complete	0	5	16	55	64	137	88	**365**
Upper secondary incomplete	0	7	26	52	88	135	96	**404**
Lower secondary complete	0	9	26	46	116	175	172	**544**
Lower secondary incomplete	0	7	18	63	98	162	149	**497**
Primary complete	0	44	128	325	478	548	386	**1909**
Primary incomplete	0	245	759	1358	1684	1271	617	**5934**
No school	0	442	1213	1605	1147	658	178	**5243**
Haiti								
Some tertiary	0	1	0	7	22	24	5	**59**
Upper secondary complete	0	0	0	3	15	28	11	**57**
Upper secondary incomplete	0	2	13	59	209	276	155	**714**
Lower secondary complete	0	1	8	42	144	217	99	**511**
Lower secondary incomplete	0	1	22	103	296	428	269	**1119**
Primary complete	0	2	22	113	288	342	176	**943**
Primary incomplete	0	23	263	932	1733	1366	462	**4779**
No school	0	90	761	1648	1712	702	164	**5077**
Mexico								
Some tertiary	2	57	329	1172	1288	1595	907	**5350**
Upper secondary complete	0	32	522	2063	2847	3506	2127	**11097**
Upper secondary incomplete	2	22	257	1037	1438	1880	1247	**5883**
Lower secondary complete	9	257	1746	8372	12577	11476	5003	**39440**
Lower secondary incomplete	4	84	462	2079	2368	1741	763	**7501**
Primary complete	76	1094	4585	10969	9412	5196	1222	**32554**
Primary incomplete	354	3603	8013	11472	6425	2548	425	**32840**
No school	179	1926	2834	3632	1680	716	120	**11087**
Peru								
Some tertiary	0	41	347	1201	1517	1177	77	**4360**
Upper secondary complete	4	118	746	2466	3365	2924	222	**9845**
Upper secondary incomplete	1	14	113	484	699	732	65	**2108**
Lower secondary complete	2	39	363	1279	1556	1208	70	**4517**
Lower secondary incomplete	3	62	494	1997	2295	1661	102	**6614**
Primary complete	0	38	494	1422	3704	2552	121	**8331**
Primary incomplete	54	967	3572	9429	6500	2635	81	**23238**
No school	30	461	1379	2107	1134	337	2	**5450**

Table A.2: Cases by schooling level: in models of progression to second birth in adolescence

School level	Ten-year birth cohort 1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	Total cases
Colombia								
Some tertiary	0	6	21	123	211	200	34	**595**
Upper secondary complete	0	19	79	326	559	540	101	**1624**
Upper secondary incomplete	0	5	18	45	91	118	29	**306**
Lower secondary complete	1	10	41	159	200	229	65	**705**
Lower secondary incomplete	1	51	205	666	857	833	147	**2760**
Primary complete	3	100	342	1037	1231	777	109	**3599**
Primary incomplete	29	282	794	1683	1730	1006	99	**5623**
No school	17	92	269	508	421	189	17	**1513**
Dominican Republic								
Some tertiary	1	2	46	89	162	87	8	**395**
Upper secondary complete	0	11	34	151	209	137	10	**552**
Upper secondary incomplete	1	15	102	285	526	353	32	**1314**
Lower secondary complete	0	31	151	325	450	209	16	**1182**
Lower secondary incomplete	2	21	121	330	445	230	18	**1167**
Primary complete	1	50	141	347	355	182	10	**1086**
Primary incomplete	61	500	1418	2027	1631	627	19	**6283**
No school	18	109	392	607	381	118	4	**1629**
Guatemala								
Some tertiary	0	1	2	1	8	8	3	**23**
Upper secondary complete	0	0	1	12	6	20	8	**47**
Upper secondary incomplete	0	3	5	11	18	22	9	**68**
Lower secondary complete	0	1	8	13	31	29	21	**103**
Lower secondary incomplete	0	4	5	20	27	34	32	**122**
Primary complete	0	20	45	114	182	164	115	**640**
Primary incomplete	0	107	359	619	792	558	203	**2638**
No school	0	205	591	841	570	332	83	**2622**
Haiti								
Some tertiary	0	0	0	0	4	1	1	**6**
Upper secondary complete	0	0	0	1	1	1	1	**4**
Upper secondary incomplete	0	1	2	10	37	31	15	**96**
Lower secondary complete	0	0	3	9	33	36	16	**97**
Lower secondary incomplete	0	1	5	19	70	78	37	**210**
Primary complete	0	0	5	33	96	82	40	**256**
Primary incomplete	0	6	93	322	611	420	152	**1604**
No school	0	39	329	766	776	300	63	**2273**
Mexico								
Some tertiary	0	15	82	207	193	180	75	**752**
Upper secondary complete	0	12	152	406	484	523	287	**1864**
Upper secondary incomplete	2	8	78	257	301	397	275	**1318**
Lower secondary complete	6	109	663	2714	3783	3398	1485	**12158**
Lower secondary incomplete	2	46	216	911	938	708	321	**3142**
Primary complete	40	540	2223	5087	3806	2055	522	**14273**
Primary incomplete	192	2068	4639	6533	3239	1205	212	**18088**
No school	100	1135	1766	2244	957	367	63	**6632**
Peru								
Some tertiary	0	9	86	208	163	56	4	**526**
Upper secondary complete	3	41	236	614	553	294	25	**1766**
Upper secondary incomplete	0	5	41	147	162	114	15	**484**
Lower secondary complete	0	12	116	444	434	245	16	**1267**
Lower secondary incomplete	1	25	186	785	826	435	24	**2282**
Primary complete	0	19	214	537	1386	813	43	**3012**
Primary incomplete	21	480	1735	4186	2809	1012	34	**10277**
No school	12	249	729	959	492	138	1	**2580**

Table A.3: Cases by schooling level: in models of progression to third birth in adolescence

A.2 Regression equations and tables

Separate regression equations were run for each parity and for cumulative fertility in each country, but they follow the same general format:

$$f(x) = \beta_0 + \beta_1 \text{birthyear}_{ij} + \beta_2 \text{schoollevel}_{ij} + \beta_3 \text{birthyear}_{ij} \times \text{schoollevel}_{ij} + \epsilon$$

For the models of parity progression, $f(x)$ takes the form of binomial regression or $\log(\frac{\pi_{ij}}{1-\pi_{ij}})$ where π represents the corresponding parity progression (either from none to first births, first to second births or second to third births for women *i* in country *j*. For cumulative adolescent fertility, $f(x)$ takes the form of a poisson regression or $\frac{e^{-\lambda}\lambda^{x}}{x!}$ where x is the number of births, *e* is the Euler's number (e=2.718), and λ is the expected value of x when also equal to its variance. For the models of age at first birth, the $f(x)$ simply represents the outcome variable of age.

The intercept β_0 is shared by all women, and *birthyear* is a linear term of the woman's year of birth while *schoollevel* is a categorical term with tertiary schooling as the reference. See individual tables of regression results for the precise schooling categories used in final models, as some individual schooling levels were collapsed when testing indicated that they were not statistically distinct from each other.

For the Generalized Additive Model regressions, the equations are similar but the β are replaced with s to denote the smoothing functions, which are restricted maximum likelihood (REML) splines.

	Dependent variable:			
	First birth	Second birth	Third birth	Average births
	survey-weighted logistic	*survey-weighted logistic*	*survey-weighted logistic*	*svyglm: quasipoisson link = log*
	(1)	(2)	(3)	(4)
Woman's birth year	0.017^{***}	-0.040^{***}	-0.023	0.010^{***}
	(0.003)	(0.008)	(0.015)	(0.002)
Some tertiary (reference)				
USC	-49.209^{***}	-26.563		-31.193^{***}
	(6.377)	(16.942)		(5.595)
USI & LSC	-83.023^{***}	-80.102^{***}		-43.059^{***}
	(8.005)	(18.027)		(6.130)
LSI	-73.341^{***}	-81.482^{***}		-30.299^{***}
	(6.676)	(16.723)		(5.475)
PC	-37.375^{***}	-78.888^{***}		-13.893^{**}
	(6.630)	(16.572)		(5.495)
PI	-26.688^{***}	-76.580^{***}		-4.355
	(6.443)	(16.125)		(5.325)
NS	13.078	-89.424^{***}		16.089^{**}
	(8.876)	(18.172)		(6.408)
Some tertiary (reference)				
Year * USC	0.025^{***}	0.014		0.016^{***}
	(0.003)	(0.009)		(0.003)
Year * USI & LSC	0.043^{***}	0.041^{***}		0.022^{***}
	(0.004)	(0.009)		(0.003)
Year * LSI	0.038^{***}	0.042^{***}		0.016^{***}
	(0.003)	(0.008)		(0.003)
Year * PC	0.020^{***}	0.041^{***}		0.008^{***}
	(0.003)	(0.008)		(0.003)
Year * PI	0.015^{***}	0.040^{***}		0.003
	(0.003)	(0.008)		(0.003)
Year * NS	-0.005	0.046^{***}		-0.007^{**}
	(0.005)	(0.009)		(0.003)
Some tertiary (reference)				
USC, USI, LSC & LSI			-6.070	
			(31.825)	
PC			-24.633	
			(31.513)	
PI			-37.569	
			(30.358)	
NS			-4.431	
			(32.335)	
Some tertiary (reference)				
Year * USC to LSI			0.003	
			(0.016)	
Year * PC			0.013	
			(0.016)	
Year * PI			0.020	
			(0.015)	
Year * NS			0.003	
			(0.016)	
Constant	-34.887^{***}	78.065^{***}	43.893	-21.577^{***}
	(5.211)	(15.623)	(29.627)	(4.935)
Observations	127,068	49,260	16,725	127,068

Note: *p<0.1; **p<0.05; ***p<0.01
USC = Upper secondary complete, USI = Upper secondary incomplete
LSC = Lower secondary complete, LSI = Lower secondary complete
PC = Primary complete, PI = Primary incomplete, NS = No school

Table A.4: Colombia regression results

	Dependent variable:			
	First birth	Second birth	Third birth	Average births
	survey-weighted logistic	*survey-weighted logistic*	*survey-weighted logistic*	*svyglm: quasipoisson link = log*
	(1)	(2)	(3)	(4)
Woman's birth year	0.016^{***}	-0.022^{***}	-0.009^{***}	0.007^{**}
	(0.004)	(0.006)	(0.002)	(0.004)
Some tertiary (reference)				
USC	-34.301^{***}			
	(10.902)			
USI	-37.030^{***}			
	(9.925)			
LSC	-41.324^{***}			
	(11.116)			
LSI & PC	-46.785^{***}			
	(10.160)			
PI & NS	-6.127			
	(8.526)			
Some tertiary (reference)				
Year * USC	0.018^{***}			
	(0.006)			
Year * USI	0.020^{***}			
	(0.005)			
Year * LSC	0.022^{***}			
	(0.006)			
Year * LSI & PC	0.025^{***}			
	(0.005)			
Year * PI & NS	0.004			
	(0.004)			
Some tertiary & USC (reference)				
USI		-32.542^{**}		
		(15.503)		
LSC		-26.002^{*}		
		(14.643)		
LSI		-41.628^{***}		
		(15.223)		
PC		-77.364^{***}		
		(15.570)		
PI		-54.355^{***}		
		(11.937)		
NS		-27.398^{*}		
		(15.059)		
Some tertiary & USC (reference)				
Year * USI		0.017^{**}		
		(0.008)		
Year * LSC		0.014^{*}		
		(0.007)		
Year * LSI		0.022^{***}		
		(0.008)		
Year * PC		0.040^{***}		
		(0.008)		
Year * PI		0.028^{***}		
		(0.006)		
Year * NS		0.015^{*}		
		(0.008)		
Some tertiary, USC & USI (reference)				
LSC, LSI & PC			0.439^{***}	
			(0.099)	
PI			0.869^{***}	
			(0.090)	
NS			1.081^{***}	
			(0.110)	
Some tertiary (reference)				
USC				-28.908^{***}
				(9.516)
USI				-21.743^{**}
				(8.501)
LSC				-14.676^{*}
				(8.468)
LSI & PC				-17.299^{**}
				(7.881)
PI				3.187
				(7.397)
NS				12.502
				(8.182)
Some tertiary (reference)				
Year * USC				0.015^{***}
				(0.005)
Year * USI				0.012^{***}
				(0.004)
Year * LSC				0.008^{*}
				(0.004)
Year * LSI & PC				0.010^{**}
				(0.004)
Year * PI				-0.001
				(0.004)
Year * NS				-0.005
				(0.004)
Constant	-32.626^{***}	41.959^{***}	15.693^{***}	-16.448^{**}
	(7.678)	(11.025)	(4.861)	(7.156)
Observations	64,128	29,998	13,608	64,128
Note:				*p<0.1; **p<0.05; ***p<0.01
				USC = Upper secondary complete, USI = Upper secondary incomplete
				LSC = Lower secondary complete, LSI = Lower secondary complete
				PC = Primary complete, PI = Primary incomplete, NS = No school

Table A.5: Dominican Republic regression results

	Dependent variable:			
	First birth	Second birth	Third birth	Average births
	survey-weighted logistic	*survey-weighted logistic*	*survey-weighted logistic*	*svyglm: quasipoisson link = log*
	(1)	(2)	(3)	(4)
Woman's birth year	-0.015^{*}	-0.004	-0.363^{**}	-0.019^{*}
	(0.008)	(0.014)	(0.176)	(0.010)
Some tertiary (reference)				
USC	-26.380			-35.040^{*}
	(19.633)			(21.064)
USI	-12.468			-19.435
	(20.033)			(22.437)
LSC	-51.350^{***}			-42.234^{**}
	(19.560)			(21.060)
LSI & PC	-57.211^{***}			-43.980^{**}
	(18.033)			(20.341)
PI	-31.772^{*}			-31.835
	(17.553)			(19.732)
NS	-34.951^{**}			-37.066^{*}
	(17.258)			(19.716)
Some tertiary (reference)				
Year * USC	0.014			0.018^{*}
	(0.010)			(0.011)
Year * USI	0.007			0.010
	(0.010)			(0.011)
Year * LSC	0.027^{***}			0.022^{**}
	(0.010)			(0.011)
Year * LSI & PC	0.030^{***}			0.023^{**}
	(0.009)			(0.010)
Year * PI	0.017^{*}			0.017^{*}
	(0.009)			(0.010)
Year * NS	0.019^{**}			0.020^{**}
	(0.009)			(0.010)
Some tertiary & USC (reference)				
USI, LSC & LSI		35.574		
		(30.046)		
PC		17.767		
		(28.599)		
PI		10.376		
		(27.576)		
NS		-7.797		
		(27.687)		
Some tertiary & USC (reference)				
Year * USI, LSC & LSI		-0.018		
		(0.015)		
Year * PC		-0.008		
		(0.014)		
Year * PI		-0.004		
		(0.014)		
Year * NS		0.005		
		(0.014)		
Some tertiary (reference)				
USC			-794.354^{**}	
			(348.932)	
USI			-801.055^{**}	
			(348.988)	
LSC, LSI & PC			-659.215^{*}	
			(347.147)	
PI			-689.473^{**}	
			(346.774)	
NS			-708.391^{**}	
			(346.921)	
Some tertiary (reference)				
Year * USC			0.402^{**}	
			(0.177)	
Year * USI			0.406^{**}	
			(0.177)	
Year * LSC, LSI & PC			0.335^{*}	
			(0.176)	
Year * PI			0.350^{**}	
			(0.176)	
Year * NS			0.360^{**}	
			(0.176)	
Constant	27.094	6.077	714.178^{**}	34.734^{*}
	(16.758)	(27.393)	(346.828)	(19.568)
Observations	32,445	15,066	6,263	32,445

Note: *p<0.1; **p<0.05; ***p<0.01
USC = Upper secondary complete, USI = Upper secondary incomplete
LSC = Lower secondary complete, LSI = Lower secondary complete
PC = Primary complete, PI = Primary incomplete, NS = No school

Table A.6: Guatemala regression results

	Dependent variable:			
	First birth	Second birth	Third birth	Average births
	survey-weighted logistic	*survey-weighted logistic*	*survey-weighted logistic*	*svyglm: quasipoisson link = log*
	(1)	(2)	(3)	(4)
Woman's birth year	-0.037^{***}	-0.043^{***}	-0.019^{***}	-0.041^{***}
	(0.014)	(0.013)	(0.005)	(0.013)
Some tertiary (reference)				
USC	-96.598^{**}			-100.851^{***}
	(40.822)			(38.332)
USI	-105.580^{***}			-100.450^{***}
	(28.682)			(26.966)
LSC	-88.674^{***}			-88.900^{***}
	(30.340)			(27.383)
LSI	-105.881^{***}			-99.034^{***}
	(28.937)			(26.453)
PC	-154.837^{***}			-128.375^{***}
	(28.899)			(26.014)
PI	-124.552^{***}			-106.756^{***}
	(27.220)			(25.266)
NS	-139.618^{***}			-112.810^{***}
	(27.861)			(25.552)
Some tertiary (reference)				
Year * USC	0.049^{**}			0.051^{***}
	(0.021)			(0.019)
Year * USI	0.054^{***}			0.051^{***}
	(0.014)			(0.014)
Year * LSC	0.046^{***}			0.046^{***}
	(0.015)			(0.014)
Year * LSI	0.055^{***}			0.051^{***}
	(0.015)			(0.013)
Year * PC	0.080^{***}			0.066^{***}
	(0.015)			(0.013)
Year * PI	0.065^{***}			0.055^{***}
	(0.014)			(0.013)
Year * NS	0.072^{***}			0.059^{***}
	(0.014)			(0.013)
Some tertiary, USC & USI (reference)				
LSC & LSI		-48.710^{*}		
		(29.045)		
PC		-61.564^{**}		
		(30.989)		
PI		-75.383^{***}		
		(26.939)		
NS		-76.743^{***}		
		(26.417)		
Some tertiary, USC & USI (reference)				
Year * LSC & LSI		0.025^{*}		
		(0.015)		
Year * PC		0.032^{**}		
		(0.016)		
Year * PI		0.039^{***}		
		(0.014)		
Year * NS		0.040^{***}		
		(0.013)		
Some tertiary (reference)				
USC			12.587^{***}	
			(0.446)	
USI, LSC & LSI			13.403^{***}	
			(0.412)	
PC & PI			13.798^{***}	
			(0.404)	
Constant	68.917^{**}	83.912^{***}	22.561^{**}	77.671^{***}
	(27.125)	(25.774)	(9.976)	(25.267)
Observations	41,702	13,259	4,546	41,702
Note:				*p<0.1; **p<0.05; ***p<0.01

USC = Upper secondary complete, USI = Upper secondary incomplete
LSC = Lower secondary complete, LSI = Lower secondary complete
PC = Primary complete, PI = Primary incomplete, NS = No school

Table A.7: Haiti regression results

	Dependent variable:			
	First birth	Second birth	Third birth	Average births
	survey-weighted logistic	*survey-weighted logistic*	*survey-weighted logistic*	*svyglm: quasipoisson link = log*
	(1)	(2)	(3)	(4)
Woman's birth year	0.0003	-0.024^{***}	-0.014	-0.003^{*}
	(0.002)	(0.006)	(0.013)	(0.002)
Some tertiary (reference)				
USC	-38.630^{***}	-8.845		-29.948^{***}
	(4.915)	(13.040)		(4.670)
USI	-73.534^{***}	-26.808^{*}		-51.307^{***}
	(6.034)	(15.284)		(5.536)
LSC	-65.140^{***}	-36.090^{***}		-43.013^{***}
	(4.288)	(11.580)		(3.878)
LSI	-63.868^{***}	-41.665^{***}		-31.050^{***}
	(6.025)	(11.965)		(4.474)
PC	-36.587^{***}	-25.189^{**}		-18.819^{***}
	(4.234)	(11.469)		(3.872)
PI	-13.676^{***}	-24.252^{**}		-4.030
	(4.368)	(11.373)		(3.879)
NS	-4.152	-27.556^{**}		1.147
	(5.163)	(11.925)		(4.227)
Some tertiary (reference)				
Year * USC	0.020^{***}	0.005		0.016^{***}
	(0.002)	(0.007)		(0.002)
Year * USI	0.038^{***}	0.014^{*}		0.027^{***}
	(0.003)	(0.008)		(0.003)
Year * LSC	0.034^{***}	0.019^{***}		0.023^{***}
	(0.002)	(0.006)		(0.002)
Year * LSI	0.034^{***}	0.022^{***}		0.017^{***}
	(0.003)	(0.006)		(0.002)
Year * PC	0.020^{***}	0.013^{**}		0.011^{***}
	(0.002)	(0.006)		(0.002)
Year * PI	0.008^{***}	0.013^{**}		0.003^{*}
	(0.002)	(0.006)		(0.002)
Year * NS	0.004	0.015^{**}		0.001
	(0.003)	(0.006)		(0.002)
Some tertiary (reference)				
USC			64.387^{**}	
			(29.726)	
USI, LSC, LSI, PC, PI & NS			30.037	
			(25.048)	
Some tertiary (reference)				
Year * USC			-0.033^{**}	
			(0.015)	
Year * USI to NS			-0.015	
			(0.013)	
Constant	-3.085	44.743^{***}	25.890	3.965
	(3.848)	(11.024)	(24.966)	(3.721)
Observations	405,499	145,752	58,227	405,499

Note: *p<0.1; **p<0.05; ***p<0.01
USC = Upper secondary complete, USI = Upper secondary incomplete
LSC = Lower secondary complete, LSI = Lower secondary complete
PC = Primary complete, PI = Primary incomplete, NS = No school

Table A.8: Mexico regression results

	Dependent variable:			
	First birth	Second birth	Third birth	Average births
	survey-weighted logistic	*survey-weighted logistic*	*survey-weighted logistic*	*svyglm: quasipoisson link = log*
	(1)	(2)	(3)	(4)
Woman's birth year	-0.001	-0.026^{***}	-0.057^{***}	-0.008^{***}
	(0.002)	(0.004)	(0.006)	(0.002)
Some tertiary (reference)				
USC	-22.088^{***}			-14.548^{***}
	(5.473)			(5.050)
USI	-51.164^{***}			-28.491^{***}
	(9.745)			(6.742)
LSC	-55.455^{***}			-27.999^{***}
	(7.357)			(5.525)
LSI	-57.355^{***}			-25.516^{***}
	(6.642)			(5.054)
PC	-39.007^{***}			-22.917^{***}
	(6.661)			(5.228)
PI	-34.343^{***}			-20.088^{***}
	(5.245)			(4.667)
NS	-24.885^{***}			-12.795^{**}
	(6.540)			(5.130)
Some tertiary (reference)				
Year * USC	0.012^{***}			0.008^{***}
	(0.003)			(0.003)
Year * USI	0.027^{***}			0.015^{***}
	(0.005)			(0.003)
Year * LSC	0.029^{***}			0.015^{***}
	(0.004)			(0.003)
Year * LSI	0.030^{***}			0.014^{***}
	(0.003)			(0.003)
Year * PC	0.021^{***}			0.013^{***}
	(0.003)			(0.003)
Year * PI	0.019^{***}			0.011^{***}
	(0.003)			(0.002)
Year * NS	0.014^{***}			0.008^{***}
	(0.003)			(0.003)
Some tertiary (reference)				
USC		-23.945^{**}		
		(9.454)		
USI & LSC		-16.043^{*}		
		(9.221)		
LSI		-24.990^{***}		
		(7.772)		
PC		53.313^{***}		
		(15.164)		
PI		48.672^{***}		
		(9.968)		
NS		8.202		
		(10.286)		
Some tertiary (reference)				
Year * USC		0.012^{**}		
		(0.005)		
Year * USI & LSC		0.008^{*}		
		(0.005)		
Year * LSI		0.013^{***}		
		(0.004)		
Year * PC		-0.028^{***}		
		(0.008)		
Year * PI		-0.025^{***}		
		(0.005)		
Year * NS		-0.004		
		(0.005)		
Some tertiary, USC, USI & LSC (reference)				
LSI & PC			-36.188^{**}	
			(15.907)	
PI			-64.941^{***}	
			(13.388)	
NS			-52.138^{***}	
			(15.432)	
Some tertiary, USC, USI & LSC (reference)				
Year * LSI & PC			0.019^{**}	
			(0.008)	
Year * PI			0.033^{***}	
			(0.007)	
Year * NS			0.027^{***}	
			(0.008)	
Constant	-0.487	49.833^{***}	109.865^{***}	12.926^{***}
	(4.555)	(7.036)	(12.182)	(4.435)
Observations	166,485	64,463	22,194	166,485

Note: *p<0.1; **p<0.05; ***p<0.01
USC = Upper secondary complete, USI = Upper secondary incomplete
LSC = Lower secondary complete, LSI = Lower secondary complete
PC = Primary complete, PI = Primary incomplete, NS = No school

Table A.9: Peru regression results

	Successive sets of quasibinomial weighted regressions		
	Parametric coefficients		Smoothing term (Woman's birth year)
Schooling level	Estimate	Standard error	Effective degrees of freedom
Colombia			
Some tertiary	-1.171	(0.007)***	7.501***
USC	-1.230	(0.007)***	6.216***
USI	-3.778	(0.019)***	5.801***
LSC	-2.991	(0.013)***	7.225***
LSI	-1.913	(0.008)***	6.541***
PC	-1.904	(0.008)***	7.356***
PI	-1.938	(0.009)***	7.538***
NS	-3.796	(0.019)***	8.531***
Dominican Republic			
Some tertiary	-1.402	(0.011)***	6.548***
USC	-1.886	(0.013)***	7.726***
USI	-1.708	(0.012)***	6.835***
LSC	-2.366	(0.014)***	6.580***
LSI	-2.742	(0.017)***	6.198***
PC	-2.801	(0.017)***	7.751***
PI	-1.263	(0.010)***	6.820***
NS	-3.110	(0.018)***	6.001***
Guatemala			
Some tertiary	-2.816	(0.028)***	7.181***
USC	-2.501	(0.023)***	8.368***
USI	-2.937	(0.029)***	4.121***
LSC	-3.032	(0.030)***	5.359***
LSI	-3.376	(0.034)***	7.727***
PC	-1.842	(0.017)***	4.637***
PI	-0.748	(0.012)***	4.522***
NS	-1.236	(0.015)***	7.247***
Haiti			
Some tertiary	-3.114	(0.0314)***	7.305***
USC	-3.863	(0.051)***	8.186***
USI	-1.822	(0.017)***	6.620***
LSC	-2.972	(0.025)***	5.180***
LSI	-2.402	(0.020)***	6.395***
PC	-2.734	(0.021)***	4.943***
PI	-1.004	(0.011)***	5.037***
NS	-1.212	(0.014)***	5.347***
Mexico			
Some tertiary	-1.616	(0.005)***	8.423***
USC	-1.953	(0.005)***	7.670***
USI	-3.100	(0.008)***	8.718***
LSC	-1.162	(0.004)***	8.365***
LSI	-3.395	(0.009)***	8.486***
PC	-1.619	(0.004)***	8.236***
PI	-2.086	(0.006)***	8.584***
NS	-3.331	(0.011)***	8.768***
Peru			
Some tertiary	-0.890	(0.006)***	5.418***
USC	-1.180	(0.006)***	6.516***
USI	-3.762	(0.017)***	7.963***
LSC	-2.990	(0.011)***	8.074***
LSI	-2.738	(0.010)***	5.765***
PC	-2.561	(0.010)***	8.728***
PI	-1.455	(0.006)***	8.214***
NS	-3.322	(0.015)***	7.261***

Note. USC = Upper secondary complete, USI = Upper secondary incomplete, LSC = Lower secondary complete, LSI = Lower secondary complete, PC = Primary complete, PI = Primary incomplete, NS = No school

Table A.10: GAM regression results: Education composition

	Successive sets of weighted regressions		
	Parametric coefficients		Smoothing term (Woman's birth year)
Schooling level	Estimate	Standard error	Effective degrees of freedom
Colombia			
First birth	-0.600	(0.006)***	7.899***
Second birth	-0.786	(0.007)***	6.216***
Third birth	-1.312	(0.021)***	3.851***
Average births	-0.704	(0.004)***	8.108***
Age at first birth	212.480	(0.083)***	5.784***
Dominican Republic			
First birth	-0.290	(0.008)***	7.362***
Second birth	-0.265	(0.012)***	4.188***
Third birth	-0.917	(0.020)***	1.008***
Average births	-0.386	(0.005)***	7.635***
Age at first birth	209.048	(0.119)***	5.454***
Guatemala			
First birth	-0.179	(0.011)***	6.804***
Second birth	-0.389	(0.017)***	4.274***
Third birth	-1.117	(0.0303)***	3.888***
Average births	-0.378	(0.007)***	7.031***
Age at first birth	211.301	(0.154)***	1.190***
Haiti			
First birth	-0.793	(0.011)***	5.518***
Second birth	-0.694	(0.019)***	4.877***
Third birth	-1.228	(0.037)***	1.003***
Average births	-0.814	(0.007)***	6.041***
Age at first birth	212.160	(0.168)***	4.287***
Mexico			
First birth	-0.633	(0.003)***	8.181***
Second birth	-0.441	(0.006)***	6.172***
Third birth	-0.954	(0.010)***	4.984***
Average births	-0.640	(0.002)***	8.340***
Age at first birth	212.628	(0.051)***	7.621***
Peru			
First birth	-0.677	(0.005)***	6.824***
Second birth	-0.775	(0.009)***	6.361***
Third birth	-1.374	(0.019)***	2.749***
Average births	-0.756	(0.004)***	1.023***
Age at first birth	213.911	(0.071)***	5.777***

Note. Age measured in months, parity progressions are binomial logistic regressions, average births are Poisson regressions, and average age are Gaussian regressions

Table A.11: GAM regression results: National-level trends

	Successive sets of weighted Gaussian regressions		
	Parametric coefficients		Smoothing term (Woman's birth year)
Schooling level	Estimate	Standard error	Effective degrees of freedom
Colombia			
USI to some tertiary	216.501	(0.140)***	6.693***
LSC	214.296	(0.337)***	2.599***
LSI	212.465	(0.183)***	4.714***
PC	211.846	(0.185)***	4.013***
PI	208.548	(0.181)***	4.042***
NS	203.141	(0.434)***	4.356***
Dominican Republic			
USC + some tertiary	216.597	(0.278)***	1.020***
USI	213.996	(0.292)***	4.252***
LSC	211.181	(0.354)***	4.158***
LSI	209.122	(0.3745)***	3.848***
PC	209.300	(0.392)***	1.549***
PI	205.039	(0.197)***	5.974***
NS	199.751	(0.454)***	3.857***
Guatemala			
USC	222.962	(0.779)***	1.001*
LSC + USI + Some tertiary	217.805	(0.4817)***	4.017
PC + LSI	214.589	(0.339)***	1.009***
PI	210.520	(0.237)***	1.008***
NS	207.960	(0.284)***	4.215***
Haiti			
LSI to some tertiary	216.906	(0.339)***	1.012***
PI + PC	212.786	(0.2468)***	4.921***
NS	208.818	(0.293)***	2.214***
Mexico			
USC + some tertiary	220.496	(0.134)***	6.363***
USI	218.671	(0.199)***	3.098***
LSC	215.699	(0.086)***	7.213***
PC + LSI	211.861	(0.094)***	4.928***
PI	208.130	(0.116)***	6.232***
NS	203.309	(0.232)***	6.127***
Peru			
Some tertiary	221.257	(0.234)***	1.003***
USC	219.486	(0.154)***	2.928***
USI	216.576	(0.339)***	2.347***
LSC	215.078	(0.239)***	1.036***
PC + LSI	212.423	(0.143)***	3.106***
PI	210.960	(0.124)***	4.814***
NS	208.593	(0.286)***	7.137***

Note. USC = Upper secondary complete, USI = Upper secondary incomplete, LSC = Lower secondary complete, LSI = Lower secondary complete, PC = Primary complete, PI = Primary incomplete, NS = No school

Table A.12: GAM regression results: Mean age by schooling level

Appendix B

Appendix to Chapter 3

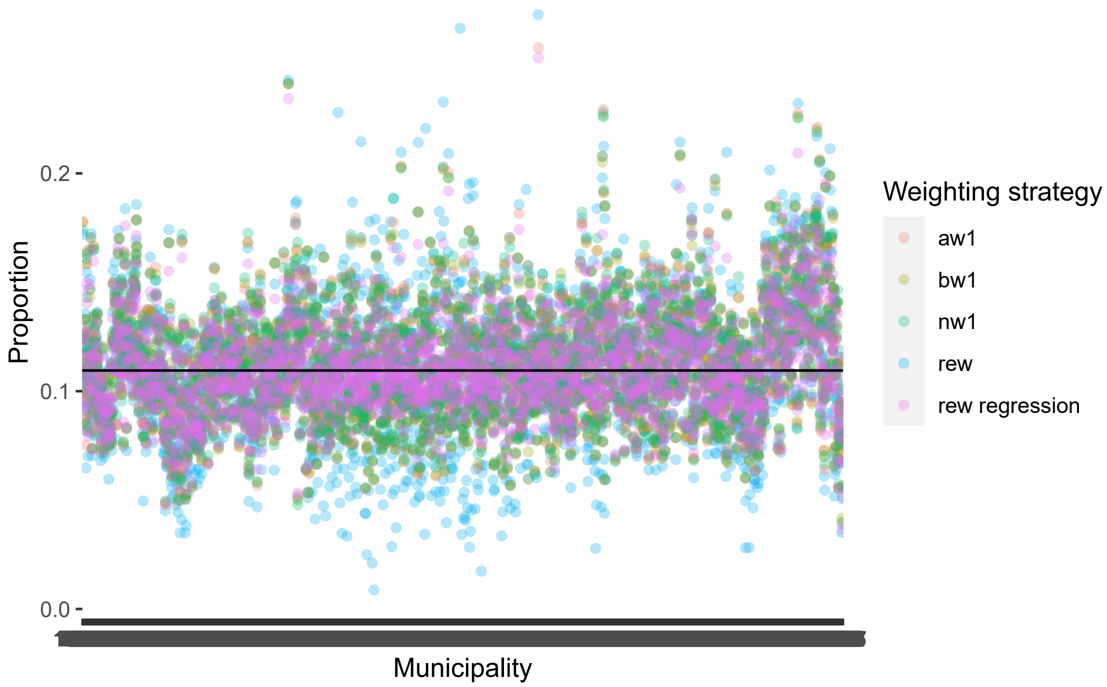
B.1 Uncertainty: weighting and confidence intervals

The following discussion of the weighting options and confidence intervals is important for understanding that there is uncertainty in the estimates of municipal parity- and age-specific fertility measures. Figure B.1 shows estimated municipal proportions (all ages across all time points for first births) by type of weighting. “Rew” are the weighted proportions (no multilevel model regressions but rather the weighted proportions using the given complex survey design weights rescaled to sample size instead of population size), which gives many more extreme values at top and bottom. “Aw1” weights are the weights rescaled to the sample size and “bw1” are weights rescaled to the effective sample size, “nw1” are no weights while “rew regression” are design weights used in regressions (rather than weighted proportions). “Aw1” seem to have the least shrinkage while “Rew regression” and “nw1” seem to have the most shrinkage. “Bw1” are more similar to “aw1” but have slightly more shrinkage so “aw1” most similar to raw proortions while “bw1” more conservative estimates.

The differences between the weights can be seen more clearly if show a selection of municipalities instead of all of them. Figure B.2 shows municipalities in the state of Aguascalientes. “rew regressions” and “nw1” generally have the most shrinkage while “bw1” and “aw1” are closer to the raw proportions, with “aw1” slightly closer than “bw1”.

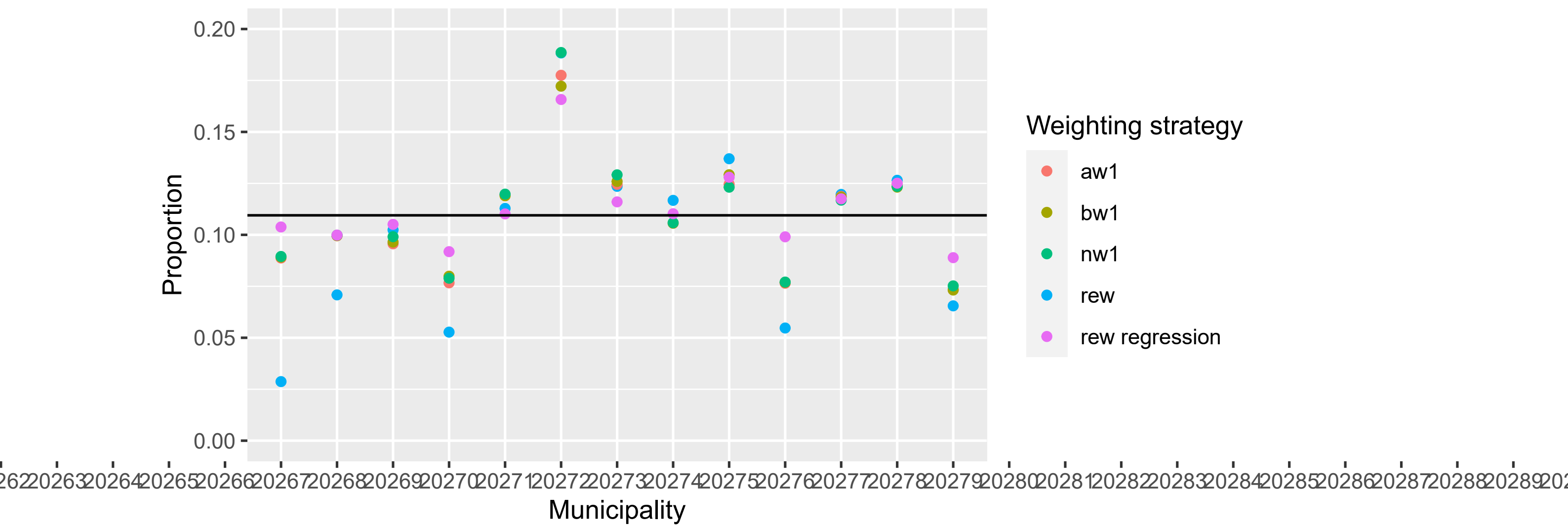
Mapping the various weighting strategies gives better idea of the range in values. Figure B.3 maps them by quintiles. While the quintiles differ very slightly, the broad geographical patterns are still the same no matter the weighting strategy, which gives more confidence to the results. Map A shows the raw weighted proportions (using raw design weights and no regression model, map B shows the unweighted model, map C shows the model with weights scaled to cluster size (aw1), map D shows model with weights scaled to effective cluster size (bw1), map E shows the model with weights scaled to sample size (original design weights are scaled to the population size).

Figure B.1: Proportion of adolescents aged 12-20 with a birth by municipality and type of weighting strategy, all municipalities



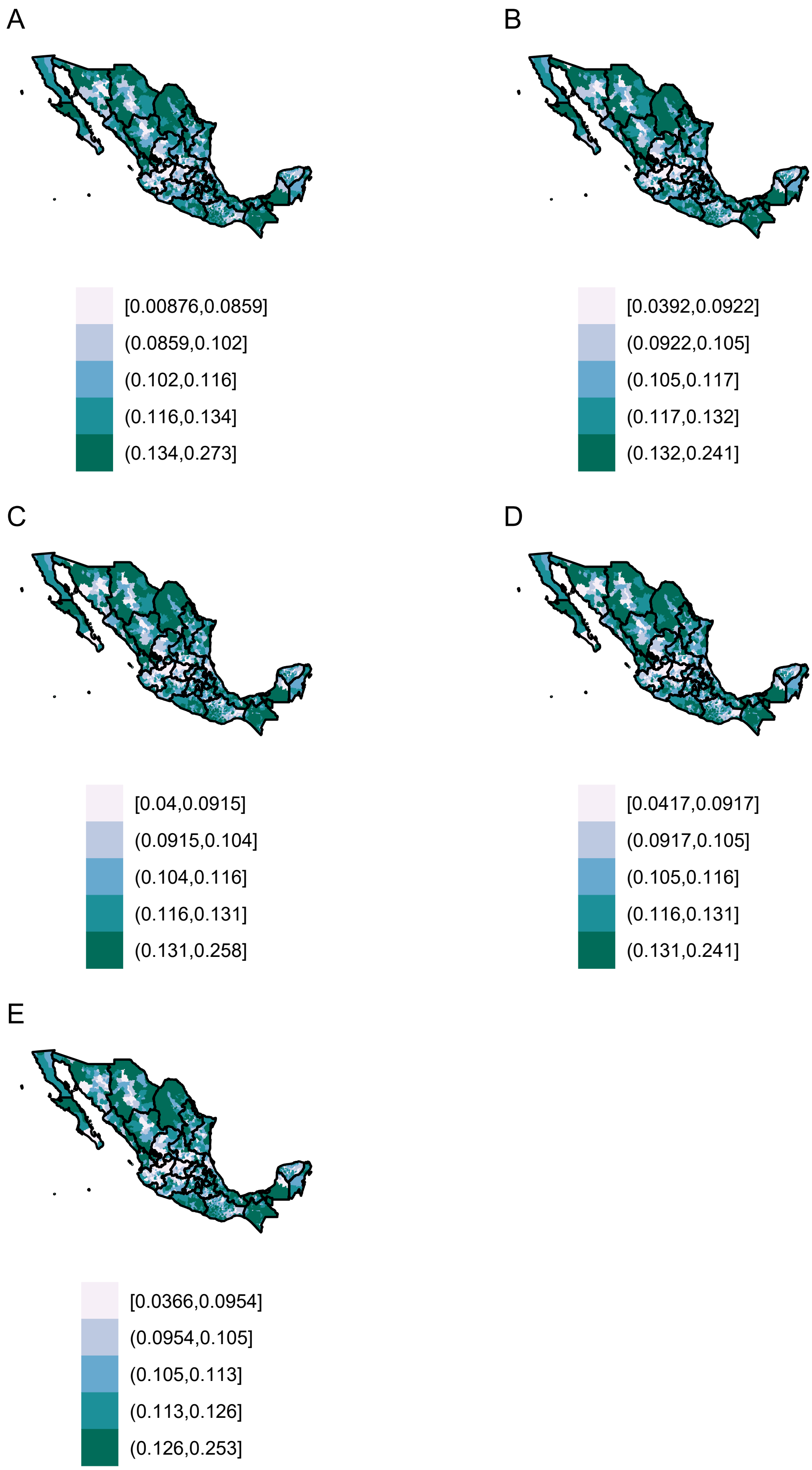
Notes:
rew weights are survey design weights rescaled to sample size,
aw1 weights are weights rescaled to the sample size,
bw1 weights are weights rescaled to the effective sample size,
nw1 are unweighted,
rew regression are design weights used in regressions (rather than proportions)

Figure B.2: Proportion of adolescents aged 12-20 with a birth by municipality and type of weighting strategy, municipalities in Aguascalientes only



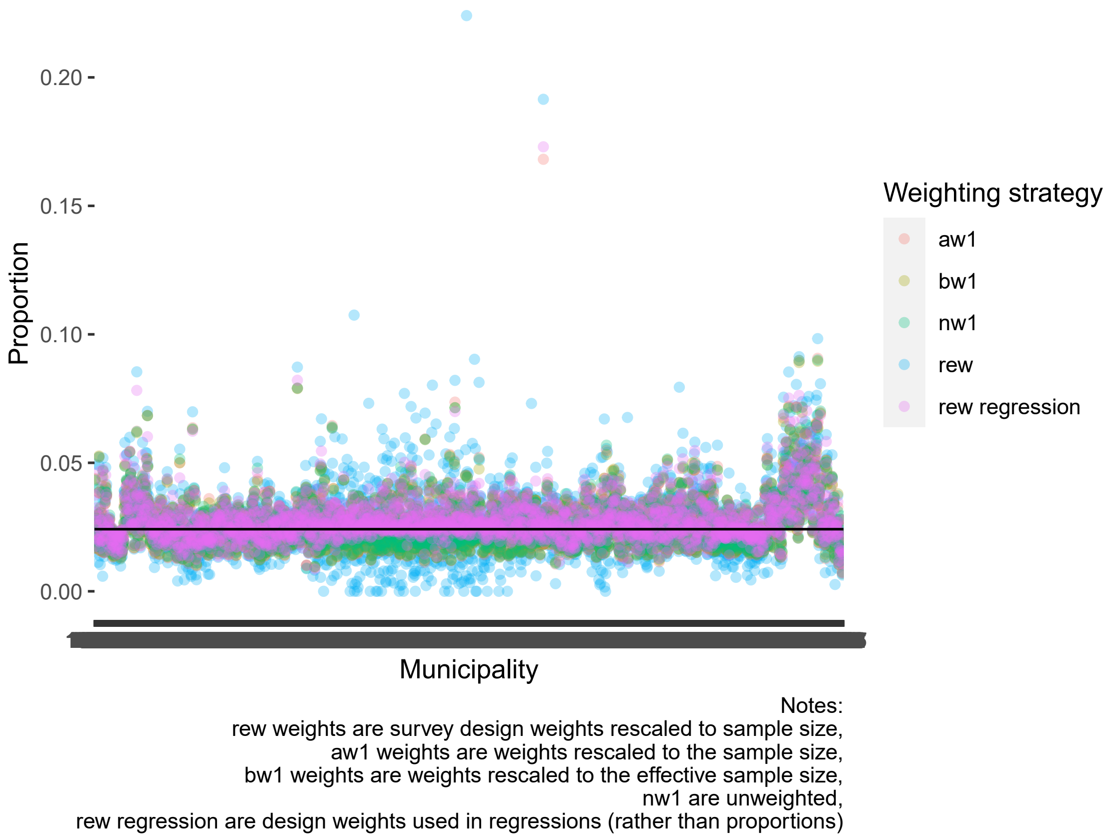
Notes:
rew weights are survey design weights rescaled to sample size,
aw1 weights are weights rescaled to the sample size,
bw1 weights are weights rescaled to the effective sample size,
nw1 are unweighted,
rew regression are design weights used in regressions (rather than proportions)

Figure B.3: Quintiles of proportion of adolescents aged 12-20 with a birth by municipality and type of weighting strategy, all municipalities



Now for second births. Figure B.4 shows estimated municipal proportions (all ages across all time points for first births) by type of weighting. Again, “rew” are the weighted proportions (no regression models but just weighted proportions using the given complex survey design weights rescaled to the sample size instead of the population size), which gives more extreme high and low values. The other weights are: aw1, which are weights rescaled to the sample size; bw1, which are weights rescaled to the effective sample size; nw1, are no weights; rew regression, which are the design weights provided in the data but used in regression models rather than simply raw proportions.

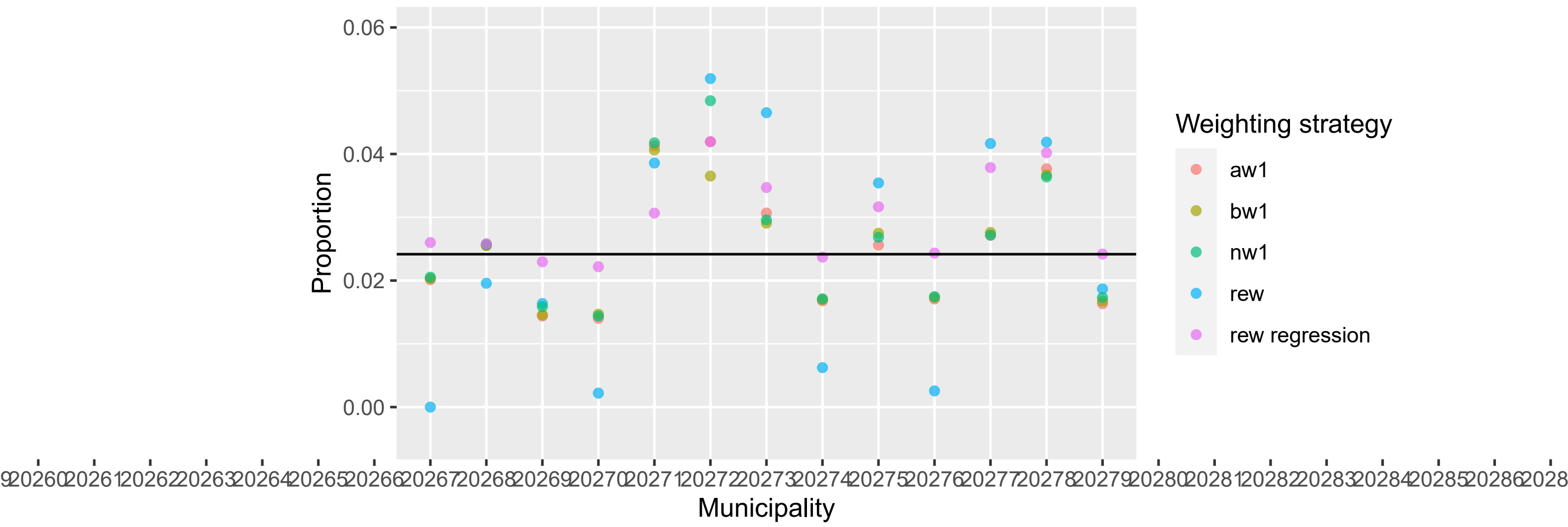
Figure B.4: Proportion of adolescents aged 12-20 with two births by municipality and type of weighting strategy, all municipalities



The differences between the weights can be seen more clearly if shown in a selection of municipalities. See Figure B.5 with the municipalities in Aguascalientes for example. The “rew regression” generally see most shrinkage, while aw1, bw1 and nw1 are generally quite similar.

To be thorough, Figure B.6 maps the quintiles of the various weighting strategies. While the quintiles differ somewhat, the broad geographical patterns are still the same no matter the weighting strategy, which gives more confidence in the restults. The map A shows the raw weighted proportions (using raw design weights and no regression model, map B shows the unweighted model, map C shows the model with weights scaled to cluster size (aw1), map D shows model with weights scaled to effective cluster size (bw1), map E shows the model with weights scaled to sample size

Figure B.5: Proportion of adolescents aged 12-20 with two births by municipality and type of weighting strategy, municipalities in Aguascalientes only



Notes:
rew weights are survey design weights rescaled to sample size,
aw1 weights are weights rescaled to the sample size,
bw1 weights are weights rescaled to the effective sample size,
nw1 are unweighted,
rew regression are design weights used in regressions (rather than proportions)

(original design weights are scaled to the population size).

Figure B.7 depicts the municipal time trends for first births as estimated using the raw proportions. There is a lot of noise and nonlinearity.

Figure B.8 depicts the municipal time trends for second births as estimated using the raw proportions. There is a lot of noise and nonlinearity.

Apart from the impact the choice of weighting has on the estimates, there remains other sources of uncertainty. Understanding and communicating the uncertainty inherent in multilevel models is not straightforward except perhaps in Bayesian analysis. There is currently no clear option for computing standard errors for the municipal predictions (or the deviations in the random effects as opposed to the fixed effects) in the models employed in this study's analysis (J. Knowles and Frederick 2020). Short of a fully Bayesian analysis, bootstrapping is considered the gold-standard for deriving prediction intervals for multilevel models. However, the large size of the data and the complexity of the models meant that neither Bayesian analysis or bootstrapping were possible due to their prohibitive computational requirements.

Measurable uncertainty in multilevel models arises from three sources: (1) uncertainty in the residual variance, (2) uncertainty in the fixed coefficients, and (3) uncertainty in the variance parameters for the grouping factors. Bootstrapping is able to incorporate all three sources of uncertainty, but again, its computational requirements made it impossible for this study's data set. An alternative method using R package merTools and the predictInterval function (J. E. Knowles and Frederick 2020) incorporates all the uncertainty from the first two sources and part of the uncer-

Figure B.6: Quintiles of proportion of adolescents aged 12-20 with two births by municipality and type of weighting strategy, all municipalities

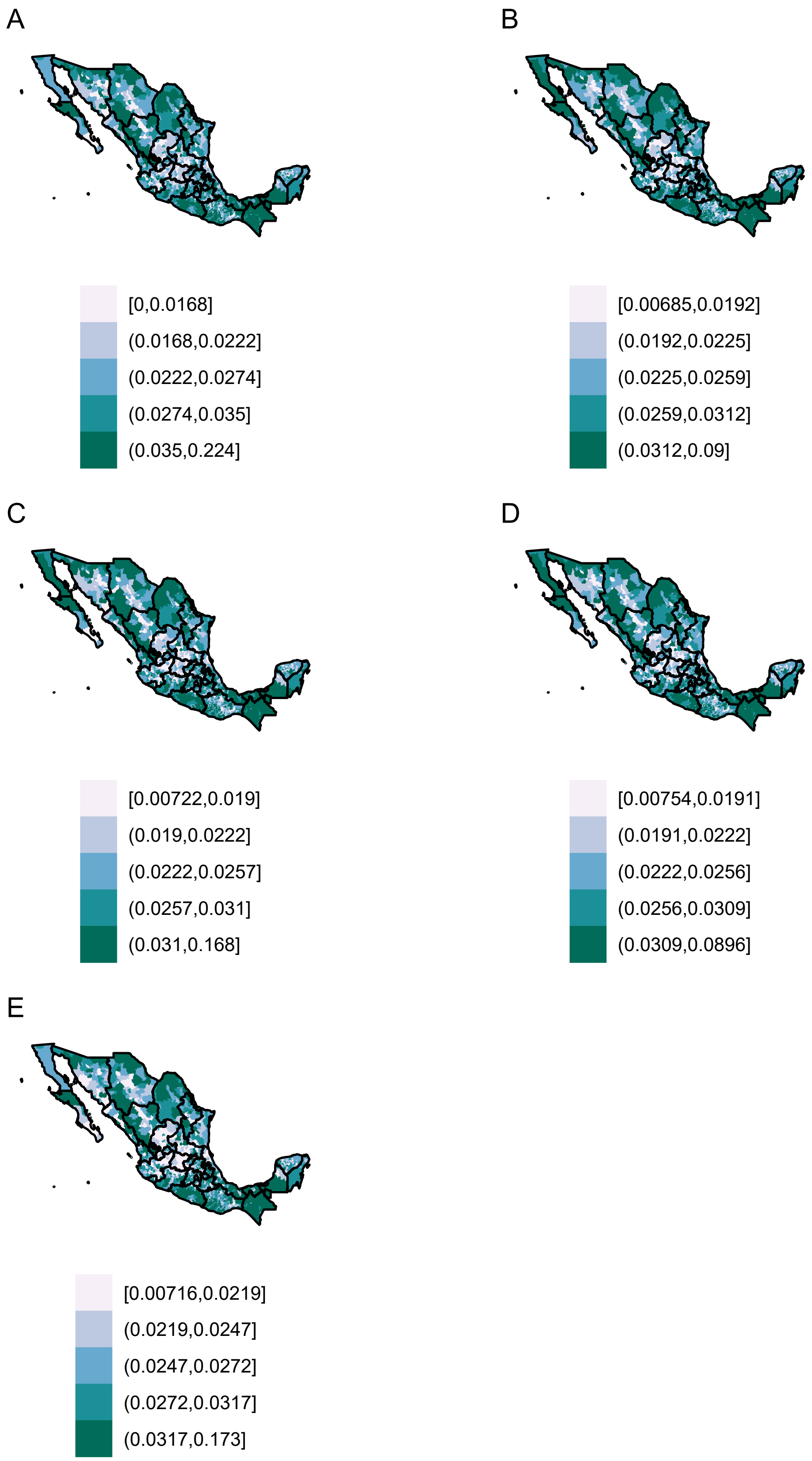


Figure B.7: Municipal trends over time in raw weighted proportions of adolescents aged 12-20 with a first birth, all municipalities 1990-2015

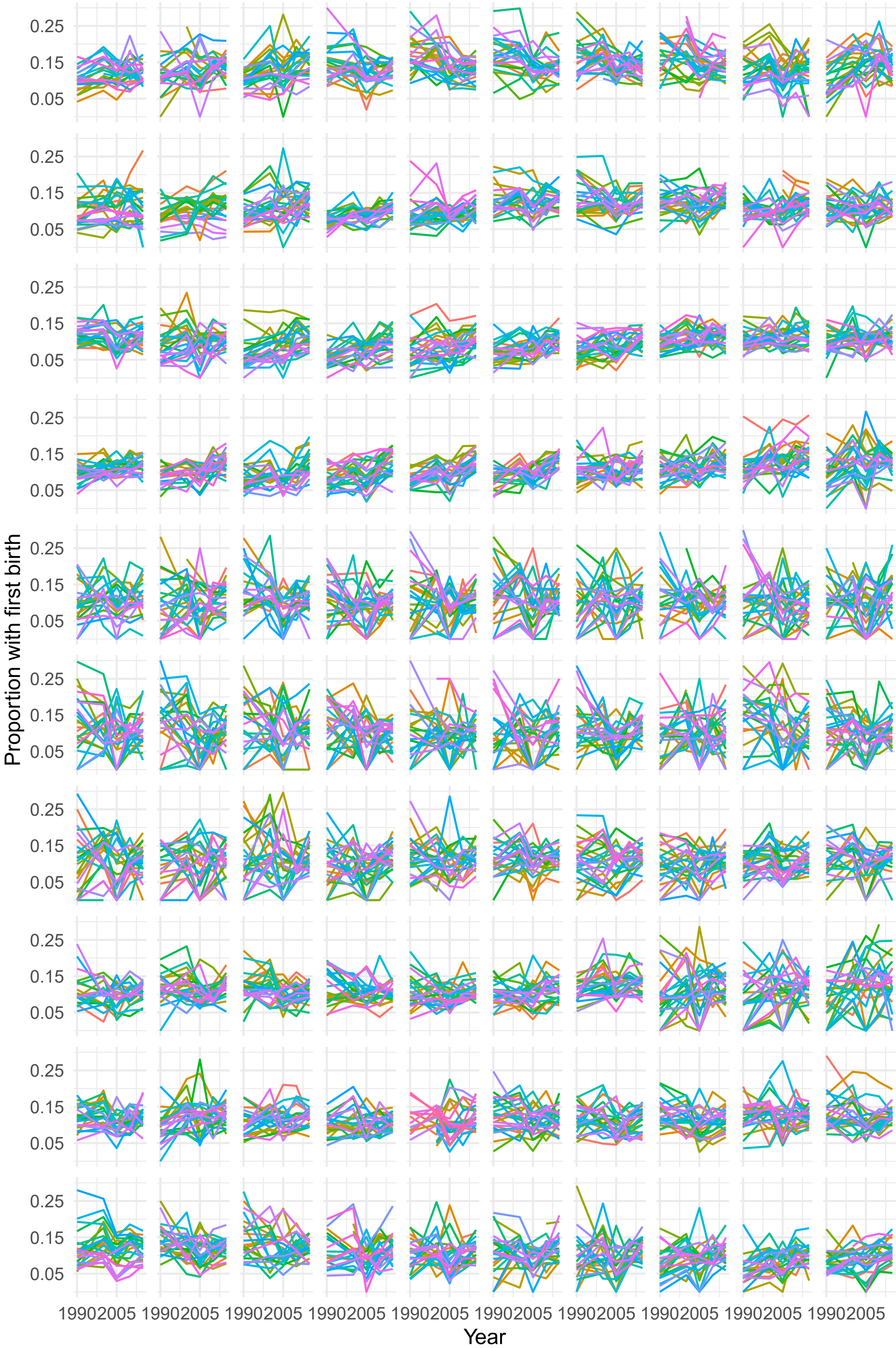
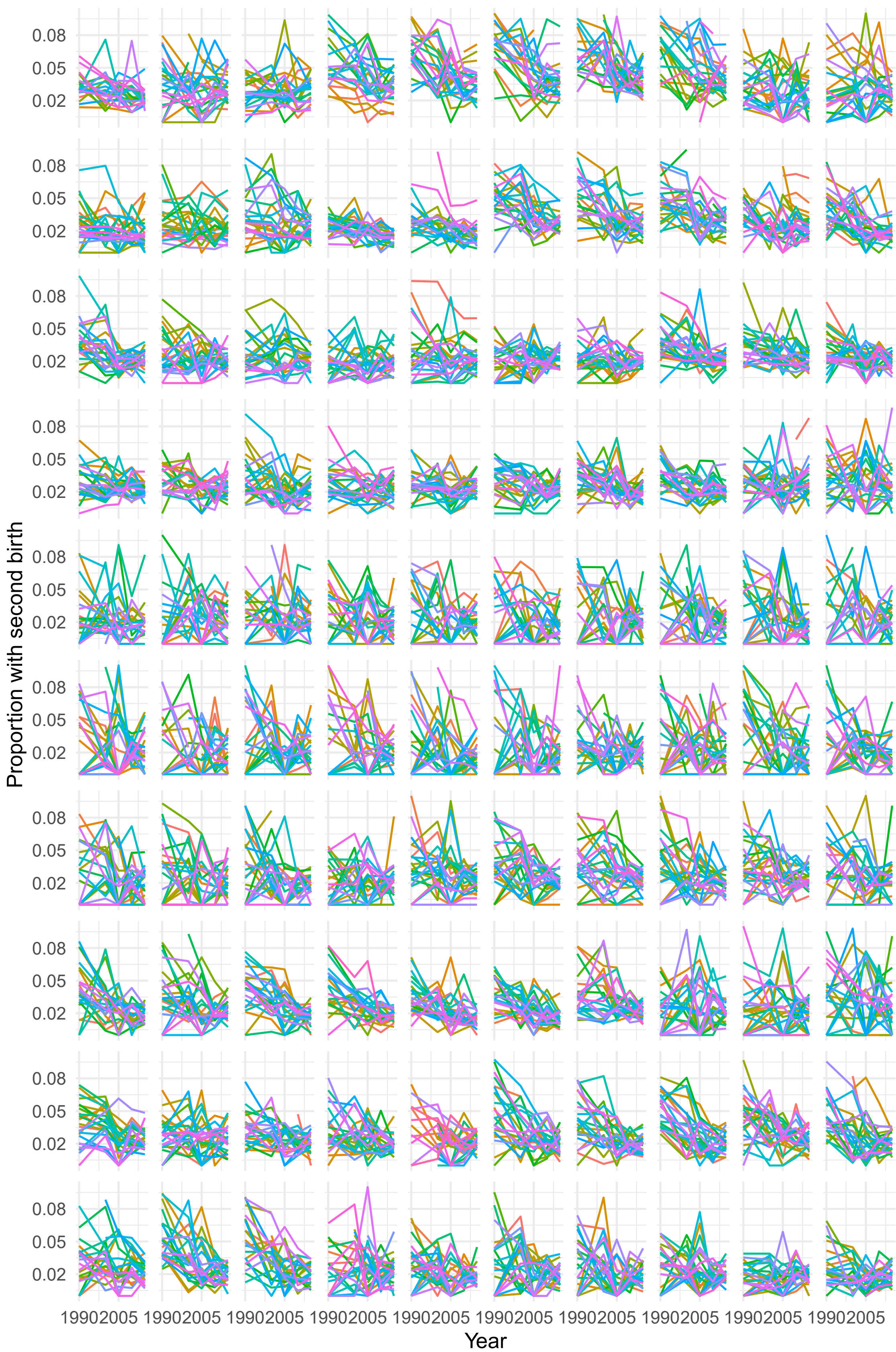


Figure B.8: Municipal trends over time in raw weighted proportions of adolescents aged 12-20 with a second birth, all municipalities 1990-2015



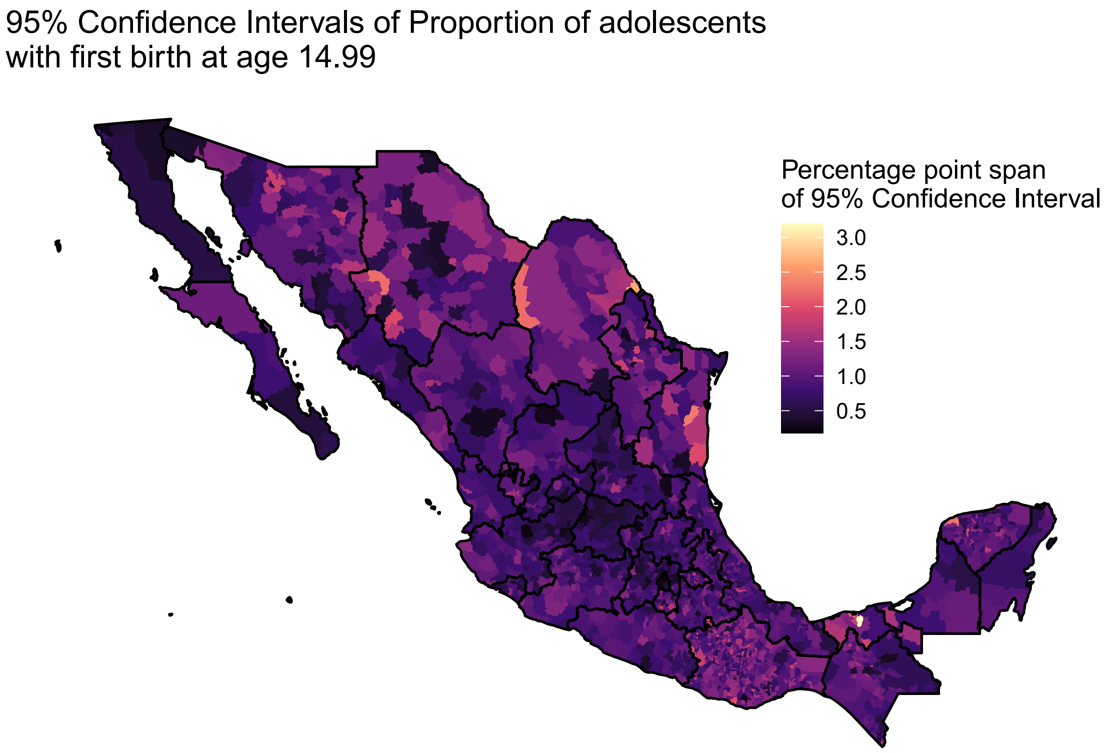
tainty of the third but treats the variance parameters as fixed, which reduces the computational requirements considerably while producing prediction intervals that are reasonably similar to more complex methods (J. Knowles and Frederick 2020).

The following maps plot the predicted 95% confidence intervals. Figures B.9 and B.10, map the 95% confidence intervals for the proportion of adolescents aged 14.99 and 19.99 with a first and second birth in 2015 by municipality. Municipalities with the largest confidence intervals (and most uncertainty) generally are those with the smallest pouplations. The state of Oaxaca stands out especially for having high uncertainty and is a state with a high number of municipalities and that have low population density.

Recall that the middle half of municipalities saw between 0.9% and 1.4% of 14.99-year-olds with a first birth in 2015. Figure B.9 plots confidence intervals by their span. For example, half of municipalities see 95% confidence intervals that have a span of 0.7 to 1.2 percentage points for estimates at age 14.99. For example, a municipality with an estimated 0.9% of 14.99-year-olds with a first birth in 2015 and a span of 0.7 in its confidence interval, sees the upper and lower limits of its confidence interval at 0.6% and 1.3%.

For estimates at age 19.99, The middle half of municipalities saw between 30.8% and 40.2% of 19.99-year-olds with a first birth. At this age, half of municipalities see 95% confidence intervals with a span of 8.8 to 15.5 percentage points. For example, a municipality with an estimated 30.1% of 19.99-year-olds with a first birth in 2015 and a span of 8.8 in its 95% confidence interval, sees the upper and lower limits of its confidence interval at 26.1% and 34.9%.

Figure B.9: First adolescent birth 95% Confidence Intervals (total percentage points of Confidence Interval's estimated interval)



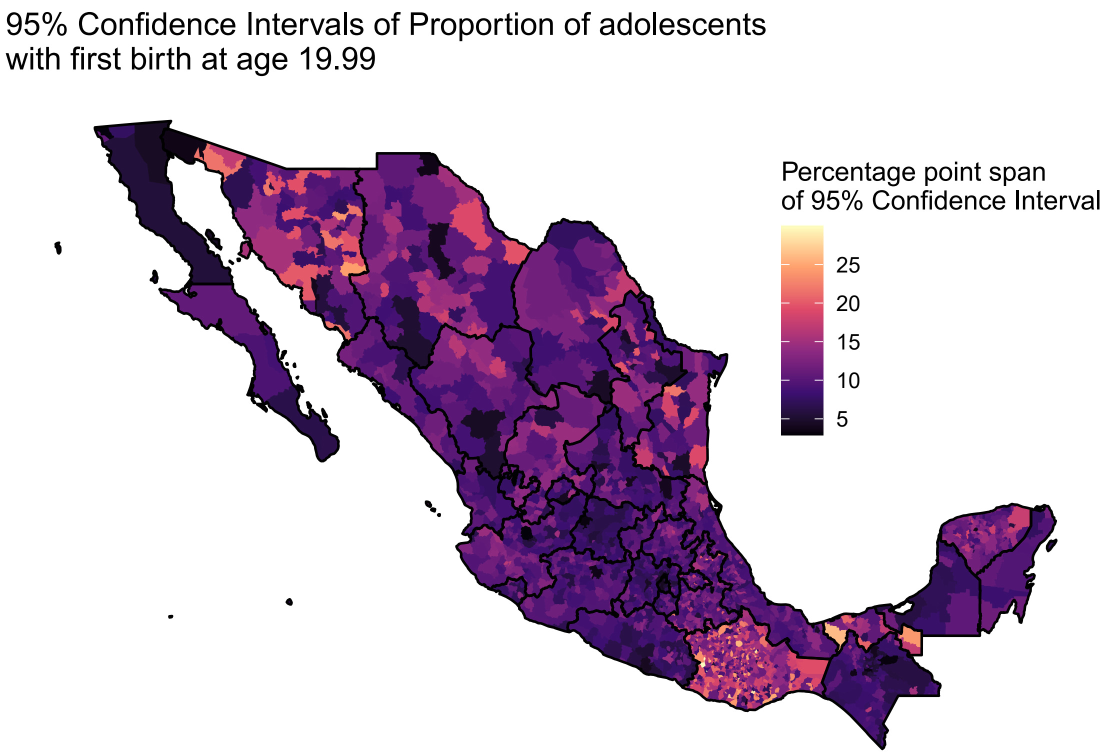
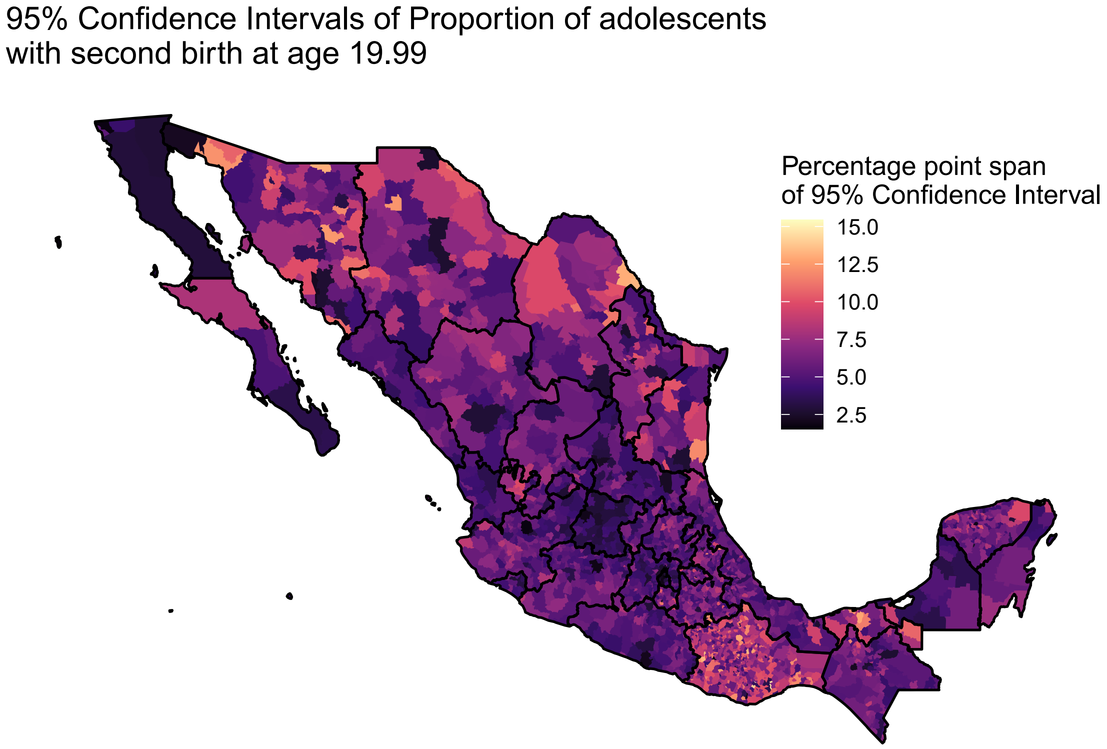


Figure B.10: Second adolescent birth 95% Confidence Intervals (total percentage points of Confidence Interval's estimated interval)



B.2 Additional maps

Figure B.11 maps the proportion of adolescent with a first birth at ages 14.99 and 19.99 in 2015 in a way that is meant to highlight municipalities that might be otherwise overlooked becaues they do not have matching quintiles of proportions at the two age points. That is, municipalities with mismatched quintiles at age 14.99 and 19.99 are shown in a darker hue.

Figure B.12 maps the change over time in the proportion of adolescent with a first birth at ages 14.99 and 19.99 where municipalities with mismatched quintiles at age 14.99 and 19.99 are shown in a darker hue.

Figure B.13 maps the second adolescent birth proportions and progression ratios where municipalities with mismatched quintiles are shown in a darker hue.

Figure B.14 maps the change over time in second adolescent birth proportions and progression ratios where municipalities with mismatched quintiles are shown in a darker hue.

Figure B.15 depicts the proportional change in first births (as opposed to percentage point change shown in the research chapter). The important thing here is that the quantiles for percentage point and proportional change are basically the same.

Figure B.16 depicts the proportional change in progression ratios to second births (as opposed to percentage point change shown in the research chapter). Unlike first births, there are differences in proportional and percentage point change seen in this map.

B.3 Exploring correspondence between intercepts and slopes

Figure B.17 highlights the underlying diversity in patterns of change even further. Each of the four rows of plots include all 2,457 municipalities, though organised into distinct groups. In the top plot (first row), when shown all together, municipal trends seem to meld into one straight, thick line. This highlights why the national trend appears so stagnant. However, underneath this apparent stagnancy lies a complex array of change. For example, the second row of plots organize municipalities into quintiles based on their incidence of adolescent fertility in 1990 so that each subplot depicts the trends of about 491 municipalities. Here, there appears a negative correlation between intercepts and slopes. That is, municipalities with the lowest proportions of 19.99 year-olds with first births in 1990 tend to see the greatest increase over time (subplot on the second row far left). Conversely, municipalities with the highest proportions in 1990 tend to see the strongest decline (subplot on the second row far right) while municipalities with more average proportions see less change (middle subplots on second row).

However, this picture is incomplete. In the third row of plots, municipalities are organised by quintiles of percentage point change, which highlights exceptions to the pattern of negative correlation

Figure B.11: Proportion of adolescents in Mexican municipalities with a first birth at ages 14.99 and 19.99 in 2015

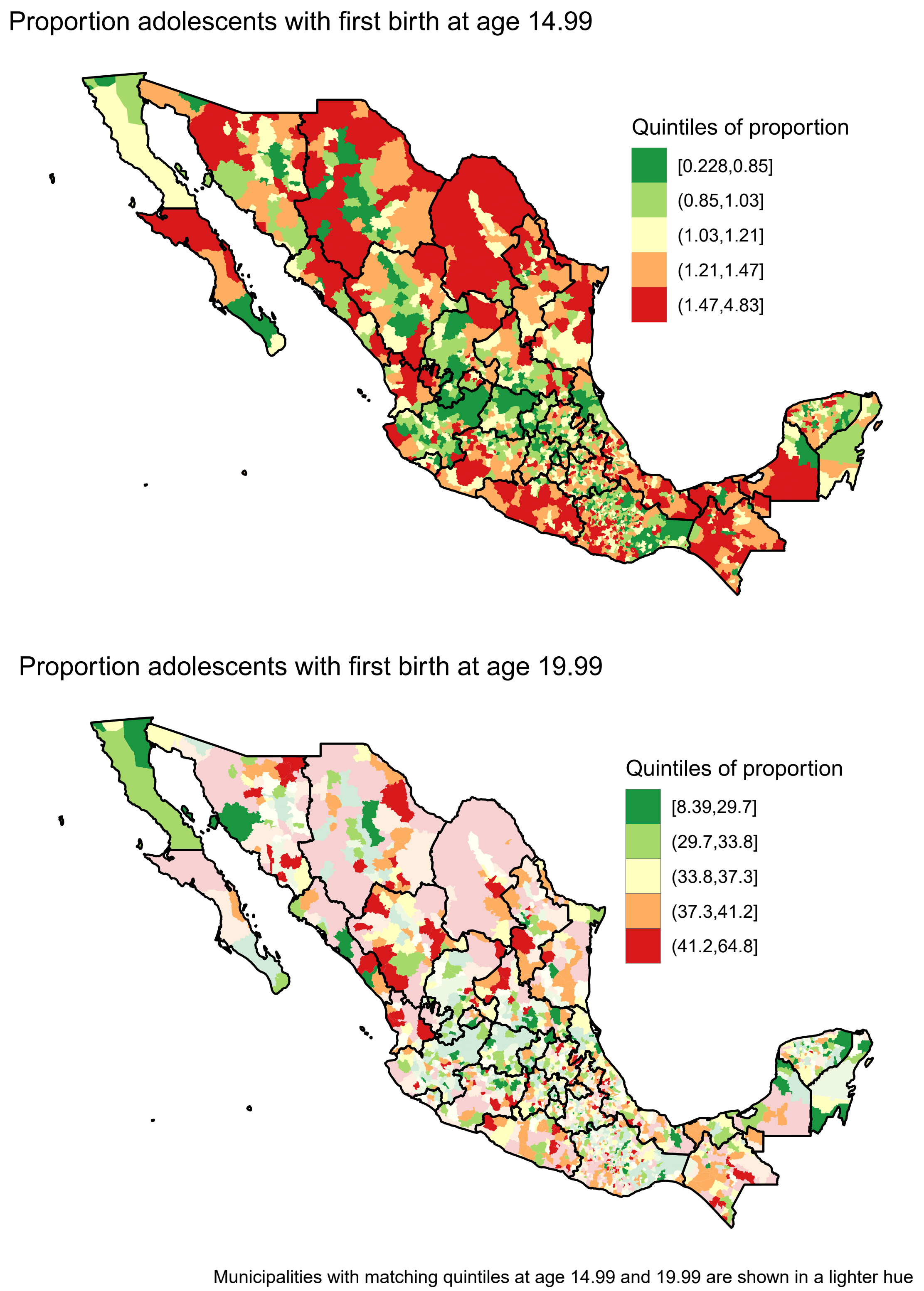
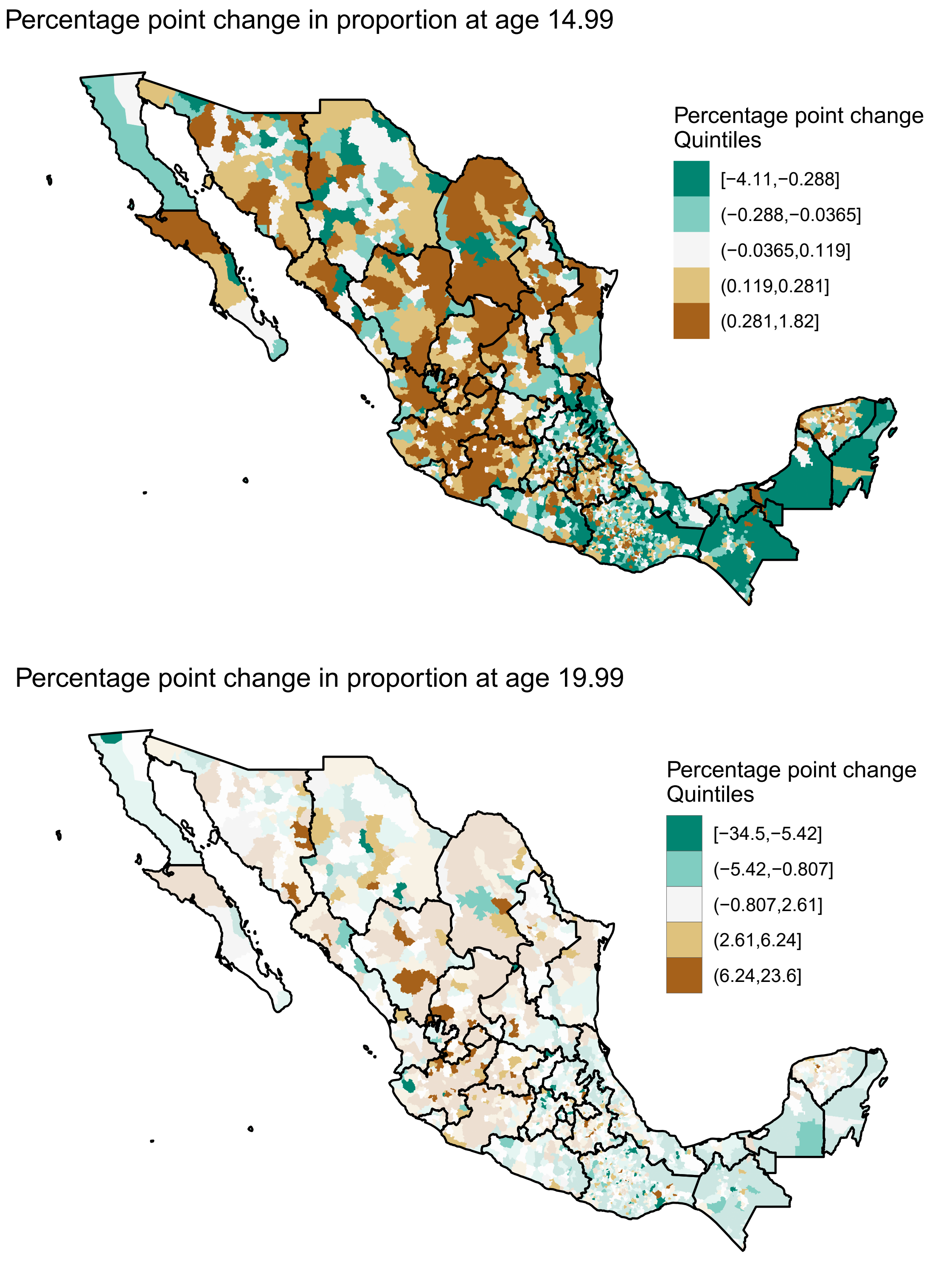


Figure B.12: Percentage point change from 1990 to 2015 in the proportion of adolescents in Mexican municipalities with a first birth



Municipalities with matching quintiles at age 14.99 and 19.99 are shown in a lighter hue

Figure B.13: Proportion of adolescents at age 19.99 with a second birth in Mexican municipalities in 2015

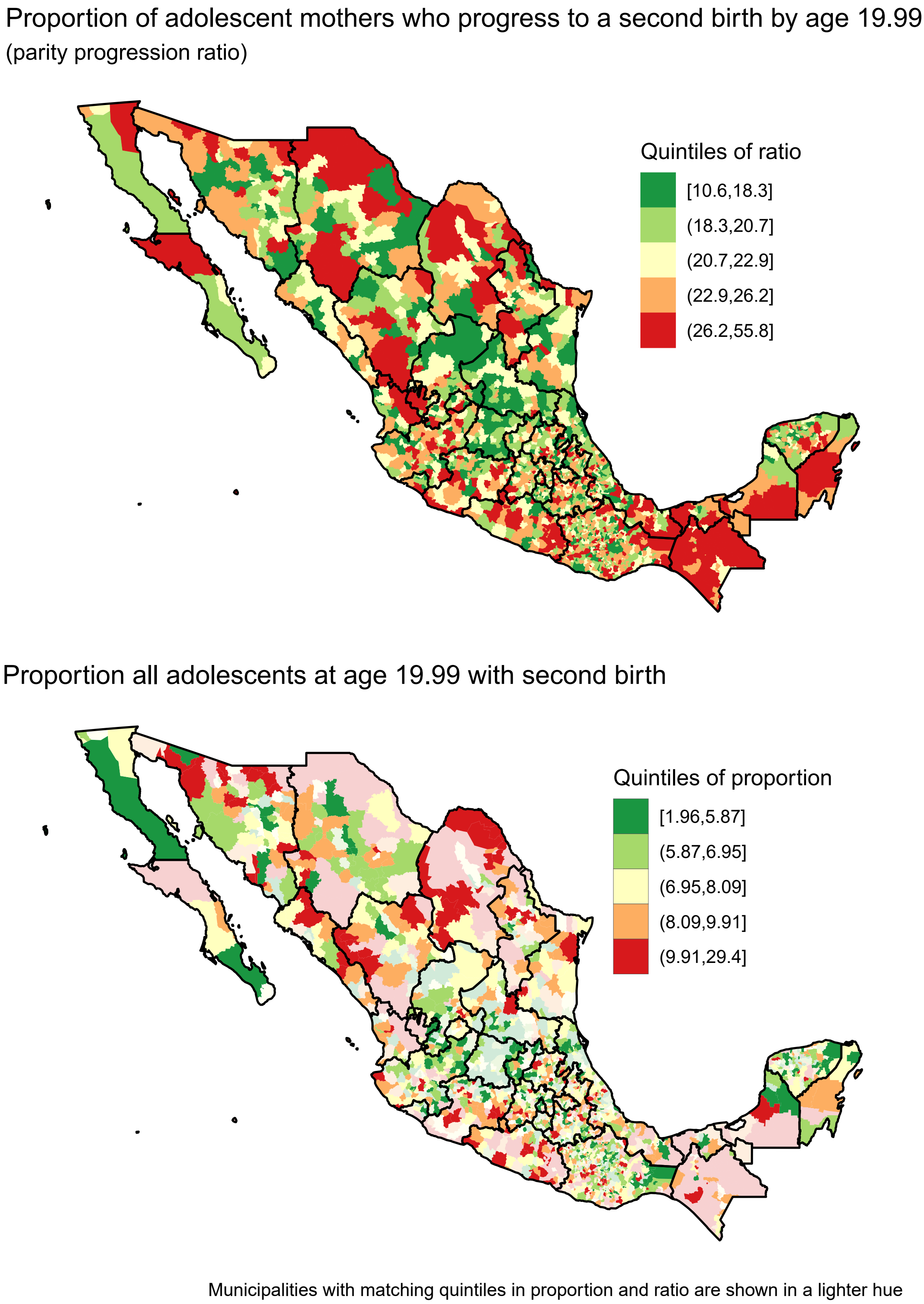


Figure B.14: Percentage point change from 1990 to 2015 in patterns of adolescents at age 19.99 with a second birth in Mexican municipalities

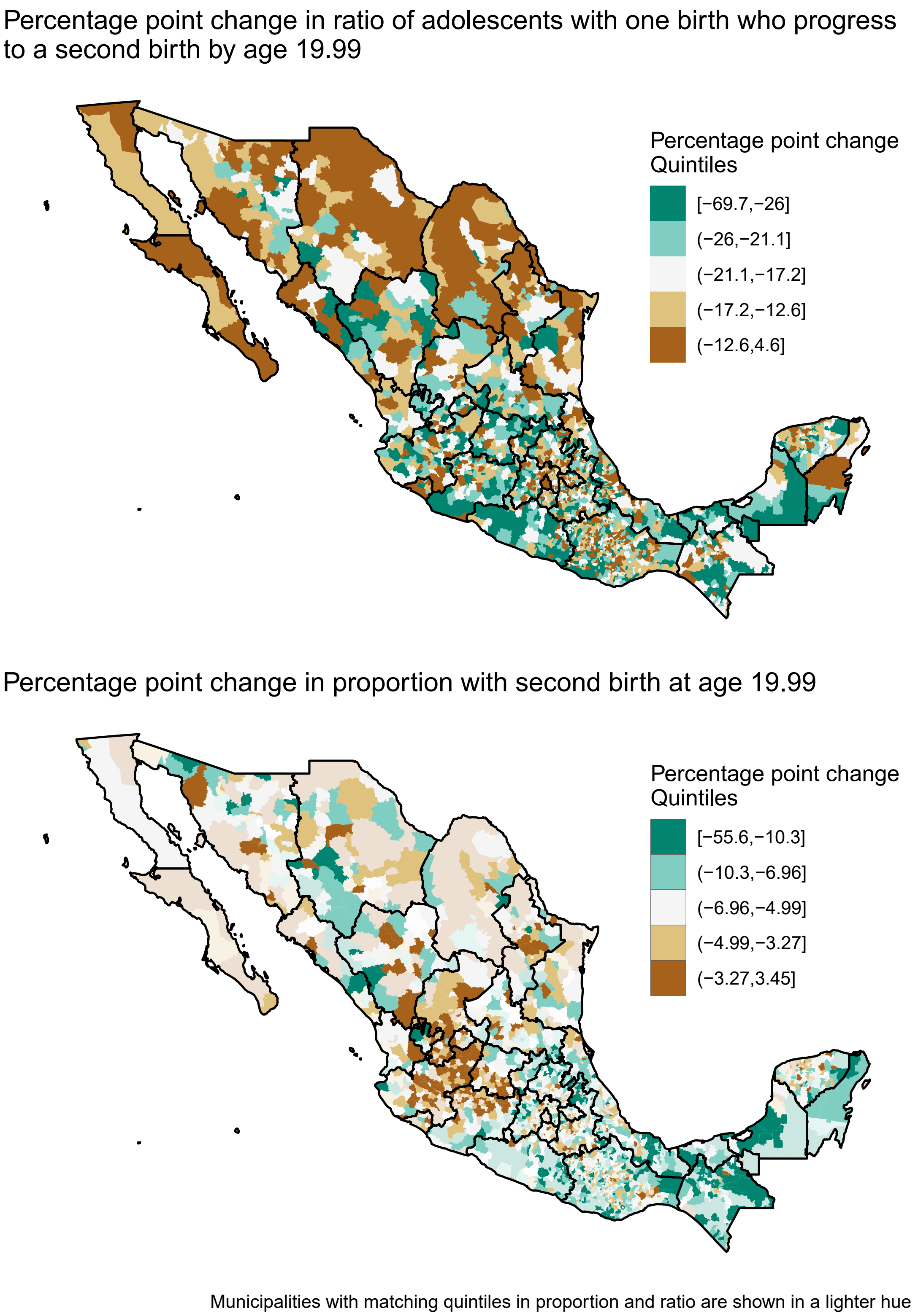
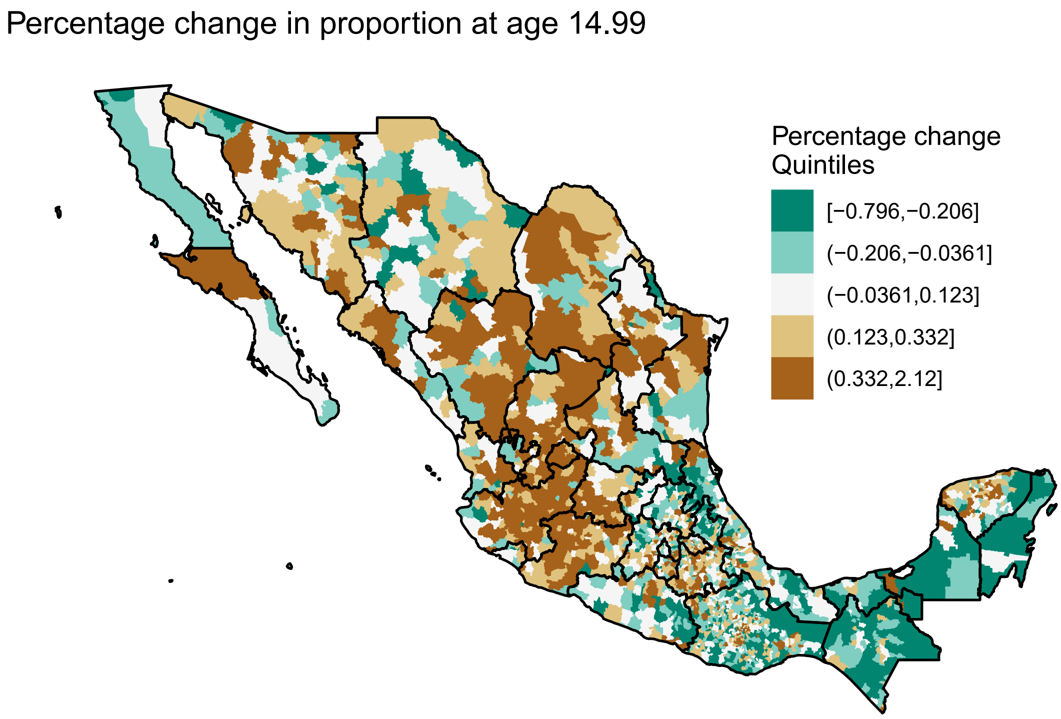
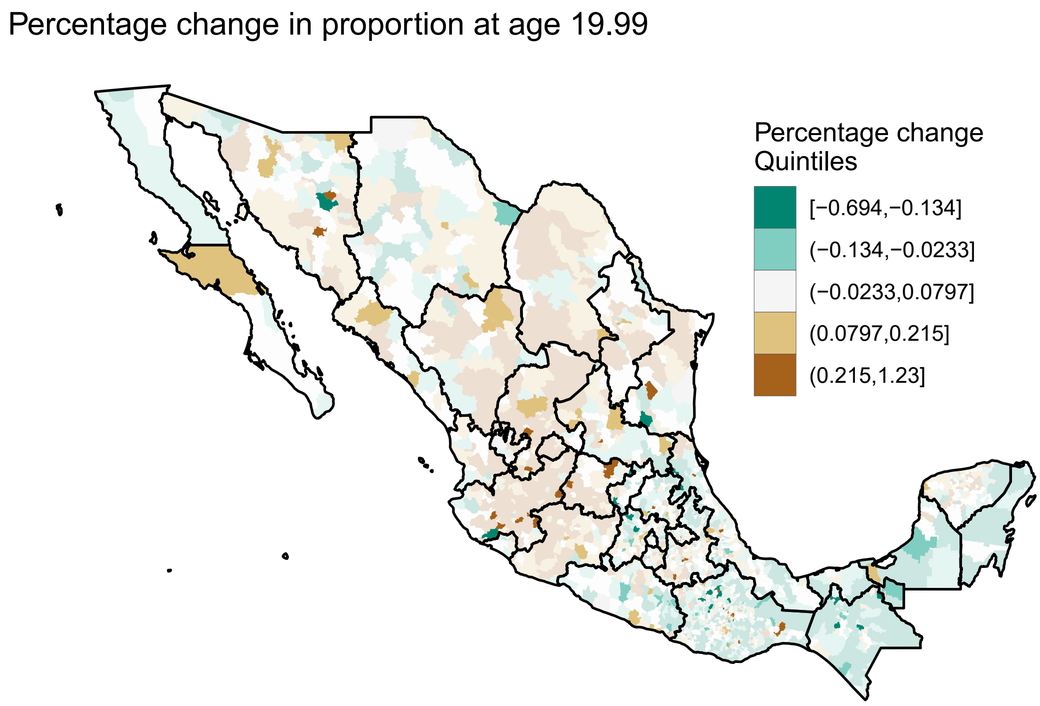


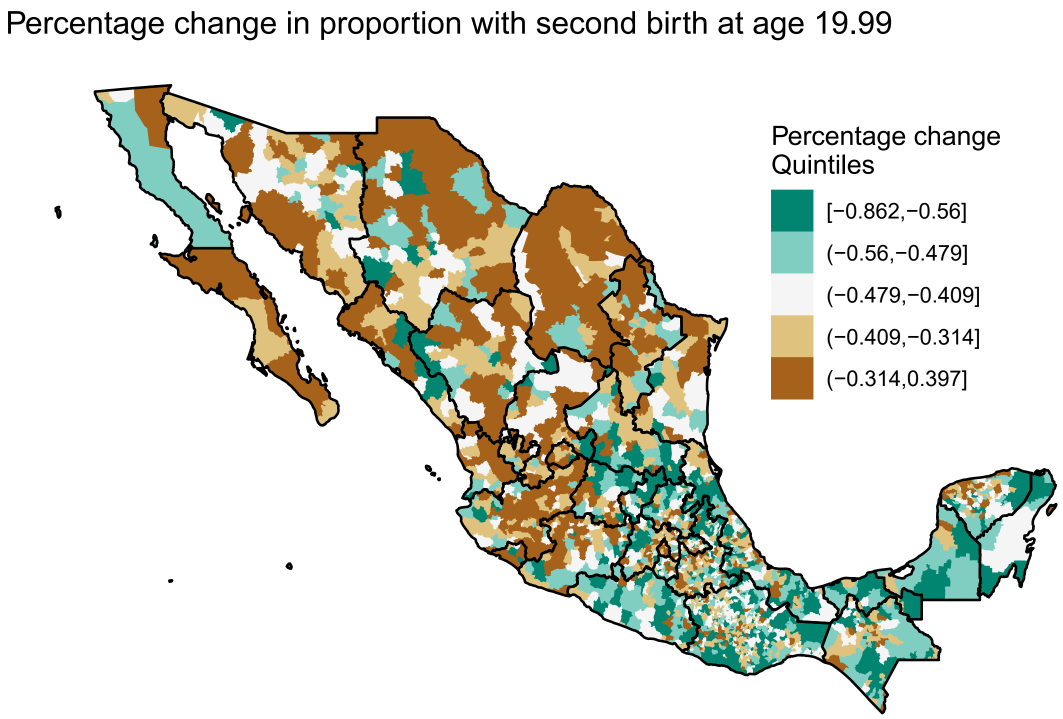
Figure B.15: Percentage change from 1990 to 2015 in the proportion of adolescents in Mexican municipalities with a first birth

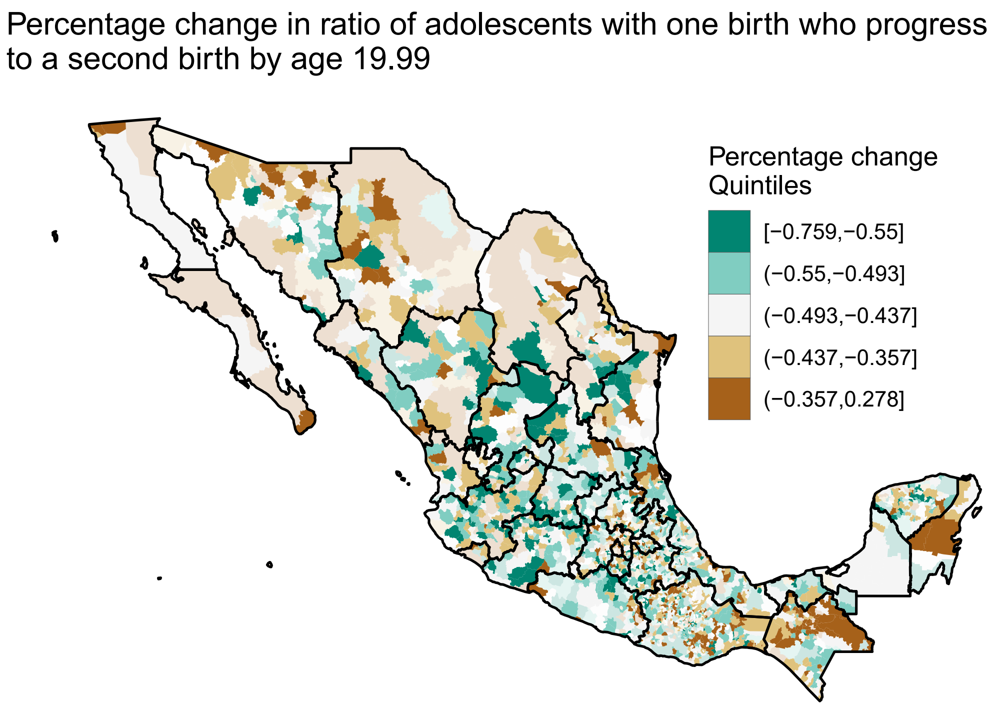




Municipalities with matching quintiles at age 14.99 and 19.99 are shown in a lighter hue

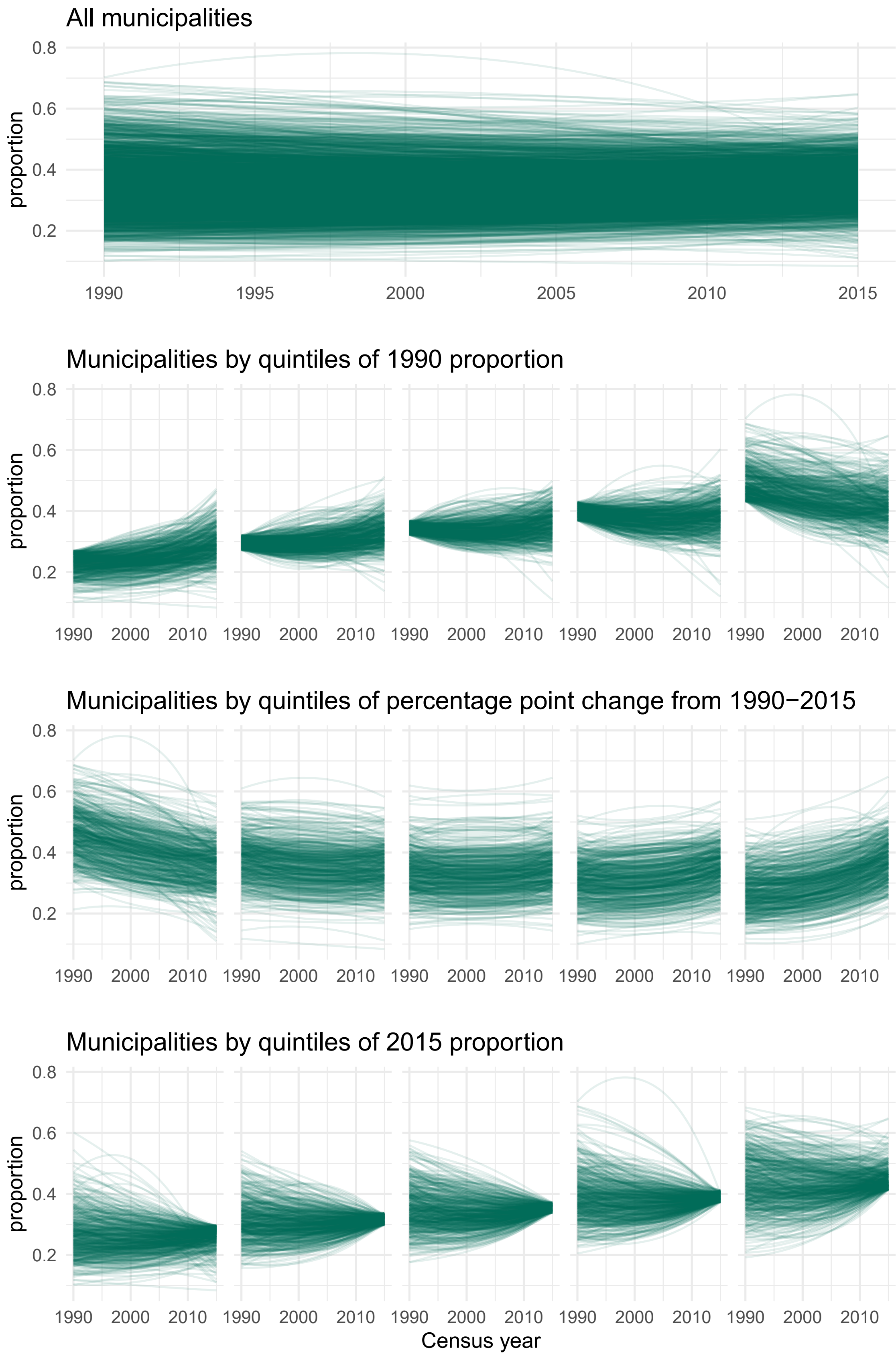
Figure B.16: Percentage change from 1990 to 2015 in patterns of adolescents at age 19.99 with a second birth in Mexican municipalities





Municipalities with matching quintiles in proportion and ratio are shown in a lighter hue

Figure B.17: Proportion of adolescents aged 19.99 with a first birth from 1990-2015 by municipality, examining correspondence between intercepts and slopes



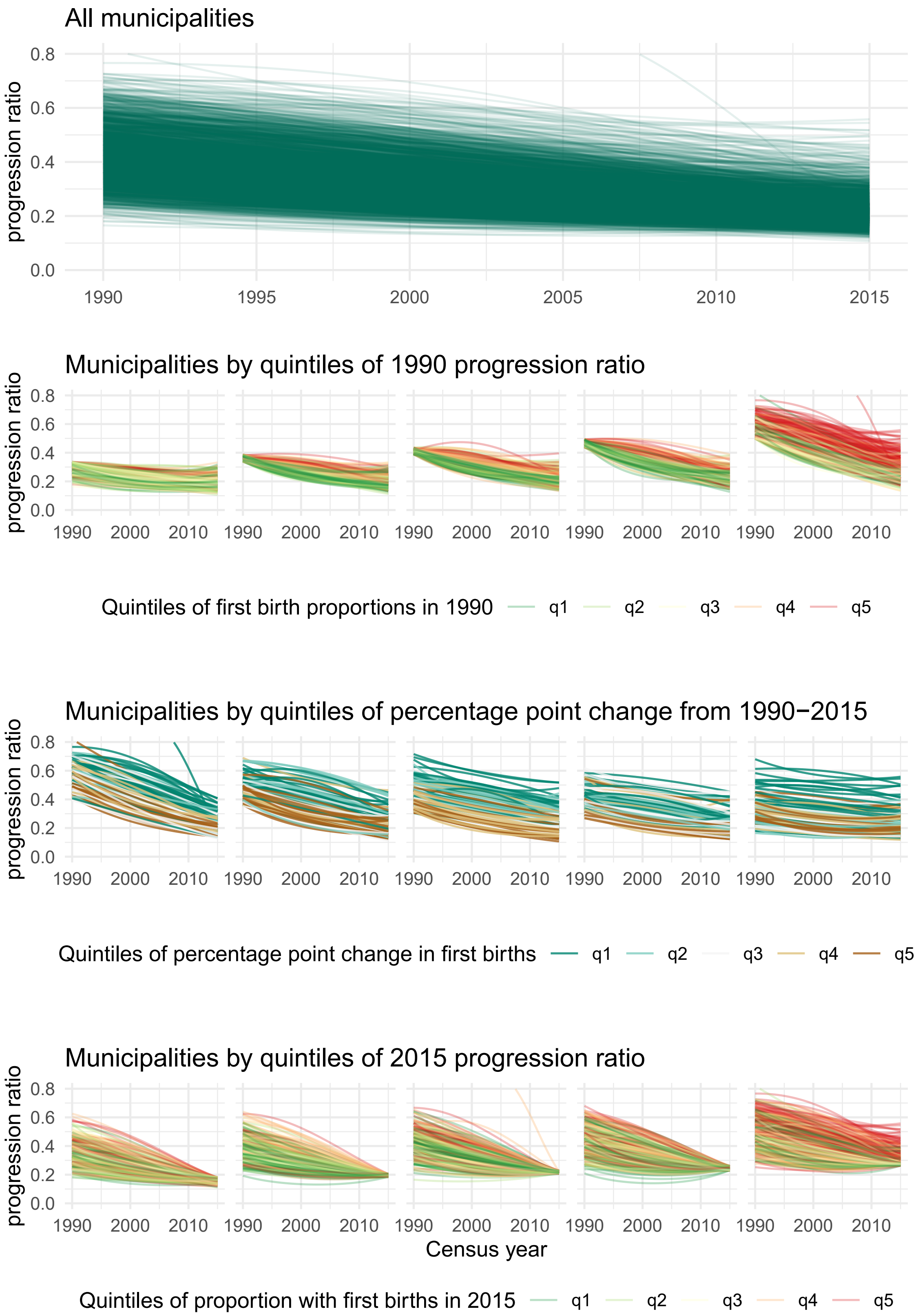
between intercepts and slopes. For instance, the first of the five subplots on the third row (far left) depicts municipalities with the greatest pace of decline and there are plenty of municipalities with relatively low proportions that have experienced considerable decline. The opposite is also true. The last of the five subplots on the third row (far right) depicts municipalities with the greatest pace of increase and here too there are, unfortunately, plenty of municipalities that started with higher proportions and also saw some of the greatest increase. Meanwhile, the centre subplot on the third row shows that municipalities with minimal change over the past twenty-five years span a wide array of starting proportions.

Finally, the plots on the last row complete the complex picture by organising municipalities into quintiles based on their proportions in 2015. The purpose of showing so many groupings of the same trends is not to confuse the patterns but rather to highlight that subnational change has been far from stubbornly predetermined. For instance, municipalities with the lowest proportions in 2015 come from a wide array of starting points, as seen in the first plot on the last row (far left), implying that decline is happening not just among a select few places with high adolescent motherhood twenty-five years ago. Conversely, municipalities with the highest proportions in 2015 also come from a wide array of starting points (far left plot of fourth row), implying that increase is not exclusive to those with low adolescent fertility in the past. In essence, there is a complex and dramatic flux in Mexico's patterns of adolescent first births, which is masked by seemingly immobile national trends.

Now, to turn to second births. There is comparatively little correspondence between patterns of first birth proportions and second birth progression ratios, and this is perhaps the most important finding for the second birth estimates. It means that a certain trend for first birth proportions does not guarantee a certain trend for patterns of progression to second births. That is, the risk of progressing to a second birth varies considerably across municipalities with similar patterns of first births. Figure B.18 uses four rows of plots to explore this complexity. Each of the four rows of plots include all 2,457 municipalities, though organised into distinct groups. In the top plot (first row), when shown all together, municipal trends seem to converge in their decline over time. Additionally, at first glance, the correspondence between changes in intercepts and slopes appears much stronger than it did for first births, where the quintile groups (in all plots) look much more tightly clustered together. Here again there is a negative relationship between intercepts and slopes, in that municipalities with the highest ratios tend to have seen the greatest decline and vice versa.

However, when patterns of first births are taken into account, the picture becomes much more nuanced. For example, the second row of plots organize municipalities into quintiles based on their progression ratios in 1990 and each subplot depicts the trends of about 491 municipalities. Within the subplots on the second row, municipalities are coloured according to the quintiles of first birth proportions at age 19.99 in 1990. While there does appear to be a negative correlation

Figure B.18: Examining correspondence between intercepts and slopes in progression ratios among adolescents aged 19.99 from 1990-2015 by municipality



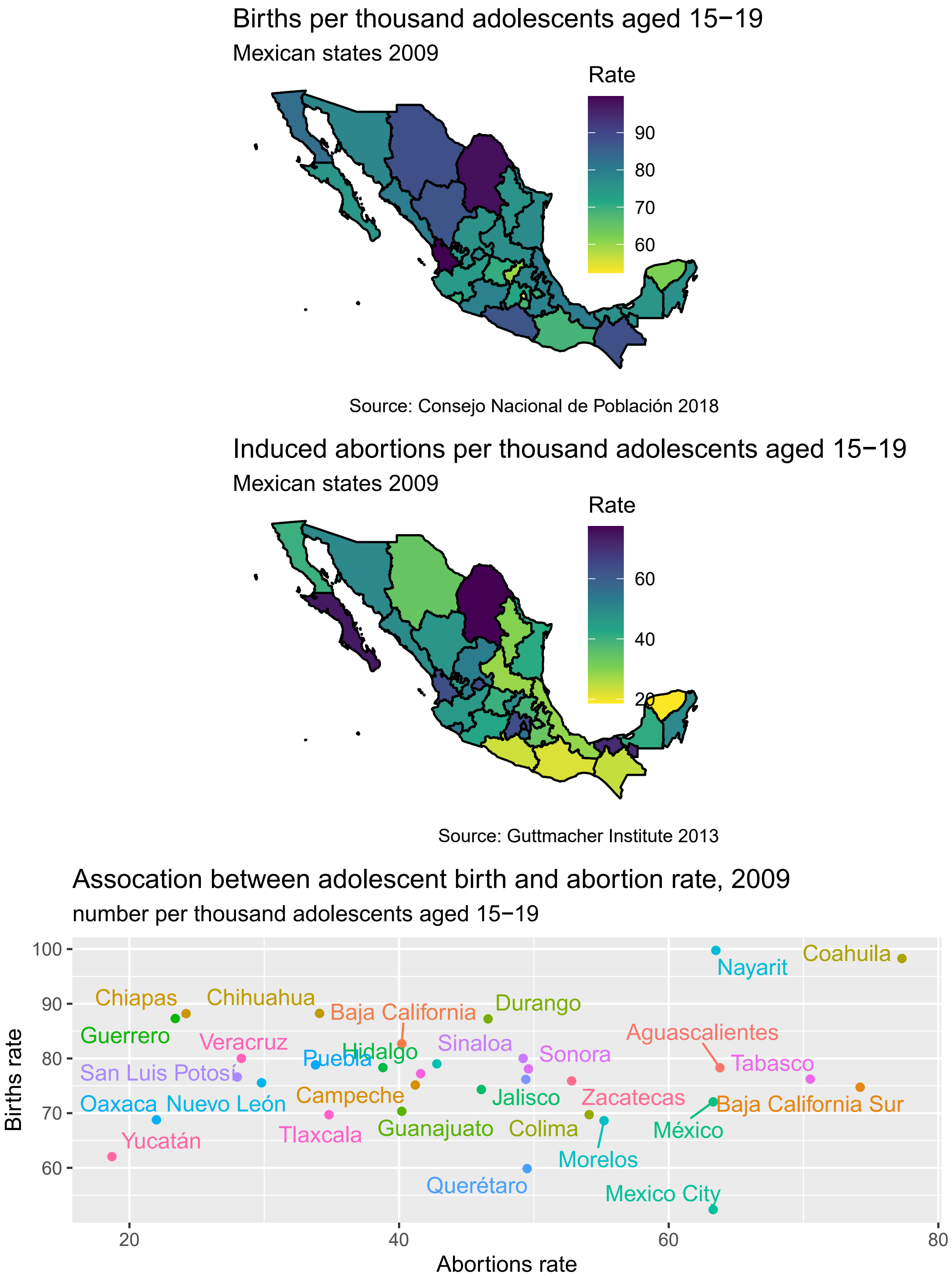
between intercepts and slopes, with municipalities that have the lowest progression ratios in 1990 seeing the least decline and those with the highest progression ratios in 1990 seeing the most decline, the correlation with first birth proportions is also important. It appears that most municipalities with the highest first birth proportions in 1990 also saw the highest progression ratios in 1990 alongside the greatest decline in progression ratios. This pattern is represented by the concentration of dark red lines in the last (far right) subplot on the second row. However, there are dark red lines in other subplots on the second row indicating that plenty of municipalities with the highest first birth proportions had relatively low progression ratios in 1990 as well as more limited decline. Conversely, municipalities with the lowest first birth proportions also tended to have lower progression ratios in 1990, as represented by the dark green lines in the second rows' first few subplots (on the left). Nevertheless, the dark green lines are spread throughout the subplots on the second row indicating that the municipalities with the lowest first-birth proportions in 1990 saw considerable diversity in their 1990 progression ratios as well as diversity in the pace of decline in those ratios. Plenty of municipalities with low first birth proportions saw high risk of progression to second births.

The third row of plots organize municipalities into quintiles of percentage point change. It highlights exceptions to the pattern of negative correlation between intercepts and slopes. For instance, the last of the five plots on the third row (far right) depicts municipalities with the least decline and includes plenty of municipalities with relatively high progression ratios, which would otherwise be expected to have declined the most. Municipalities are coloured according to quintiles of their percentage point change in first birth proportions, with those shaded green having largely experienced declines in first births and those shaded brown having seen increases in first births over the last twenty-five years (these are the same quintiles depicted in the lower map in Figure 3.11). The distribution of greens and browns appears quite even throughout the five subplots, further confirming that the trends in first births do not predicate trends for second births. For example, municipalities with the strongest declines in progression to second births saw some of the strongest increases in first births as well as some of the strongest declines in first birth proportions (far left plot third row).

The plots on the last row complete the complex picture by organising municipalities into quintiles based on their 2015 progression ratios. The colours are tied to quintiles of the 2015 first birth proportions with red lines for those with the highest proportions and green for those with the lowest first birth proportions (the same quintiles depicted in the lower map in Figure 3.10). Here, the negative correlation between slopes and intercepts appears much less defined than it did in the subplots on the second row. That is, every subplot shows a similarly wide range of 1990 ratios ending within their respective quintile of estimated ratios in 2015. This means that plenty of municipalities with exceptionally high ratios in 1990 now have some of the lowest 2015 ratios while many municipalities with the lowest 1990 ratios now have some of the highest 2015 ratios. The diversity of correspondence with first birth proportions is important as well. The dark red lines concentrate heavily in the last (far right) subplot on the bottom row, indicating that many municipalities with the highest first birth proportions in 2015 also have the highest progression ratios in 2015. Nevertheless, there are dark red lines in all the other subplots in the last row. For example, plenty of municipalities with the highest incidence of first births in 2015 have among the lowest incidence of progression ratios to second births in 2015 (red lines in far left plot bottom row). Conversely, plenty of municipalities with the lowest incidence of first births in 2015 have comparatively high risk of second births (green lines in plots toward the right on the bottom row).

B.4 Proximate determinants of adolescent fertility in Mexico

Figure B.19: Adolescent births and induced abortion rates in Mexican states, 2009



Appendix C

Appendix to Chapter 3 (Extension)

The fertility estimates produced in the study "Adolescence in flux" leave unanswered the question of what socioeconomic factors undergird Mexico's changing fertility landscape at the subnational level. Furthermore, the strategy documents of Mexico's initiative to reduce adolescent fertility prioritize schooling as an important way to reduce early fertility, but analysis released alongside the 2010 and 2015 municipal teen birth rates found almost no relation between adolescent schooling and fertility at the municipal level (Ailines Genis 2018), which undermines the prioritization of girls' schooling for reducing adolescent fertility. However, at the state level, education does show a consistent negative relationship with adolescent fertility (Gómez and González 2018). Specifically, lower levels of education are associated with greater risk of adolescent fertility, and inversely, greater educational access is associated with lower adolescent fertility across Mexican states.This appendix explores whether parity-specific estimates present a more congruent relationship with schooling levels than with the adolescent birth rate. This research extension shows that despite the changing fertility landscape, municipal parity-specific estimates do demonstrate the expected relationship with schooling that the adolescent fertility rates did not. That is, higher levels of schooling are related to lower levels of adolescent fertility both across and within municipalities over time. The results also caution against a hasty expansion of access to higher education levels at the expense of leaving the most vulnerable in lower levels of schooling behind.

Mexico's adolescent fertility initiative speaks to the importance of schooling for reducing early childbearing, but tracking progress in this area is complicated by the absence of a relationship between indicators of schooling and adolescent fertility at the municipal level. The recently released official 2010 and 2015 municipal $ASFR_{15\text{-}19}$ estimates find almost no relationship with aggregate adolescent schooling in municipalities. That is, when municipal $ASFR_{15\text{-}19}$ was compared to the proportion of females aged 15-19 enrolled in school (in simple bivariate regressions), the 2010 estimates offered an r-squared value of 0.04 while 2015 estimates offered an r-squared value of 0.0005 (Meneses and Hernández 2019). Recall that r-squared is a statistical measure that describes the goodness of fit of a regression model. In this case, an r-squared value of 1.00 would mean that 100% of the differing levels of adolescent fertility rate across municipalities could be perfectly explained without error by the levels of female school enrolment in the municipalities. An r-squared value of 0.00 would mean that none of the adolescent fertility rate can be explained by female school enrolment. In other words, the percentage of variation in $ASFR_{15\text{-}19}$ across municipalities that is explained by school enrolment was 4% in 2010 and almost nothing (one twentieth of one percent, or 0.05%) in 2015 (Meneses and Hernández 2019). That is, municipalities with the highest adolescent birth rates were effectively just as likely to also have the most adolescent girls enrolled in school as they were to have the fewest adolescents girls enrolled in school. Equivalently, being a municipality with the highest levels of enrolment among female adolescents was effectively unrelated to a lower adolescent birth rate. While aggregate levels of education may well misalign with aggregate levels of adolescent fertility, even when there is a strong relationship at the individual level, the lack of a relationship detracts from the case for prioritizing schooling improvements in Mexico's national strategy.

This study extension examines whether municipal schooling levels are related to parity-specific adolescent fertility to clarify and strengthen the case for schooling improvements. It looks at the relationship both across municipalities in 2015 and within municipalities over time (from 1990-2015). Not only does this analysis offer insight into the important debate about the role of education in Mexico's adolescent fertility patterns, but also sheds light on the inadequacy of reliance on $ASFR_{15\text{-}19}$ for tracking (and tackling) adolescent fertility in lower- and middle-income countries. The relation between schooling and adolescent fertility has crucial bearing not only for Mexico's national strategy, but also the broader debate about the importance of education for combating adolescent fertility in lower- and middle-income countries.

It was already noted that the 1990-2015 period saw impressive gains in secondary schooling and, at the national level, the expansion occurred at a fairly steady pace. Nevertheless, aggregate trends mask a long history of uneven schooling expansion subnationally. The country's history of educational expansion has, in broad terms, prioritized the more populated and economically advanced areas of the country, with rural and indigenous communities following far behind (Binder and Woodruff 2002; Rocha and Romero 2019). The expansion of secondary schooling has largely followed the same evolution of inequalities as primary school though on a different timeline (Rocha and Romero 2019). Access to both lower- and upper-secondary schooling remains highly uneven, despite considerable government effort. More than two decades of Mexico's *Progresa-Oportunidades* program, one of the world's largest and longest-running schooling conditional cash transfer programs, has not yielded the same success in closing the secondary schooling gap as it has for primary schooling (P. T. Schultz 2004).

State-specific net enrolment rates speak to these persistent inequalities to some extent. For example, Mexico City, the country's political and economic powerhouse, consistently ranks far above secondary schooling levels elsewhere. Mexico City's evolution in lower-secondary rates saw 77% net enrolment in 1990 when the country average was at 50% and Mexico City reached universal enrolment in 2012, when the country average by 2015 was still at 88%. Meanwhile, Chiapas, the country's southern-most state, had the lowest enrolment in 1990 with 25% net enrolment in lower secondary. In 2015, net enrolment had increased to 78%. In upper secondary, Mexico City climbed from 43% to 98%, while Michoacán, a state just west of Mexico City and with the lowest enrolment in 2015, increased from 15% to 51%. Again, for comparison, the national average increased from 23% to 62% from 1990-2015 (Consejo Nacional de Población 2018a). Nevertheless, what little evidence exists suggest that educational access varies much more at the municipal level than it does the state level (Gutiérrez, Sánchez, and Giorguli 2011), but official municipal education measures do not exist for the entire 1990-2015 period.

C.1 Data preparation

Data preparation undertaken uses census responses to estimates simple municipal proportions rather than model-based proportions. For example, for the indicator of *school* enrolment, a value of one was assigned to cases where the census response indicated that the woman or girl aged 12 to 20 was currently enrolled school, and the value of zero was assigned to the remaining cases. The municipal proportion is calculated by dividing the weighted sum of girls enrolled in school by the weighted sum of all girls in each municipality. Weights used are those provided by the census surveys, but readjusted to the sample size rather than the population size.

To look at the proportion with completed lower secondary schooling, *attain lower secondary*, cases were restricted to those aged 15 to 20 at the time of the census, as the theoretical age of completion of lower secondary schooling is age 14. Mexican census data on educational attainment records the highest level of schooling attained and the number of years completed within each level. Cases that indicated they had completed three years of lower-secondary schooling or its equivalent (secundaria and technical tracks requiring complete primary in the census data) or any number of years at a higher level, were considered to have attained complete lower secondary schooling.

To look at the proportion with completed upper secondary schooling, *attain upper secondary*, cases were restricted to those aged 18 to 20 at the time of the census, as the theoretical age of completion of upper secondary is age 17. Here, cases that indicated they had completed three years of upper-secondary schooling (preparatoria and technical tracks requiring complete lower-secondary in the census data) or any number of years at a higher schooling level, were considered to have attained complete upper secondary schooling.

For *work*, *healthcare*, *indigenous*, *migrant*, *rural*, and *poverty* cases include all women and girls aged 12 to 20. Only those who were not currently enrolled in school and reported that they had worked in the week preceding the census (or had a job despite not working in the preceding week) were coded as having *work*. *Healthcare* access is designated by census responses that indicated those who did not report that they had no entitlement to either public or private healthcare (note the double negative). *Indigenous* records those who reported speaking an indigenous language, and *migrant* identifies cases whose municipality of residence five years prior to the census survey was not the same as the municipality of residence at the time of the census survey. *Rural* identifies those whose place of residence was a community with up to 2,499 inhabitants and *poverty* identifies those living in households with more than 2.5 occupants per room in the dwelling. Note that *work* questions were not asked in the 2005 census sample, *healthcare* in the 1990 census sample, and *migrant* status was not calculable in the 1990 and 2005 census samples.

While the census samples were not necessarily designed to provide reliable estimates of these variables for the subsamples of females 12-20, 15-20 and 18-20 years old at the municipal level, exploratory work indicated that the equivalent indicators for the entire municipal populations—which can be estimated much more reliably and in some cases have existing official estimates—had a much weaker relationship to adolescent fertility. As such, and given that the aim is not to produce municipal estimates of these socioeconomic variables but rather to examine, in broad strokes, their relationship with adolescent fertility, the more uncertain proportions describing the adolescent landscape were chosen over more reliable proportions describing the adult landscape in municipalities. Exploratory work also examined using model-based methods to smooth out the statistical noise inherent in the raw proportions, but the broad conclusions from the final regression analysis remained unchanged.

The regression equations exploring the relationship between these various indicators and parity-specific adolescent fertility use grand-mean centering. That is, for each indicator, once the estimated municipal proportions were produced, the grand mean (average proportion for all municipalities and all years) was subtracted from each individual municipal proportion. This adjustment does not change the nature of the regression analysis but simply aids in the interpretation of the results. It makes the intercept predictive of the adolescent fertility that would be expected if all other indicators were at their averages. Otherwise, the intercept would be predictive of the adolescent fertility in a hypothetical and rather unlikely municipality where all other variables are at 0% (i.e., no out-of-school adolescents who are working, no adolescents with healthcare access, no indigenous language speakers, no migrants, no poverty and no rural communities). Finally, while 20-year-olds are no longer adolescents, they are retained in the municipal socioeconomic and educational indicators so that the population of reference for both the parity-specific adolescent fertility measures and educational and socioeconomic indicators is the same. Recall that females aged 20 years are included in the fertility estimates to improve estimation of the shape of the adolescent fertility age schedule.

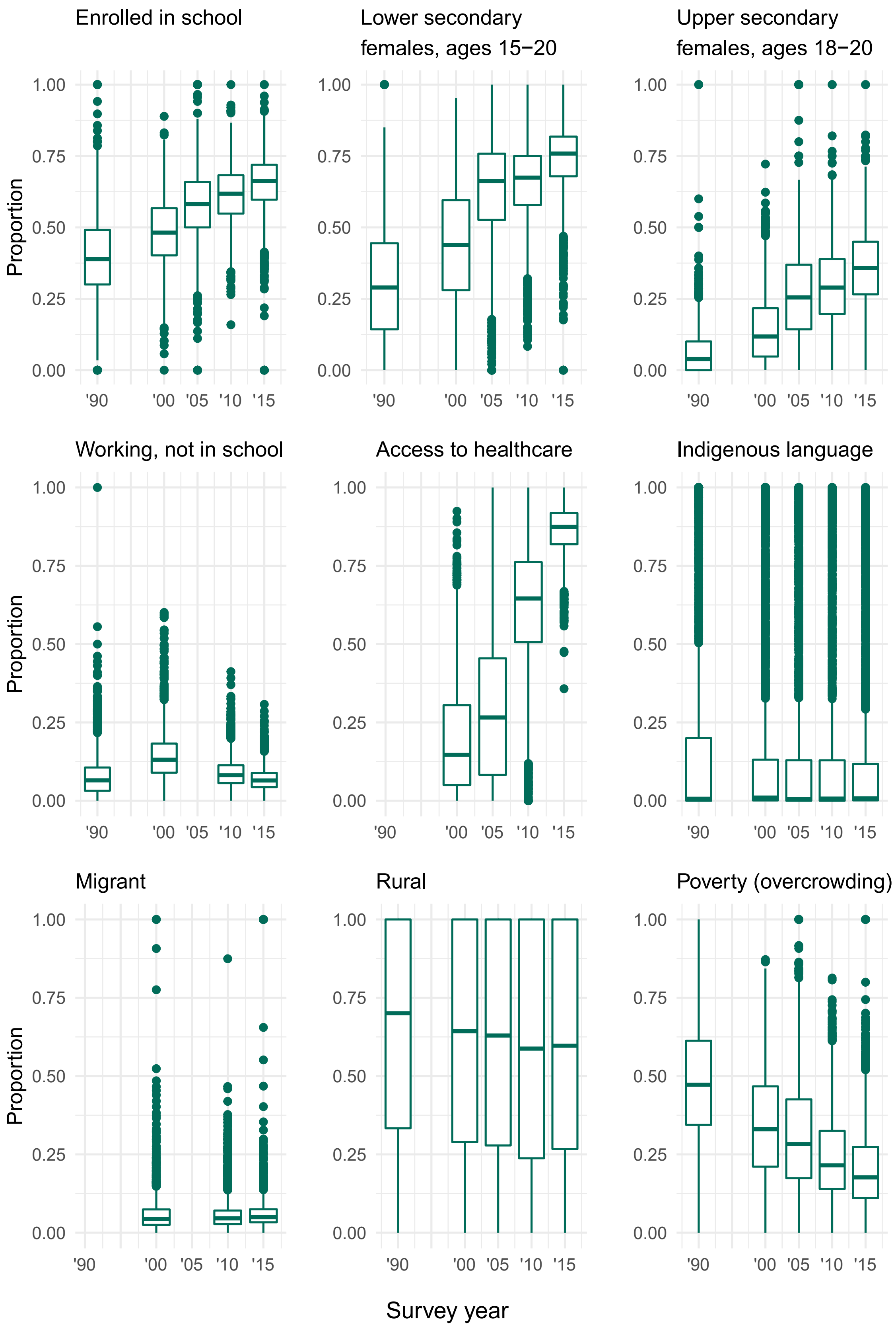
C.2 Descriptive analysis

As a first approach to describing trends in schooling, and other socioeconomic variables of interest, this section presents a number of basic descriptive statistics from the data.Figure C.1 presents box-plots of this study's selected covariates. Again, the covariates are *school*, *attain lower secondary*, *attain upper secondary*, *work*, *healthcare*, *indigenous*, *migrant*, *rural*, and *poverty*. Like the trends in adolescent fertility, many educational and socioeconomic indicators also see convergence over the 1990-2015 period, but rather than stagnation, there is considerable change. Improvement is seen in municipal schooling indicators, with graduation from lower secondary schooling seeing stronger growth than enrolment or upper secondary completion. That is, in 1990, half of municipalities (the range of the second and third quartiles) saw between about 15-45% of females aged 15-20 with complete lower secondary schooling while in 2015, the proportion was between 65-80%. For school enrolment, half of municipalities saw about 30-50% of their adolescent females aged 12-20 enrolled in school in 1990, and this increased to about 60-70% enrolled in 2015. Graduation from upper secondary among females aged 18-20 grew from between about 0-15% in 1990 in half of municipalities to 25-45% in 2015.

Adolescent employment increased from 1990 to 2000 but declined from 2000 to 2015 such that in half of municipalities only about 5-10% of females aged 12-20 who were not in school were working in 2015. Nevertheless, considerable improvement is seen in adolescent access to healthcare. In 2000, half of municipalities saw between 5-30% of females aged 12-20 enrolled with a healthcare provider, while in 2015 this increased to 80-90% of adolescents with access in half of municipalities. Most municipalities have few indigenous language speakers. Half of municipalities saw fewer than 12% of females aged 12-20 speaking an indigenous language (20% in 1990), but there are many outliers with high concentrations of indigenous populations—municipalities with up to 100% of girls aged 12-20 speaking and indigenous language. Internal migration sees little change, with half of municipalities consistently seeing between about 5-10% of their females aged 12-20 who did not live in the same municipality 5 years previous. The rural/urban composition of munciaplities is exceptionally diverse. Half of municipalities see between 25-100% of females aged 12-20 living in communities of less than 2,500 inhabitants. Note that this does not reflect the composition of the population as a whole, but instead is a reflection of the typical municipal profile. Indeed, only about a quarter of all females aged 12-20 in the country live in rural communities. Finally, poverty declined, with half of municipalities seeing 30-60% of females aged 12-20 living in overcrowded dwellings in 1990 and, in 2015, between 15-25% doing so.

Mapping these municipal $ASFR_{15\text{-}19}$ and covariates provide a helpful point of reference. Figure C.2 depicts the municipal 2015 values. The map of the $ASFR_{15\text{-}19}$ reveals that high rates of adolescent fertility are concentrated in the north and south, as well as in many coastal municipalities, while low rates of adolescent fertility cluster in the central region, parts of the Yucatan peninsula and some northwestern municipalities as well. A number of the most sparcely-populated munici-

Figure C.1: Proportion of females aged 12-20 (unless otherwise specified) with various educational and socioeconomic profiles in Mexican municipalities by year, 1990-2015



palities do not have adolescent birth rate estimates (those in white). The geography of the various educational indicators do not provide a clean match to the $ASFR_{15\text{-}19}$ map. Many municipalities in the central west region where adolescent fertility is low also see low levels of school enrolment, while many northern and southern regions with high $ASFR_{15\text{-}19}$ also see lower levels of school enrolment. High levels of lower and secondary secondary attainment are seen in many of the northern municipalities with some of the highest $ASFR_{15\text{-}19}$, while there are markedly lower attainment levels in the southern municipalities that have similarly high levels of $ASFR_{15\text{-}19}$. Mexico city and its environs also have high levels of education.

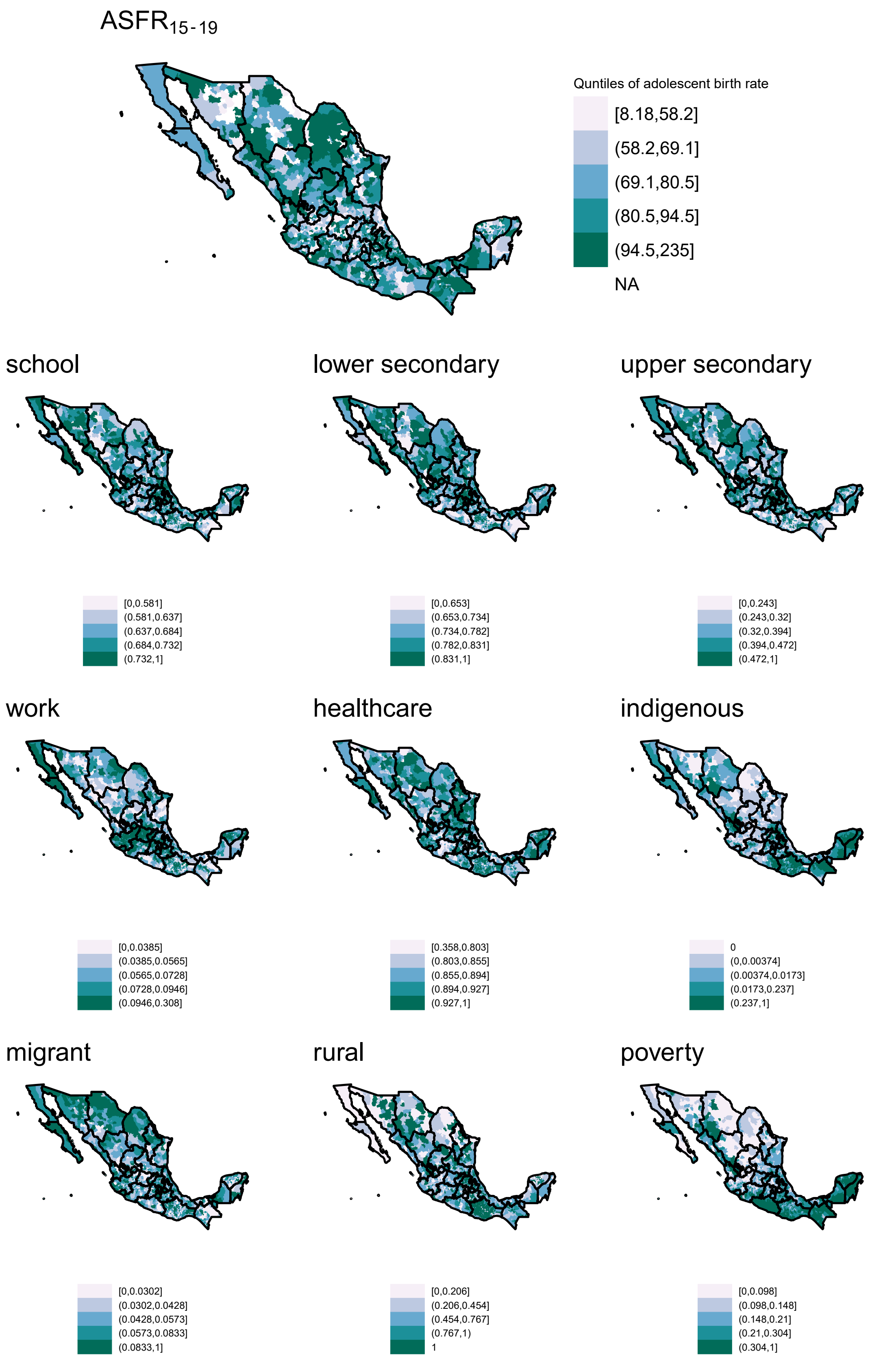
Higher proportions of working out-of-school adolescents concentrate in the central and northwestern municipalities. Healthcare access is better in the north where migration is also higher, while indigenous populations and poverty are strongly concentrated in the south. Rural geographies are generally those that show the poorest educational indicators (rural map is largely a reverse image of the educational maps).These maps are of 2015 indicators but the geographies of the indicators in earlier years look almost identical, meaning that the relative position of municipalities in terms of their educational and socioeconomic profiles have remained largely unchanged despite substantial improvements in education and healthcare access and reductions in poverty.

In the absence of other evidence, these indicators suggest the connection between aggregate levels of adolescent fertility and schooling in Mexican municipalities is complex. Drawing inference about the relationship between schooling and adolescent fertility in municipalities, without taking parity-specific patterns into account and, simultaneously, differences in poverty levels or access to healthcare among other things, may be premature.

C.3 Methods

The analysis uses ordinary least squares (OLS) regressions to examine the relationship between adolescent fertility and schooling across municipalities in 2015, and it uses multilevel models to examine the relationship between adolescent fertility and schooling within municipalities over time (from 1990-2015). The basic question the OLS regression analysis seeks to query is whether there is a negative relationship between aggregate municipal indicators of adolescent education and adolescent fertility—when adolescent fertility measures are parity-specific—given that there seems to be no relationship between municipal $ASFR_{15\text{-}19}$ and schooling in recent years. However, other research in the region has found that cross-sectional analysis is often inadequate for describing the relationship between changes over time in fertility and socioeconomic development within subnational regions (Potter, Schmertmann, and Cavenaghi 2002). As such, multilevel regressions will be used to explore, in broad strokes, whether there is a negative relationship between changes in adolescent fertility and adolescent education over time within municipalities. In other words, whether improvements in education are associated with declines in adolescent

Figure C.2: Mapped quintiles of proportions of summary statistics by Mexican municipality, 2015



fertility over time on average in Mexican municipalities.

To better explore the advantages of parity-specific measures over $\text{ASFR}_{15\text{-}19}$, this study extension turns to OLS regressions to investigate whether the parity-specific estimates offer a more consistent picture of the relationship between adolescent fertility and schooling across municipalities in 2015. As already mentioned, previous research has found that the negative relationship between municipal $\text{ASFR}_{15\text{-}19}$ and rates of school enrolment among adolescent females aged 15-19 is not only quite small, but disappearing (Meneses and Hernández 2019). This comparison is done by using orindary least squares (OLS) regressions to look at data from 2015, which is the most recent of the two years for which official municipal $\text{ASFR}_{15\text{-}19}$ are available and the year in which education had the least explanatory power for fertility patterns. The cross-sectional regressions provide a high-level assessment of the relationship between municipal adolescent fertility and schooling, and of particular interest, a benchmark measurement of the ability of the model to fit the data.

Three groups of models look at (1) municipal measures of $\text{ASFR}_{15\text{-}19}$ as the outcome variable, (2) municipal proportions of 19.99-year-old adolescents with first births as the outcome variable, and (3) municipal progression ratios to second births, or the proportion of adolescent mothers who progressed to a second birth by age 19.99 as the outcome variable. For each of the three outcome variables, there are six equations. The first equations are basic models that looks at the association between adolescent fertility and levels of school enrolment across municipalities. These equations are:

$$\text{ASFR}_{15-19j} = \alpha + \beta_1 \text{school}_j + \varepsilon_j$$

Where $\text{ASFR}_{15\text{-}19}$ is the age-specific fertility rate among 15-19 year-olds in municipality *j*, which is determined by the components of intercept α (shared across all municipalities), slope coefficients β and the error term ε. The variable *school* represents the centered proportion of adolescents aged 15-19 enrolled in school within municipality *j*. The same equation will be used for looking at explanatory variable $\text{birth1}_{19.99j}$, or the proportion of adolescents aged 19.99 with a first birth in municipality *j* as well as the proportion of adolescent mothers who progressed to a second birth by age 19.99 ($\text{progression2}_{19.99j}$):

$$\text{birth1}_{19.99j} = \alpha + \beta_1 \text{school}_j + \varepsilon_j$$
$$\text{progression2}_{19.99j} = \alpha + \beta_1 \text{school}_j + \varepsilon_j$$

To test whether there is a relationship between *school* and adolescent fertility (as measured by the three distinct outcome variables) across municipalities when other potential factors that could otherwise explain or mediate the relationship are present, the regression models are expanded to include the socioeconomic variables described previously: *work*, *healthcare*, *indigenous*, *migrant*, *poverty*, *rural*. In the case of $\text{progression2}_{19.99}$, the expanded model includes the addition of a coefficient for the incidence of first births (grand mean centered) to be able to examine the relationship between second births and schooling that is independent of the incidence of first births.

A second and third serious of OLS regressions examine the relationship between lower secondary attainment (*attain lower secondary*) and upper secondary attainment (*attain upper secondary*) and each of the three different outcomes measures of adolescent fertility. The basic and expanded models are identical to those seen for enrolment except *attain lower secondary* or *attain upper secondary* replaces *school* throughout. Attainment and enrolment cannot be included in the same regressions without problems of multicollinearity, but attainment and enrolment depict important and distinct aspects of the adolescent education landscape. Differences between the models of attainment and enrolment offer valuable insight into possible differences in trends of schooling's incarceration and aspirational aggregate changes across municipalities.

To look at change over time within municipalities, multilevel random intercept regressions are used to quantify the association between adolescent fertility and levels of school enrolment and attainment. Because municipal measures of $\text{ASFR}_{\text{15-19}}$ are unavaiable prior to 2010, the models only look at (1) municipal proportions of 19.99-year-old adolescents with first births as the outcome variable, and (2) municipal progression ratios to second births, or the proportion of adolescent mothers who progressed to a second birth by age 19.99 as the outcome variable. The first equations are a basic model that looks at the association between adolescent fertility and levels of school enrolment over time (1990 is coded as year 0). These equations are:

$$\begin{aligned} \text{birth1}_{19.99ij} &= \beta_0 + \beta_1 \text{school}_{ij} + \beta_2 \text{year}_{ij} + u_{0j} + e_{ij} \\ \text{progression2}_{19.99ij} &= \beta_0 + \beta_1 \text{school}_{ij} + \beta_2 \text{year}_{ij} + u_{0j} + e_{ij} \end{aligned}$$

In these models, the intercept β_0 is the overall mean for Mexico, and u_{0j} is the difference between municipality *j*'s mean and Mexico's overall mean. Importantly, the relationship between adolescent fertility and schooling within municipalities (rather than across them) is represented by slope β_1. Random effects are assumed to follow a normal distribution with variance σ^2_{u0}. Multilevel models could take the exploration much further to, for example, explore more nuance and difference in the association, but for the purpose of the analysis at hand—which is to determine, in broad strokes, whether there is, on average, a negative relationship between adolescent education and fertility within municipalities over time in Mexico—the random intercepts models are adequate. Just as with the OLS regressions, additional models incorporate additional socioeconomic variables to determine whether the relationship holds when controlling for other aspects of municipalities' socioeconomic and demographic landscape.

C.4 Results

The following paragraphs review the results of the exploration of the relationship between schooling and adolescent fertility across municipalities, with particular interest in whether parity-specific proportions show a more consistent relationship than do measures of $ASFR_{15\text{-}19}$. Afterward, it reviews the results of the exploration of the relationship between schooling and fertility over time within municipalities.

In Table C.1, basic regression models compare levels of school enrolment (*school*) against municipal $ASFR_{15\text{-}19}$ (model one), proportion of 19.99-year-olds with a first birth (model seven) and proportion of adolescent mothers who progressed to a second birth by age 19.99 (model thirteen). Most importantly, school enrolment does indeed have greater explanatory power in the parity-specific regressions than it does for $ASFR_{15\text{-}19}$, even when controlling for other socioeconomic differences across municiaplities (models four, ten and sixteen). Specifically, 9% of the variation in $ASFR_{15\text{-}19}$ is explained by school enrolment along with the other socioeconomic factors (model four, r-squared of 0.09), while 20% of the variation in municipal proportions of 19.99-year-olds with a first birth is explained by school enrolment along with the other factors (model ten, r-squared of 0.20) and 22% of the variation in second birth proportions along with the other factors (model sixteen, r-squared of 0.22). Importantly, school enrolment and attainment have a negative relationship with adolescent fertility in all regression models. That is, even when controlling for the other socioeconomic indicators of interest, municipalities with higher enrolment or attainment see lower adolescent fertility on average.

In looking at school enrolment and $ASFR_{15\text{-}19}$, model four suggests a municipality with average school enrolment (65% of adolescent females aged 12-20 enrolled in school) has a predicted $ASFR_{15\text{-}19}$ of 77 births per thousand in 2015, while a municipality with one percentage point higher enrolment sees 0.5 fewer predicted births per thousand when controlling for other socioeconomic differences. For first births, model ten indicates that a municipality with average school enrolment has a predicted proportion of 36% of adolescents with a first birth by age 19.99 and 24% of adolescent mothers with a second birth by age 19.99. Municipalities with one percentage point higher enrolment, controlling for other socioeconomic differences, are predicted to see 0.3 fewer first births and 0.06 fewer second births among those at risk.

Just as is the case with school enrolment, the relationship between school attainment and adolescent fertility across municipalities is also negative, even when controlling for differences in other municipal socioeconomic factors. That is, municipalities with higher proportions of adolescents completing lower secondary and upper secondary have a lower incidence of adolescent fertility on average. Interestingly, when considering first adolescent births, models looking at upper secondary attainment have the greatest explanatory power (highest r-squared values) even though the coefficient for school enrolment is larger. That is, for every percentage point increase in enrol-

	Dependent variable:																	
	ASFR						birth1_19.99						progression2_19.99					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
school	−0.436***			−0.545***			−0.206***			−0.271***			−0.142***			−0.055***		
	(0.052)			(0.064)			(0.013)			(0.016)			(0.010)			(0.013)		
attain_lsc		−0.422***			−0.433***			−0.161***			−0.189***			−0.183***			−0.111***	
		(0.042)			(0.057)			(0.011)			(0.014)			(0.008)			(0.011)	
attain_usc			−0.270***			−0.261***			−0.198***			−0.210***			−0.109***			−0.026***
			(0.040)			(0.049)			(0.010)			(0.011)			(0.008)			(0.009)
working				−1.159***	−0.840***	−0.849***				−0.350***	−0.174***	−0.235***				−0.191***	−0.184***	−0.158***
				(0.160)	(0.152)	(0.155)				(0.039)	(0.038)	(0.037)				(0.030)	(0.028)	(0.029)
healthcare				−0.152**	−0.117	−0.181**				0.061***	0.072***	0.052***				−0.069***	−0.054***	−0.072***
				(0.072)	(0.073)	(0.072)				(0.017)	(0.018)	(0.017)				(0.013)	(0.013)	(0.013)
indigenous				−0.062***	−0.079***	−0.064***				−0.022***	−0.028***	−0.029***				0.024***	0.017***	0.024***
				(0.021)	(0.021)	(0.021)				(0.005)	(0.005)	(0.005)				(0.004)	(0.004)	(0.004)
migrant				−0.480***	−0.425***	−0.334***				−0.269***	−0.239***	−0.197***				−0.009	−0.021	0.006
				(0.072)	(0.071)	(0.071)				(0.018)	(0.018)	(0.017)				(0.014)	(0.013)	(0.013)
poverty				0.289***	0.246***	0.365***				0.032***	0.026**	0.039***				0.112***	0.077***	0.119***
				(0.049)	(0.053)	(0.049)				(0.012)	(0.013)	(0.012)				(0.009)	(0.010)	(0.009)
rural				−0.125***	−0.106***	−0.113***				−0.009**	0.001	−0.013***				−0.012***	−0.013***	−0.010***
				(0.017)	(0.017)	(0.018)				(0.004)	(0.004)	(0.004)				(0.003)	(0.003)	(0.003)
birth1_19.99c																0.090***	0.072***	0.097***
																(0.015)	(0.015)	(0.016)
Constant	77.371***	77.367***	77.397***	77.131***	77.181***	77.169***	35.582***	35.582***	35.582***	35.582***	35.582***	35.582***	22.537***	22.537***	22.537***	22.537***	22.537***	22.537***
	(0.536)	(0.532)	(0.538)	(0.520)	(0.522)	(0.525)	(0.134)	(0.135)	(0.130)	(0.126)	(0.129)	(0.125)	(0.105)	(0.098)	(0.105)	(0.096)	(0.095)	(0.096)
Observations	2,340	2,340	2,340	2,340	2,340	2,340	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457	2,457
R^2	0.029	0.042	0.019	0.090	0.085	0.074	0.093	0.084	0.150	0.202	0.164	0.212	0.074	0.182	0.077	0.222	0.249	0.218
Adjusted R^2	0.029	0.041	0.019	0.088	0.082	0.071	0.093	0.083	0.150	0.200	0.162	0.210	0.073	0.182	0.076	0.219	0.246	0.215
Residual Std. Error	25.906	25.742	26.043	25.113	25.184	25.343	6.662	6.695	6.448	6.255	6.402	6.215	5.195	4.881	5.186	4.769	4.686	4.780
F Statistic	70.985***	101.770***	45.714***	33.080***	31.014***	26.469***	251.383***	224.285***	433.383***	88.637***	68.716***	94.344***	195.413***	546.693***	204.338***	87.084***	101.207***	85.287***

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$
standard errors shown in parentheses

Table C.1: Regression results examining associations across municipalities in 2015 (OLS regressions) ment, first birth proportions are 0.3 percentage points lower on average while for every percentage point increase in upper secondary attainment, first birth proportions are 0.2 percentage points lower. In contrast, for second birth progression, lower secondary attainment has both the greatest explanatory power and largest coefficient.

The other socioeconomic factors considered in the models show unexpected results on several fronts that are worth mentioning. For example, municipalities with higher levels of healthcare access also have higher levels of adolescent first births when controlling for all other considered factors. However, interestingly, municipalities with higher levels of healthcare access have lower levels of adolescent second births on average. Additionally, municipalities with a higher proportion of adolescents in rural communities tend to have slightly lower levels of adolescent fertility when controlling for other socioeconomic differences—but the size of the coefficient is exceptionally small for the parity-specific models so the difference it makes across municipalities is marginal. In contrast, adolescent employment and poverty show an expected association. Municipalities with higher youth employment have lower adolescent fertility and, conversely, municipalities with higher youth poverty have higher adolescent fertility on average. Interestingly, the coefficient for youth employment is generally larger than the coefficients for enrolment and lower secondary attainment (but not upper secondary attainment); and the magnitude of the coefficient for poverty is small for first births (but not for second births). That is, when controlling for other socioeconomic factors across municipalities, the prevalance of poverty makes almost no difference for the levels of first adolescent births while it makes a considerable difference for levels of second birth progression. Additionally, municipalities with higher concentrations of indigenous populations tend to have slightly lower levels of first births in adolescence but higher risk of second births (again, the magnitude of the coefficient is very small). Similarly, municipalities with higher concentrations of migrant populations tend to have lower adolescent first birth proportions, while there is no relationship between migration patterns and the incidence of progression to second adolescent births across municipalities in 2015.

In summary, patterns of parity-specific adolescent fertility proportions, as opposed to the adolescent birth rate, have a stronger association with schooling levels across municipalities in 2015—whether measured by school enrolment or lower and upper secondary attainment—among adolescent females. This finding is an important point of departure for the subsequent analysis that looks at how changes in parity-specific adolescent fertility and education within municipalities from 1990-2015 were related.

Table C.2 presents the regressions that quantify how levels of school enrolment and attainment were related to changes in adolescent fertility within municipalities over nearly three decades of subnational flux. In the table, models one to six look at first birth proportions while models seven to twelve look at second birth progression ratios. Most importantly, all educational indicators show a negative relationship with adolescent fertility change. Even when controlling for other socioeconomic factors, increases in school enrolment and attainment within municipalities were related to declines in first and second adolescent births. Except in the case of upper secondary attainment and second birth progression ratios, where the association is not statistically different from zero. However, the magnitude of the relationship across all models is altogether quite small.

For example, according to the model four, which looks at the relationship between school enrolment and first adolescent births, controlling for other socioeconomic factors, a municipality with average indicators across all variables is predicted to see 30.8% of women with a first birth by age 19.99 in 1990. In the same municipality, the proportion of first adolescent births would be predicted to increase to 36.7% by 2015 if there had been no changes otherwise in its schooling and socioeconomic profile. If the municipality instead experienced improvements in school enrolment, but no change in any other socioeconomic indicators—moving from 39% enrolled in 1990 to 66% enrolled in 2015, which was the average change in enrolment within municipalities, for example—its predicted proportion of adolescent mothers would have increased instead to 35.5% in 2015, only 1.2 percentage points lower. Nevertheless, no other socioeconomic factor has a larger coefficient than school enrolment, meaning that changes in first birth proportions see even less association with changes in poverty, healthcare access, or other measured socioeconomic factors than they do with schooling. On average, improvements in school enrolment within municipalities have not been able to offset increases in first births in adolescence that are otherwise unrelated to changes in schooling and the other included socioeconomic variables.

In the case of second births, the relationship is even more marginal. The predicted decline from 35.7% to 24.9% would have instead reached 24.1% of adolescent mothers with a second birth by age 19.99 in 2015 if similar educational improvements had occurred (and with no other changes in the municipality's socioeconomic profile). Essentially, the bulk of the strong declines in second births appear to be largely unrelated to changes in enrolment. To be clear, there is a measurable statistical relationship, but the magnitude of the relationship is such that it has little substantive relevance. Instead, first birth proportions and poverty levels have the largest coefficients, predicting that for every 1 percentage point decrease in their proportions, there is a corresponding 0.1 percentage point decrease in the second birth progression ratios, all else equal. Adolescent employment and healthcare access also have larger coefficients than school enrolment, which suggests they are in some respects more relevant for municipal trends in second adolescent births than schooling.

Differences between models of enrolment and attainment in relation to first adolescent births are minimal. That is, the coefficients for the education indicators in models four through six are very similar (as are the coefficients for all other variables). Nevertheless, the model looking at lower secondary attainment performs slightly better (better goodness of fit statistics) and has a slightly larger coefficient for the education indicator. Within municipalities, lower secondary completion increased considerably from 1990 to 2015, from 30% to 75% of adolescents aged 12-20 attaining that education level on average. Nevertheless, increases were not enough on their own to offset the pattern of increasing adolescent first births.

Differences between models of enrolment and attainment in relation to progression to second adolescent births are more marked. Here again, the model looking at lower secondary attainment performs better and has a much larger coefficient than the models looking at enrolment and upper secondary attainment. This suggests that improvements in lower secondary coverage are related to comparatively larger declines in second birth progression ratios than improvements in enrolment and upper secondary attainment. In fact, the size of the coefficient for lower secondary attainment is nearly double that of enrolment, and the coefficient for upper secondary completion is not statistically different from zero. Additionally, only the first birth proportion has a larger coefficient than attainment, whereas several other factors had larger coefficients than enrolment. This suggests that after changes in first births, trends in lower secondary attainment are more relevant for municipal trends in second adolescent births than are any of the other socioeconomic variables—though poverty and employment follow close behind in magnitude.

In looking at the other socioeconomic factors, it is worth briefly noting instances where the association within municipalities over time is different than that found across municipalities in 2015. For example, increases in access to healthcare is associated with slight declines in first and second adolescent births, all else being equal. Recall that in 2015, municipalities with higher levels of healthcare access saw higher levels of adolescent first births on average. Additionally, declines in the rural or indigenous makeup of a municipality are associated with slight declines in first births, all else being equal. Across municipalities in 2015, rural and indigenous municipalities had slightly lower levels of adolescent fertility on average. Additionally, changes in adolescent employment did not matter for trends in first births within municipalities, though they were relatively important for differences across municipalities in 2015.

In summary, educational expansion within municipalities is associated with declines in the incidence of adolescent childbearing over the last several decades. However, the magnitude of the relationship is surprisingly small. The models suggest that that bulk of changes in parity-specific adolescent childbearing are, on average, independent of municipal levels of adolescent education, employment, poverty, healthcare access, indigenous profile, migratory status and rurality, at least in terms of how these aspects are quantified in the models. Additionally, the way the educational expansion is measured—be it in terms of adolescent enrolment or attainment of lower secondary or upper secondary—matters relatively little for modeling the change within municipalities over time in first births. Though there is indication that changes in lower secondary attainment has a more coherent association with changes in levels of adolescent first births over time within municipalities, the substantive conclusions remain largely unchanged across all models of enrolment and attainment. However, for changes in progression to second births, lower secondary attainment has a much clearer connection than do the other educational measures.

	Dependent variable:											
	birth1_19.99						progression2_19.99					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Fixed effects												
school	−0.050***			−0.044***			−0.040***			−0.031***		
	(0.004)			(0.007)			(0.004)			(0.007)		
attain_lsc		−0.055***			−0.053***			−0.070***			−0.076***	
		(0.003)			(0.005)			(0.003)			(0.005)	
attain_usc			−0.015***			−0.046***			−0.013***			−0.005
			(0.004)			(0.005)			(0.004)			(0.005)
year	0.063***	0.107***	0.027***	0.233***	0.247***	0.251***	−0.737***	−0.655***	−0.766***	−0.431***	−0.388***	−0.445***
	(0.005)	(0.006)	(0.005)	(0.015)	(0.015)	(0.015)	(0.006)	(0.007)	(0.006)	(0.016)	(0.016)	(0.017)
working				−0.007	0.007	0.011				−0.063***	−0.060***	−0.050***
				(0.009)	(0.009)	(0.009)				(0.010)	(0.009)	(0.009)
healthcare				−0.010***	−0.002	−0.009***				−0.037***	−0.026***	−0.038***
				(0.003)	(0.003)	(0.003)				(0.003)	(0.003)	(0.003)
indigenous				0.035***	0.030***	0.032***				0.023***	0.016***	0.023***
				(0.004)	(0.004)	(0.004)				(0.004)	(0.004)	(0.004)
migrant				−0.037***	−0.034***	−0.029***				−0.006	−0.009	0.0004
				(0.008)	(0.007)	(0.007)				(0.008)	(0.008)	(0.008)
poverty				0.035***	0.017***	0.034***				0.100***	0.070***	0.105***
				(0.006)	(0.006)	(0.006)				(0.006)	(0.006)	(0.006)
rural				0.012***	0.011***	0.011***				0.001	−0.002	0.002
				(0.003)	(0.003)	(0.003)				(0.003)	(0.003)	(0.003)
birth1_19.99c										0.138***	0.122***	0.141***
										(0.011)	(0.011)	(0.011)
Constant	33.767***	33.138***	34.268***	30.834***	30.552***	30.505***	40.565***	39.411***	40.968***	35.666***	34.937***	35.850***
	(0.167)	(0.169)	(0.168)	(0.290)	(0.290)	(0.295)	(0.158)	(0.159)	(0.160)	(0.294)	(0.292)	(0.300)
Random effects:												
intercept variance	51.95	49.54	52.93	41.94	41.79	41.6	42.23	37.91	43.06	25.49	22.96	24.15
(standard deviation)	7.21	7.04	7.28	6.48	6.46	6.45	6.5	6.16	6.56	5.05	4.79	4.91
Observations	12,208	12,196	12,133	7,355	7,355	7,353	12,208	12,196	12,133	7,355	7,355	7,353
Log Likelihood	−35,646.980	−35,521.870	−35,546.200	−21,738.510	−21,704.300	−21,717.430	−36,302.390	−36,067.970	−36,153.450	−21,529.880	−21,434.360	−21,533.800
Akaike Inf. Crit.	71,303.960	71,053.750	71,102.390	43,499.010	43,430.610	43,456.870	72,614.770	72,145.950	72,316.900	43,083.760	42,892.720	43,091.610
Bayesian Inf. Crit.	71,341.010	71,090.790	71,139.410	43,574.950	43,506.540	43,532.800	72,651.820	72,182.990	72,353.910	43,166.600	42,975.560	43,174.440

Note: *p<0.1; **p<0.05; ***p<0.01
standard errors shown in parentheses

Table C.2: Regression results examining associations within municipalities over time, 1990-2015 (multilevel models)

C.5 Discussion

This thesis' first study found that in Mexico the sharpest increases in incidence of adolescent first births have occurred in groups who attain lower secondary schooling (and whose theoretical age for exiting school is 14 years), the level where a considerable portion of girls still find themselves despite the country's dramatic educational progress. Those with completed upper secondary (with a theoretical exit age of 17 years) have seen more modest increases in first adolescent births, but have seen increases nevertheless. At the same time, for second births, there has been more limited decline for each specific schooling level than what is suggested by the strong aggregate decline. As such, it is in some sense surprising that all the regression models of first adolescent births find a negative relationship with adolescent fertility and education, whether it is measured by enrolment, lower secondary attainment or upper secondary attainment. To be sure, there is a statistical preference for using lower secondary attainment for changes in adolescent fertility within municipalities over time and upper secondary attainment in looking at first births across municipalities in 2015, which hints at the growing importance of upper secondary for tackling adolescent fertility in Mexico. However, the substantive differences between enrolment and attainment, as captured in the models, are ultimately quite marginal.

Given the findings in the first study, the lack of a more marked difference in regressions looking at enrolment and attainment—as well as the exceptionally small magnitude of the education coefficients—are at first glance rather unsatisfying. Nevertheless, the findings caution against a hasty expansion of access to higher educational levels at the expense of leaving the most vulnerable in lower levels of schooling behind. Indeed, the distribution of Mexico's public spending on education at upper secondary and tertiary is in many ways contributing to greater inequality in the country (Carnoy 2011). That is, public investments in upper secondary and tertiary schooling have mainly benefited the middle and upper classes, primarily in urban areas (Lopez-Acevedo and Salinas 2000).

Additionally, the way aggregate enrolment and attainment are decoupled in the data may well reflect a distinction that is rather less clear cut in the population. Improvements in aggregate enrolment go hand-in-hand with improvements in aggregate attainment. As more adolescents remain enrolled in school through older adolescent ages, the population collectively, progressively attains higher levels of education. Exploratory work that tried to capture more nuanced educational distinctions in the data were uninformative, and enrolment and attainment measures could not be combined in the same model because of problems of collinearity. For example, analyses looking at whether patterns of enrolment at specific ages (for example, proportions enrolled at ages 17 and older compared to younger ages) found no indication of important differences. The models did not perform as well as those that instead looked at the proportion enrolled at all adolescent ages and the estimated coefficients were similar enough that the conclusions remained consistent: higher levels of adolescent enrolment in school—no matter the age—are correlated with lower levels of adolescent fertility both across municipalities in 2015 and over time. Instead, for aggregate patterns, a girl in school whatever her age is of value. That is, for these municipal patterns, it appears it is no more valuable for a 19-year-old to be in school than it is for a 12-year-old to be.

Exploratory work also examined the role of the expansion of tertiary attainment, but the models were uninformative. Again, this could reflect something of how attainment of the highest education levels and enrolment among the oldest adolescents is still largely confined to those who are already better off, and whose risk and patterns of adolescent fertility remain distinct. Another possibility, already discussed in other research, is that Mexico's educational expansion has not yet led to widespread postponement because most of the educational changes have occurred at ages that are still too young to conflict with the timing of transitions to motherhood (Kroeger, Frank, and Schmeer 2015; Lindstrom and Paz 2001). Despite the dramatic improvements over the last decades, about one third of 17-year-olds and two thirds or 19-year-olds in Mexico remained out of school in 2015. However, this national average diverges from the profile of a typical municipality because the largest urban areas have much better educational outcomes. Instead, the average municipality sees 59% of its 17-year-olds in school and only 27% of its 19-year-olds in school.

Finally, it seems likely that the limited explanatory power of the $ASFR_{15\text{-}19}$ regressions is more about the opposing patterns in parity-specific change than about fundamental differences in the relationship between adolescent education, employment, healthcare access, poverty levels or prevalence of indigenous, rural and migrant populations with adolescent fertility. Indeed, the leading socioeconomic covariates maintain their respective positive or negative relationships with adolescent fertility across the regressions for $ASFR_{15\text{-}19}$ and first and second birth proportions. They also show the same relationship within municipalities and their change over time. That is, schooling enrolment, schooling attainment, and youth employment have a consistently negative relationship. Poverty has a consistently positive relationship. This consistency is reassuring, as it also aligns with individual-level evidence.

In cases where the association was inconsistent, the within-municipality analysis offered important clarification, especially in regards to healthcare access. Mexico's national strategy emphasizes that adolescent fertility should be targeted through improvements in adolescent schooling and particularly, youth-friendly health services and better comprehensive sexuality education. Across municipalities in 2015, higher levels of healthcare access was associated with higher levels of adolescent first births (but lower progression to second births). However, within municipalities, as healthcare access increased over time, adolescent first and second births decreased, all else equal. Interestingly, the regressions also make a case for the value of investing in the employment prospects of adolescent females, particularly when it comes to progression to second adolescent births, something that is given less attention in the strategy documents.

However, the complexity of the longer-term trends add a note of caution, which is also hinted at in the comparatively low r-squared values of the OLS regressions and the small coefficients in the multilevel regressions. Research in the United Kingdom, for example, find much greater consistency between subnational contextual indicators of schooling and poverty and adolescent fertility, with as much as three quarters of the variation across subregions explained by these differences in aggregate socioeconomic conditions (Bradshaw, Finch, and Miles 2005), whereas in Mexico less than a quarter of the aggregate variation is explained. In essence, the bulk of the change (or lack of change) in adolescent fertility appears to be independent of the educational and other socioeconomic factors identified, or at least independent of how they are quantified in the regressions. Given the patterns of convergence seen across schooling levels and across municipalities, a logical next step for examining the ecological relationship would be to use methods that can account for underlying shifts in the various schooling levels while avoiding problems of multicolinearity.

Appendix D

Appendix to Chapter 4

Regression models in the study "Context is Key" consider only adolescent births that occurred in the 15 months preceding the survey. When looking at all births, differences by schooling position are not quite as extreme, and predicted probabilities at older ages are much higher because they are about the cumulative incidence of adolescent fertility.

D.1 Results: all adolescent births

The following sections present some of these results when considering all adolescent births.

D.1.1 Model 1: Municipal clustering (all births)

Table D.1 presents the regression results for the null model, which does not include any explanatory variables but only estimates the proportion of adolescents in municipalities with a birth. The aim of this model is to identify the existence of possible contextual phenomena, which can be quantified by clustering of adolescent fertility within municipalities. The model estimates that a municipality with $u_{0j} = 0$ has -2.395 log odds of adolescent first births. This converts to 8.4% of all adolescents having a first birth (exp(-2.395)/(1+exp(-2.395))=0.084). For second births, a municipality with $u_{0j} = 0$ has -1.801 log odds of second birth progression, which converts to 14.2% of all adolescent mothers having progressed to an additional birth. Recall that for models looking at births within the last fifteen months, estimates were 3.9% and 9.1% respectively.

The model also indicates that there is municipal clustering, or that girls living in the same municipality share a common likelihood of adolescent fertility that differs from the overall likelihood by an amount that corresponds to the municipal residual. The variance partition coefficient for first births is 0.025 and for second births is 0.027. That is, 2.5% of the total individual differences in

	Model 1			
	First births		Second birth Progression	
	Regression Coefficeint	(standard error)	Regression Coefficeint	(standard error)
Fixed part				
Intercept	-2.395	(0.007)***	-1.801	(0.011)***
	Variance	(standard deviation)	Variance	(standard deviation)
Random part				
Intercept	0.084	(0.29)	0.092	(0.30)
Observations	1,762,920		153,768	
Log Likelihood	-518,294		-65,495	

Note:
*** p-value < 0.0001

Table D.1: Model 1 Results

the likelihood of a first birth are at the municipal level, and 2.7% of the total individual differences in the likelihood of progressing to a second birth are at the municipal level. For births within the last 15 months, the variance partition coefficients were 0.016 and 0.028 respectively. In looking at median odds ratios, this implies that if any girl were to move from one random area to another random area with higher risk, her odds of an adolescent first birth would increase by 32% simply by virtue of the place she is living and no other change in her personal characteristics. For second births, her odds would increase by 34%.

D.1.2 Model 2: Individual characteristics and population composition (all births)

When incorporating information about individual characteristics into the model, the direction of the associations already seen when looking at births within the previous 15 months do not change. However, the probabilities are higher across the board (because they are about the cumulative progression to an adolescent birth rather than probabilities at specific ages), and, importantly, intensities by relative position become comparatively less pronounced. For example, as shown in Figure D.1, though the likelihood for 19-year-old girls who are out of school in places where it is common to be in school can reach as high as 0.75 and in low enrolment areas the likelihood can reach above 0.50, this represents only about a 50% increase in likelihood in moving from low enrolment to high enrolment settings. In models of births in the previous 15 months, there is about a 100% increase in likelihood in moving from low enrolment to high enrolment settings. This likely suggests that girls can return to school after a birth, particularly in places where lots of their peers are in school.

Additionally, differences by most individual characteristics for progression to second births become much less pronounced than they were in models of births within the preceding 15 months as is seen in Figure D.2, For example, the higher likelihood of those who have healthcare access is not as distinguishable.

Figure D.1: Model 2 Predicted probabilities for 14- and 19-year-olds to have given birth in the previous 15 months by schooling status

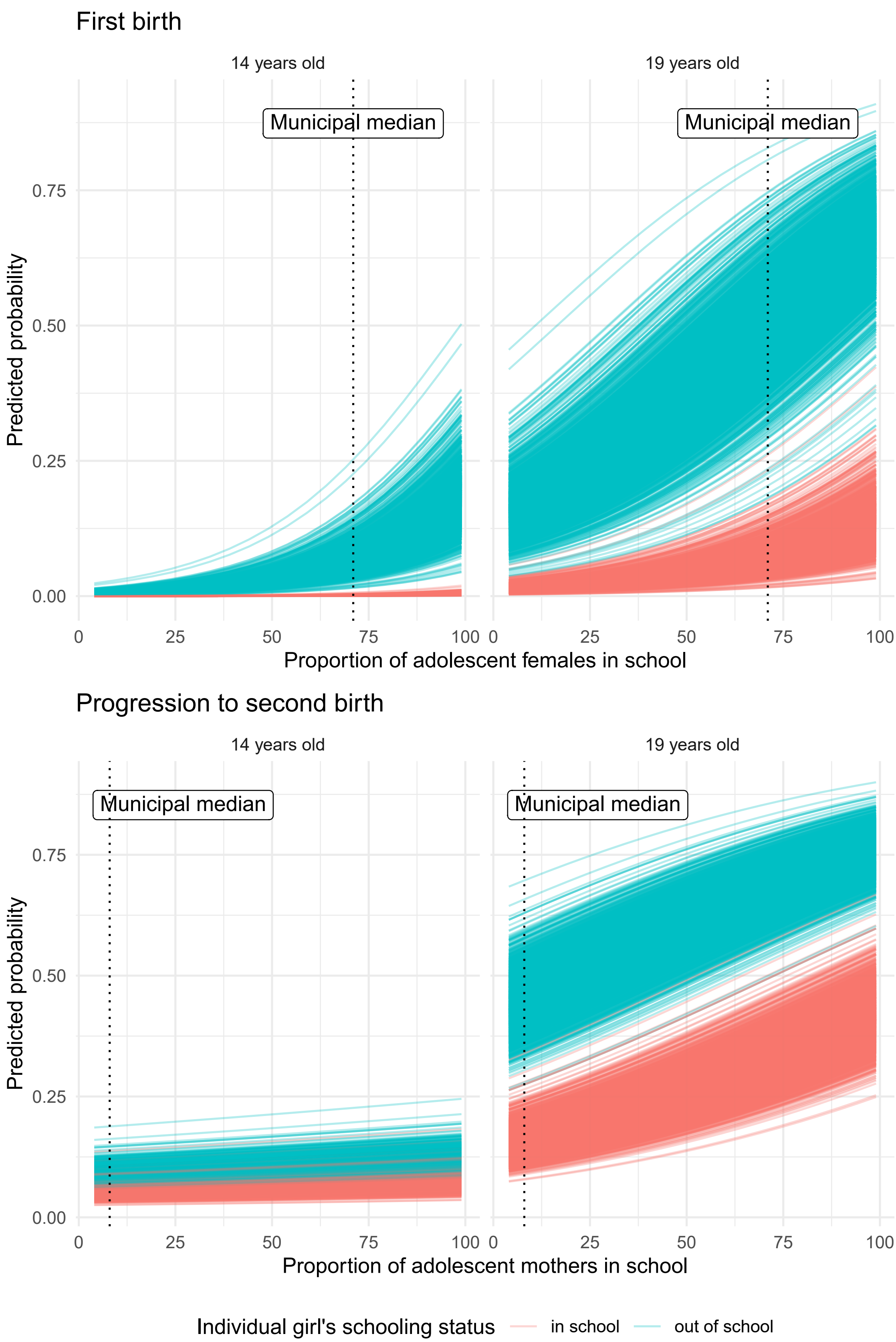
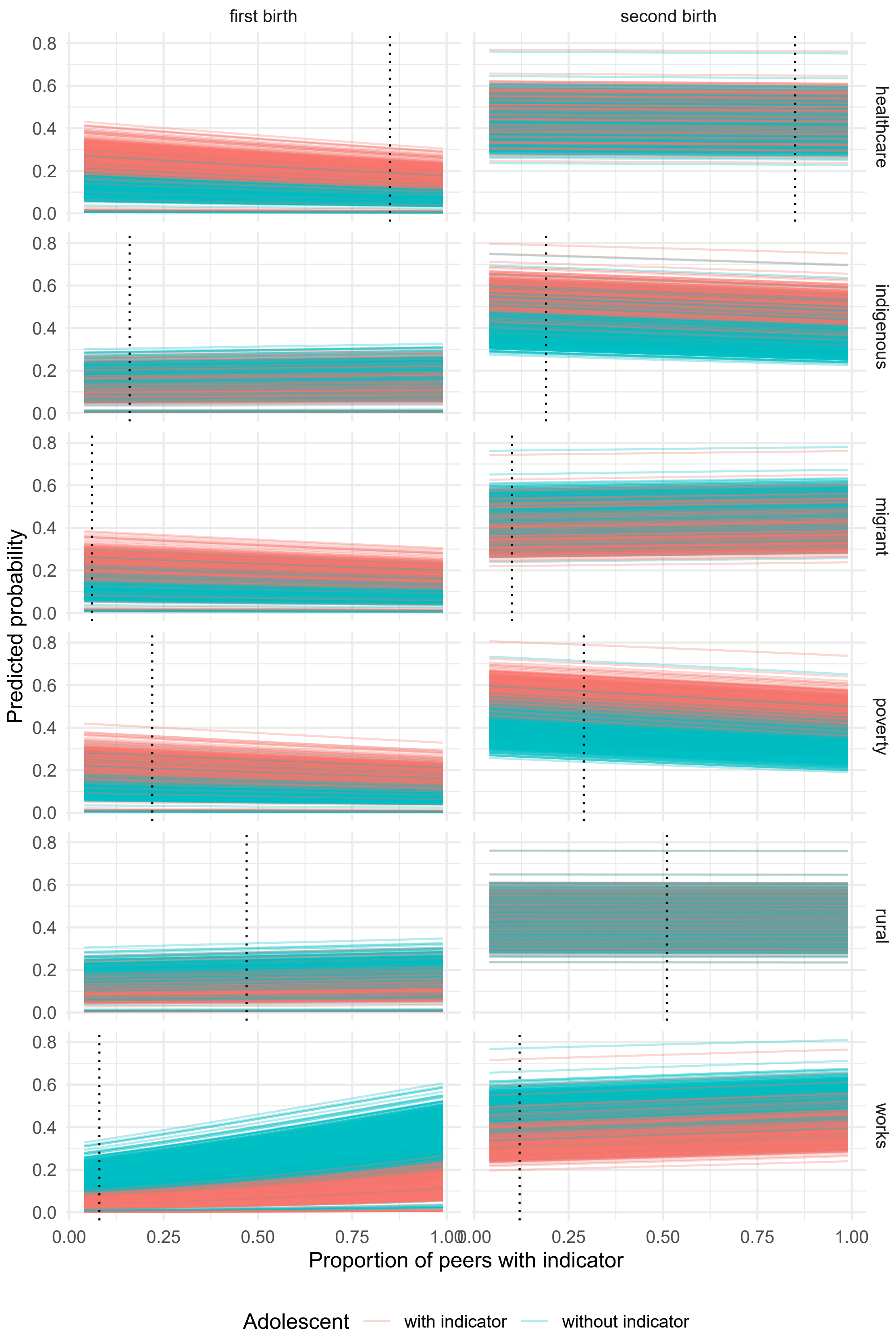


Figure D.2: Model 2 Predicted probabilities for 19-year-olds by individual characteristics



	Model 2			
	First births		Second birth Progression	
	Regression Coefficeint	(standard error)	Regression Coefficeint	(standard error)
Fixed part				
Intercept	-4.461	(0.014)***	-1.921	(0.012)***
age	0.721	(0.004)***	0.443	(0.008)***
school	-3.560	(0.017)***	-0.687	(0.035)***
poverty	0.407	(0.008)***	0.411	(0.016)***
indigenous	-0.124	(0.014)***	0.278	(0.032)***
migrant	0.375	(0.011)***	-0.107	(0.026)***
works	-1.209	(0.009)***	-0.270	(0.024)***
healthcare	0.574	(0.009)***	0.051	(0.009)*
rural	-0.203	(0.009)***	0.009	(0.020)
age_school	0.263	(0.007)***	-0.227	(0.032)***
	Variance	(standard deviation)	Variance	(standard deviation)
Random part				
Intercept	0.133	(0.36)	0.102	(0.32)
Observations	1,762,920		153,768	
Log Likelihood	-317,942		-62,819	

Note:
*** p-value < 0.0001

Table D.2: Model 2 Results

D.1.3 Model 3: Municipal means (all births)

Model 3 also lends itself to questions of how aggregate levels of school enrolment, poverty, employment, healthcare access and concentrations of indigenous and rural populations are related to adolescent childbearing across municipalities. That is, whether municipalities with larger proportion of girls in school or working also have lower levels of adolescent fertility, for example. To examine aggregate associations, issues of centring must be treated with care. When the primary substantive focus is on a cluster level predictor variable (that is, the municipal aggregates), grand mean centring is the method of choice. This is because grand mean centring estimates the municipal-level predictor variables, controlling for individual-level covariates whereas centring within clusters does not control for the effects of individual-level covariates. The results between models with the two centring techniques are drastically different, as can be seen in Table D.3 for first births and Table D.4 for progression to second births.

For instance, when controlling for the negative relationship between adolescent fertility and schooling at the individual level, there is no relationship between schooling and first adolescent births across municipalities. That is, municipalities with a larger proportion of their adolescent female population enrolled in school tend to see no higher or lower levels of first births in adolescence, all else equal. In the model that does not control for the individual-level covariates (the centring within clusters model), there is a positive relationship at the municipal level. Additionally, while being poor, indigenous or having rural residency matter at the individual level, there is no relationship between first births in adolescence and municipal levels of poverty, indigenous identity and rural residency in 2015. That is, municipalities that are poorer, more rural or more indigenous have no higher or lower incidence of adolescent fertility than other municipalities, all else equal.

	Model 3b			
	Centring within cluster		Grand mean centring	
	Regression Coefficeint	(standard error)	Regression Coefficeint	(standard error)
Fixed part				
Individual level				
Intercept	-7.413	(0.716)***	-5.136	(0.256)***
age	0.547	(0.005)***	0.540	(0.006)***
school	-3.650	(0.023)***	-3.605	(0.023)***
poverty	0.247	(0.010)***	0.247	(0.010)***
indigenous	-0.140	(0.018)***	-0.139	(0.018)***
migrant	0.361	(0.014)***	0.363	(0.014)***
works	-1.257	(0.014)***	-1.264	(0.014)***
healthcare	0.548	(0.012)***	0.545	(0.012)***
rural	-0.204	(0.011)***	-0.204	(0.011)***
age_school	0.433	(0.008)***	0.412	(0.008)***
Municipal level				
age	0.222	(0.045)***	-0.024	(0.017)
school	-1.255	(0.081)***	1.434	(0.079)***
poverty	0.229	(0.059)***	0.021	(0.058)
indigenous	-0.174	(0.028)***	-0.034	(0.033)
migrant	-0.520	(0.115)***	-1.152	(0.100)***
works	-0.154	(0.189)	1.177	(0.155)***
healthcare	0.158	(0.088)	-0.451	(0.084)***
rural	-0.195	(0.023)***	0.013	(0.025)
	Variance	(standard deviation)	Variance	(standard deviation)
Random part				
Intercept	0.161	(0.40)	0.153	(0.391)
age	0.001	(0.04)	0.003	(0.053)
school	0.131	(0.36)	0.126	(0.355)
Observations	1,762,920		1,762,920	
Log Likelihood	-218,370		-218,495	

Note:
*** p-value < 0.0001

Table D.3: Model 3b Results. First births

	Model 3b			
	Centring within cluster		Grand mean centring	
	Regression Coefficeint	(standard error)	Regression Coefficeint	(standard error)
Fixed part				
Individual level				
Intercept	-2.422	(1.402)	4.393	(0.910)***
age	0.365	(0.010)***	0.368	(0.011)***
school	-0.950	(0.085)***	-0.895	(0.078)***
poverty	0.406	(0.019)***	0.407	(0.019)***
indigenous	0.269	(0.038)***	0.260	(0.038)***
migrant	-0.052	(0.031)	-0.046	(0.031)
works	-0.528	(0.031)***	-0.527	(0.031)***
healthcare	0.152	(0.026)***	0.156	(0.026)***
rural	0.003	(0.024)	-0.001	(0.024)
Municipal level				
age	0.034	(0.077)	-0.338	(0.051)***
school	-1.425	(0.223)***	-0.499	(0.214)*
poverty	0.234	(0.087)**	-0.174	(0.089)
indigenous	0.223	(0.045)***	-0.035	(0.059)
migrant	-0.160	(0.149)	-0.097	(0.151)
works	-0.228	(0.182)	0.314	(0.181)
healthcare	-0.531	(0.120)***	-0.696	(0.121)***
rural	-0.165	(0.043)***	-0.164	(0.049)***
	Variance	(standard deviation)	Variance	(standard deviation)
Random part				
Intercept	0.072	(0.27)	0.070	(0.27)
age	0.002	(0.04)	0.002	(0.04)
school	0.102	(0.32)	0.065	(0.26)
Observations	153,768		153,768	
Log Likelihood	-47,548		-47,549	

Note:
*** p-value < 0.0001

Table D.4: Model 3b Results. Second birth progression

In contrast, migration status and healthcare access have a positive association at the individual level, but a negative association at the municipal level; just as adolescent employment has a negative association at the individual level and a positive association at the municipal level. That is, adolescent who are out of school and are working, for example, have lower probabilities of having experienced an adolescent birth in the previous 15 months than adolescents who are not working, but municipalities with a larger proportion of employed adolescents tend to see higher levels of adolescent first births, all else equal.

For progression to second births, there is a negative relationship between schooling and adolescent fertility across municipalities when controlling for the relationship at the individual level. That is, municipalities with a larger proportion of adolescents enrolled in school also tend to see lower levels of progression to second births, all else equal. Recall that for first births there was no relationship. In the model that does not control for the individual-level covariates (the centring within clusters model), there is no association. Additionally, while being poor, indigenous, or working matter at the individual level, there is no association between adolescent second births and municipal levels of poverty, indigenous identity and female employment. That is, municipalities with larger portions of the population that are poor, indigenous or working have no higher or lower incidence of adolescent fertility than other municipalities, all else equal. In contrast, rural residency does not matter at the individual level but municipalities with larger portions of the population in rural locales tend to see lower levels of progression to second adolescent births, all else equal. Finally, there is also a relationship between adolescent second births and healthcare access. Municipalities with more widespread healthcare access tend to see lower levels of second births to adolescent mothers.

Appendix E

PhD Training and Motivation

E.1 PhD Training and Development

Table E.1 reviews the training, teaching and seminars I have undertaken throughout my PhD. A few courses that I took during my MSc Demography prior to the PhD are worth mentioning for their application to my current work, though I do not include them in the table. These are: STAT 6108 Analysis of Hierarchical Data, DEMO 6020 & 6022 Demographic Methods I & II, and a National Centre for Research Methods (NCRM) course on Spatial analysis and statistics in R. I was selective about my teaching and only took on courses where I had particular expertise. In all cases I either developed completely new curriculum or substantially reworked existing curriculum. I gave a few seminars to research groups both at Southampton and Lund University in Sweden. The Lund seminar came by invitation from a professor at the University.

Table E.2 reviews the conferences and professional development opportunities I have had during my PhD. Prior to the PhD, I worked for a non-governmental organisation in the education sector in Mexico. My interest in adolescent fertility and schooling comes from that work. After the PhD, I plan to return to work in international development. As such, much of my efforts during the PhD have been focused on acquiring experiences that could best serve me in my return to the field of development.

The table includes all of the conferences I was accepted to present at, but unfortunately, all were cancelled or postponed due to the COVID-19 pandemic. I spent a significant amount of time over my PhD extending and preparing my Master's thesis research for publication. The research is on adolescent fertility in West Africa and is titled "The untold story of fifty years of adolescent fertility in West Africa: A cohort perspective on the quantum, timing, and spacing of adolescent fertility." In January 2021 the research was published in Population and Development Review, one of the leading journals in the field of Demography. Only a few weeks after publication, the United Nations Population Fund (UNFPA) contacted me to express their interest in the new adolescent fertility

Date	Activity
Oct-Mar 2019	Course RESM 6017: Critical perspectives on population change
Oct 2018	Training course: Creating a thesis - save time and tears part 1
Oct 2018	Training course: Creating a thesis - save time and tears part 2
Nov 2018	Training course: Research Data Management
Nov 2018	Course STAT 6116: Survey Fundamentals
Nov 2018	Training course: E-thesis: What you need to know from the start
Dec 2018	Training course: Data Management Plan: Why Plan?
Jan 2019	National Centre for Research Methods course: Longitudinal structural equation modelling
Feb 2019	Research presentation: University of Southampton's Family Demography Group
Feb-May 2019	Course DEMO 6008: Family Demography
Aug 2019	Southampton Statistical Sciences Research Institute course: R Package Development & Boosting tidyverse productivity
Oct 2019	Training course: Orientation to teaching and demonstrating - Seminar Leader
Oct 2019	Teaching DEMO 2010: updated the curriculum and led seminar on Early Marriage
Oct 2019	Teaching DEMO 2010: developed the curriculum and led seminar on education and development
Nov 2019	Training course: The A-Z of a PhD Viva
Nov 2019	Teaching DEMO 2010: updated the curriculum and gave lecture on adolescent health opportunities and challenges
Nov 2019	Teaching DEMO 2010: developed the curriculum and led seminar on girls and women targeted development goals
Feb 2020	South Coast Doctoral Training Partnership course: Being an academic in Demography: a masterclass for PhD students
Feb-May 2020	Course STAT 6118: Complex Survey Data Analysis
Mar 2020	Research presentation: University of Southampton's Family Demography Group
Mar 2020	Course STAT 6106 (COVID cancelled): Small Area Estimation
Jun 2020	Course STAT 6106 (COVID cancelled): Small Area Estimation
Nov 2020	National Centre for Research Methods course: Spatio-temporal modelling in R
Mar 2021	National Centre for Research Methods course: Models for Cause and Effect
Mar 2021	Teaching DEMO1003: developed the curriculum and led a seminar on Teenage Childbearing in low- and middle-income countries
Apr 2022	Research presentation: Lund University's Department of Economic History seminar series

Table E.1: PhD Training, Teaching, and Seminar Presentations

measures from the publication. In the second half of 2021, I undertook a six-month consultancy to replicate the analysis for other countries across the globe and produce a technical report with the findings. The report, "Motherhood in Childhood: The Untold Story", was released in May 2022. Findings from my research were also highlighted in the UNFPA's annual flagship report, the State of the World Population 2022 report. Worth mention is another publication I submitted and which is currently under peer review with the Journal of Migration and Health. The article, "Sexual and Reproductive Health and Rights Challenges of South-South Migrant Girls and Women in Central America and Mexico: A Scoping review of the literature" arose out of work I did as a research assistant earlier in my PhD. I had a number of other small consultancies for development organisations that are mentioned in Table E.2.

The COVID-19 pandemic and lockdowns were a significant challenge. School shutdowns from 20 March to 4 June 2020 and 5 January to 8 March 2021 kept my two primary school-aged children at home and in need of attention for home learning and care. All of their scheduled summer camps from 14 July to 6 September 2020 were also cancelled. Together, this represented more than six months of interruption from added childcare demands. Additionally, given the large size of my datasets, my regression models were computationally-intensive and the pandemic meant I could not access more sophisticated on-campus computing options, which made running the models on my personal computer quite slow. For the second paper, I had hoped to use Bayesian analysis to include more robust measures of uncertainty in the municipal estimates. However, running Bayesian models on the computers available to me proved impossible given how computationally intensive they are. For the third paper, I had originally hoped to conduct analysis at areas smaller than municipalities in my research, but this would have required me to visit secure labs in Mexico to access the sensitive data. This was made impossible due to travel restrictions, health safety risks

Date	Activity
Apr 2019	Workshop participant: Migration and gender in Latin America, which led to work as a research assistant
Feb - Jul 2020	Research assistant: Global Challenges Research Fund grant on 'Redressing Gendered Health Inequalities of Displaced Women and Girls in Latin America.' Conducted a literature review and wrote extensive review document (later submitted for publication)
Mar 2020	Publication submission: 'The untold story of fifty years of adolescent fertility in West Africa: A cohort perspective on the timing, spacing and quantum of teenage childbearing' developed from my masters thesis, submitted to Population and Development Review
Apr 2020	Conference (COVID postponed): Presentation of West Africa adolescent fertility research at International Union for the Scientific Study of Population seminar on African historical demography in Kenya
Apr 2020	Conference (Covid cancelled): Presentation of first PhD chapter at Population Association of America annual conference in Washington DC
Apr 2020	Conference (Covid cancelled): Poster on West Africa adolescent fertility research at Population Association of America annual conference
Aug 2020	Conference (COVID postponed): Presentation of first PhD chapters at International Union for the Scientific Study of Population seminar on Demographic Processes and Socioeconomic Reproduction in the Long Run in Paris
Jul 2020	Publication submission: Received a revise and resubmit invitation from Population and Development Review
Jul 2020	Consultancy work: Contributed pro-bono analysis to ADD International reports 'COVID-19: Double Jeopardy for Persons with Disabilities' and 'COVID-19: Violence risk and income loss among persons with disabilities' available at https://add.org.uk/research
Jan 2021	Publication: West Africa adolescent fertility research published!
Feb 2021	Consultancy work: United Nation Population Fund contacts me to request I replicate analysis in my West Africa publication to produce a technical report on global trends
Mar 2021	Peer review: Conducted peer review of Demographic Research article on birth intervals in Africa
Apr - May 2021	Consultancy work: Conducted analysis to produce maps of geographic dispersion of indigenous language speakers and their literacy rates in several Latin American countries for literacy nonprofit, Interweave Solutions. https://bookdown.org/content/d9f3ca9e-3314-4f4f-b952-ccf75f62addb
Jun 2021	Publication submission: 'Sexual and Reproductive Health and Rights Challenges of South-South Migrant Girls and Women in Central America and Mexico: A scoping review of the literature' developed from literature review during my research assistantship and submitted to Journal of Migration and Health'
Jun - Dec 2021	Consultancy work: Replicate my West Africa analysis to produce technical report for United Nations Population Fund
Dec 2021	Conference: Presentation of West Africa adolescent fertility research at International Union for the Scientific Study of Population seminar on African historical demography in Kenya
Mar 2022	Publication: Research from my consultancy with United Nations Population Fund is included in their 2022 State of the World Population report 'Seeing the Unseen: The Case for Action in the Neglected Crisis of Unintended Pregnancy'
Apr 2022	Publication submission: Journal of Migration and Health submission finally accepted for reivew process
Apr 2022	Peer review: Conducted peer review of Demographic Research article on fertility timing-quantum in Latin America
May 2022	Publication: 'Motherhood in Childhood: The Untold Story' is the technical report from my consultancy with the United Nations Population Fund

Table E.2: PhD Conferences and Professional Development and lockdowns in Mexico. Though municipalities may not be the geographic delineation of most relevance for identifying the true influence of context on individual adolescent fertility risks (city or village of residence would likely show stronger contextual effects), municipality-level analysis is valuable nonetheless for the policy relevance that I described in the third paper.

Ultimately, the pandemic notwithstanding, my PhD has been an incredibly rewarding experience. Not only am I enthusiastic about the research I have produced in this thesis, but it has been satisfying to see my new skills have real-world application in the consultancies I have undertaken during my PhD.

E.2 Motivation

Reina and I huddle quietly under the small overhang of a tin roof that barely protects us from the cold mountain drizzle. Thick, damp highland mist encircles everything, isolating us from everyone. We are two teenage girls cocooned in soft but fervid dreams. We have only just met. Her village is poor—no bathrooms except the open fields; no running water save the village cistern next to the elementary school; and every home's dirt floors, walls of wooden slats, and rusting tin roofs are coated in sticky, black tar from open cooking fires. There is something uncannily familiar about Reina; something I cannot put my finger on. She tells me how she recently moved to this village to live with her grandmother and shorten her previously two-hour walk to high school down to one hour each way. She is midway through tenth grade. She loves it. More than anything, she wants more.

I have come to Reina's village as a volunteer to scout for potential scholarship recipients for the boarding school in Mexico City that I had attended some years previous. This is the first of several haphazard, though heartfelt, searches in Chiapas, Mexico. Chiapas is a land of paradox. Though it provides the rest of Mexico with much of its food and energy, its people receive little in return. It is Mexico's poorest state, particularly in terms of human development. In sharp contrast to the socioeconomic deprivation, the cultural and geographic richness of Chiapas is dazzling. It sits at the country's southernmost tip, wedged in where the last of Mexico squeezes into Central America.

Mountains engulf most of the state of Chiapas. They rise up like an enthusiastic afterthought to the rest of the Sierra Madre that run from Arizona in the United States down through Mexico like one enormous, rugged backbone. On the western side of Chiapas' mountains, a long, narrow strip of coastline runs along the Pacific and ends in the small but rich Soconusco region, a land of abundant coffee, corn and mangos. To the northeast, on the other side of the mountains, a strip of sweaty tropics extends into Guatemala, Belize and Mexico's Yucatan Peninsula. At the eastern corner of the state pulses the heart of the exotic Lacandon Jungle, North America's last large pocket of tropical rainforest that, though under threat, is still big and healthy enough to support most of the continents' few remaining jaguars. In the North, the impressive ruins of Palenque, home to a millennia of Mayan civilisation, where absorbed back into the rainforest and slowly digested over four hundred years by stately mahogany, cedar and ceiba trees before Spanish explorers rediscovered them in the 16th century. In the subsequent four hundred years, archaeologists have recovered only a fraction of the ancient city from the wily jungle's grasp.

Moving in from the periphery, small pockets of cloud forest secret themselves in the saddles of the mountains that cradle both sides of the state. These rare habitats of abundant moss and fog are the northernmost home of the endangered and the wonderfully named Resplendent Quetzal bird. In the state's lofty middle, which undulates between 2,000 and 3,000 meters above sea level, are the scattered villages of the indigenous Tzotzil and Tzeltal heartland as well as San Cristóbal de las Casas, the former colonial capital where dozens of distinct indigenous cultures and languages clash in a vibrant, magical cacophony of trade and traffic. Though still the tropics, this central highland region is too high to really merit the designation. It lacks the sultry heat and humidity of the rest of the state. Older generations remember snow but these days cold winter nights only just reach freezing. The chill of the rainy season in late summer and early fall feels wintry enough. At this kaleidoscopic core sits Reina's placid village.

The organisation I am with has dabbled for years in various micro-enterprise and community projects that all eventually fizzled out unsuccessfully. The scholarship program is the only thing that has worked. I am in my first year at university and have travelled to Chiapas during my Christmas holidays. Miraculously, Reina has heard of the school and wants to go, though she had never considered it seriously because the monthly tuition of $150 dollars is about five times more than her family of twelve's total income. Not to mention the insurmountable logistical hurdle of applying without mail or phone service, buying all the necessary school supplies and uniform, and then traveling to and navigating frenetic Mexico City, one of the world's largest cities and a place that no one she knows has ever been. She has no example to follow and nowhere to turn for answers for her questions about educational opportunities outside the neighbouring villages. Most of her family dropped out of elementary and the very few people in any of the nearby villages who went to high school never returned. Her oldest brother is the only member of her family who went to high school, but like the others, he never came home after finishing school. Her family has not heard from him in years. He is in his late thirties now but Reina does not even know what he does or whether he is married. Last she heard from him he was in Baja California.

A light turns on in Reina's otherworldly eyes when I begin to explain that the scholarship will mean her father does not have to pay anything, and we will help her through the application process, cover her bus tickets to and from Mexico City, and help her get the uniform and school supplies.

In an eager whisper she begins to ask me what the school is like, if the other students are nice, and if she will make friends. After all, Reina is just another timid teenager and for her, Mexico City is another planet. She has never been beyond the town where she is going to high school. The technology of her world is limited to an occasional television, a few light bulbs, and specially outfitted Nissan trucks that can carry twenty plus people standing in the bed. Showers, stoves, flushing toilets, tile floors, computers, and, especially, the frenzied energy of Mexico City's twenty million exist completely beyond her imagination. But she is brave, and most important of all, she carries, carefully, a hope for the impossible.

"My father doesn't like that I'm going to school," she confides softly, after we have been conversing for some time, "He doesn't think it's a girl's place." Deep pain, almost imperceptible in her voice, throbs in her expressive eyes. I feel it too. "Don't worry," I tell her presumptuously as I imagine I know something of her hardship, "My parents didn't want to me to go to the school either. They thought it was too far away and unsafe, but I finally convinced them. I know you will love it." She smiles and we continue our eager conversation. My naive inability to pick up on the seriousness of her subtlety will haunt me soon enough.

Although I am reserved and she is painfully shy, something between us blossoms and our hearts unlock. I feel the warmth of her dreams; they feel no different than my own. I still cannot shake the inexplicable familiarity of the scene. Before leaving, I tell her we will need some time to figure out how to enrol her in the school mid-year, but I am ebullient with confidence of success.

During the precarious drive back to civilisation on the dangerously steep and rain-gutted dirt roads, I feel my doubting anthropologist's soul awake. I am enchanted by this vibrant Mayan world that offers all the trappings of millennia-old traditions while globalisation knocks at the door: an animistic Catholicism that prescribes sacrificing chickens and Coca-Cola to a favourite saint to heal the sick; bold, hand-woven clothing made from the wool of a woman's own sheep and accented in the brightest, most synthetic embroidery imaginable; and mountain-top villages sprinkled with tiny shops that sell a staple of Doritos, powdered-sugar doughnuts, and 20 cent soda pop, all surrounded by hectares of sloping cornfields and verdant orchid forests. I doubt I fully realize the consequences of my good intentions. If Reina leaves for school, she will likely never want to go back to her village. Her slow and peaceful, though impoverished, existence will be traded for the cut-throat capitalism of modern Mexico. Do I want to be the harbinger of such a confused choice?

After all, this is the heartland of the Zapatistas, a name, a people, a movement synonymous with the rejection of the ideology of modernity's oppressive inequality. Or more tangibly, a professed secession from a government that practiced nothing but exploitation. At the turnoff where a narrow dirt road leads unstably up the mountain to Reina's village from the semi-paved road back to the city of San Cristóbal de las Casas, there is a hand-painted sign that announces, "Está usted en territorio Zapatista. Bienvenido al municipio autónomo rebelde Zapatista San Pedro. Aquí el pueblo manda y el gobierno obedece." [You are in Zapatista territory. Welcome to the autonomous rebel municipality of San Pedro. Here, the people command and the government obeys.]

The roots of the Zapatista rebellion run deep. According to Subcomandante Marcos, the enigmatic voice of the Zapatista National Liberation Army (EZLN), the origin goes back more than 500 years to Christopher Columbus' unsolicited importation of terror, slavery, and disease. More recently, on 1 January 1994 EZLN declared war on the Mexican government. Just thirty cold minutes into the New Year, armed rebels entered San Cristóbal de las Casas, their faces covered with black ski masks. They overtook the city with remarkable deftness. From San Cristóbal's central plaza, Marcos announced the "revolution" and explained the rules of their short-lived occupation. The Zapatista takeover was quickly squashed in the regular—though no less objectionable for its familiarity—heavy-handed military response. The armed aspect of the rebellion did not last long, for Mexico was up-and-coming and had no room for embarrassing groups of citizens disgruntled enough that they sought for revolution. It might have easily been hushed up if its leader had not been so compellingly eloquent and the world's eyes were not already zeroed in on the country at the dawn of the North Atlantic Free Trade Agreement (NAFTA).

The Zapatista uprising coincided with the official birth of NAFTA in 1994, which made the cause a natural rallying point for human rights advocates and various long-time critics of globalisation. The tragic story of massacre, displacement, poverty and hunger that had followed Reina's people for hundreds of years—from Columbus to Century 20. Criticising NAFTA's ostensibly new brand of foreign domination, they cried ¡Ya Basta!, [Enough is Enough!] and caught the world's ear.

Funds flowed in, mostly from Europe, to help the Zapatista fight globalisation by enabling the communities to build their own schools and finance their own social services after running the government off their land. A decade on, when I first visited Chiapas, most of the international money had long since dried up, and the Zapatista communities were tentatively letting the government back in. They wanted roads, medicine, and schools. But everyday life for the erstwhile rebels still seemed to have changed very little. With tiny village after tiny village spread out over rugged, unwelcoming terrain there is little infrastructure to encourage development in the region.

Fundamentally, the Zapatistas called for a new economic system that provided the indigenous with a dignified way of making a living as well as representation in government. Their name comes from Emiliano Zapata, an early revolutionary fighter who represented the liberation of the Mexicans from the Spanish and, more fundamentally, the liberation of Mexican peasants from the Spanish landowners. But the pattern of colonial oppression supposedly overthrown 200 years earlier with Mexico's independence from Spain lived on in Chiapas. Up until the Zapatistas, big ranchers hoarded the most fertile regions of the state, either expelling the indigenous from the land or subjecting them to exploitative sharecropping arrangements.

Reina's own parents lived most of their lives under just such a repressive system. A few times a year, Reina's father and the other men of the village would walk the landowner's horses down steep mountain paths to San Cristóbal de las Casas to bring the owner and his supplies back to the village on the horses they cared for all year long but could never ride or use otherwise. The landowner would take an inventory of their crops and extract an extravagant portion of their harvest, leaving them with little to live on.

Reina's parents, like all the people of the one-time Zapatista strongholds still have a distinct political culture. Their relationship with the government is incendiary. When the government falls short, they do not hesitate to block roads and highways in protest. Sometimes there is violence. Mostly, they impose fees for passage. Many communities are crippled by deep political divisions among groups sympathetic with re-invented Zapatista ideals and the others who are more ready to work within the contemporary political system. In the places where community infighting does not hamper development, the widespread cronyism of local leaders perpetuates the ineffective use of funds appropriated by the state and federal government.

Yes, Reina's history is tantalisingly complex and I am conflicted. I am not convinced that privation's best alternative is the culture of consumption that reigns at home. Yet I know of no viable substitute, no moderate middle ground. Individual action can always navigate between extremes, but there is no guarantee that I am offering that alternative.

Then Reina's face comes back to me. I am startled by the intensity of the emotion conveyed in her quiet eyes, and, once again, I feel that her hopes are no different than my own. I see the same something inside the two of us, goading us on; youth and yearning tells us to reach for the inconceivable, to search for an unknowable potential. Her dream—her own dream, confided to me in that timorous voice—is to go to Mexico City for high school. Who am I to abandon that dream when it is within my power to help her reach it?

It is several weeks before the logistical questions are settled with the school. By this time, I have long since returned home and am fully immersed in the absorbing stress of student life. I call our Chiapas volunteer and ask him to drive back to Reina's village, tell her the good news, and fill out the requisite paperwork. When the man calls back, he tells me the unthinkable. "She's gone," comes his cracking and distant voice through the shoddy phone line, "Nobody will tell me where or why. She's just gone."

I am heartbroken. I feel guilty. It took longer than it should have to figure out how she could start boarding school, but her desire to learn seemed unshakable. And she had already surmounted incredible odds to attend the nearby village high school. It was the middle of the school year. Surely, only something terrible could take her away from that. But what could have happened and why do I feel accountable?

Soon after my first visit, the road to San Cristóbal de las Casas from the airport in Tuxtla Gutiérrez was replaced by an impressive highway with expansive bridges built by Dutch engineers. The journey that once took two hours of nail-biting curves and reckless drivers passing heavy trucks on blind turns is now a 40-minute affair. It would take decades more before paved roads begin to find their way to the villages. Months pass then years roll by. I keep returning to Chiapas, sometimes for a week, sometimes for months, and eventually move there permanently after completing a masters in 2010. Just as Chiapas' development progressed, the charity I work with continues to blossom. We build dozens of new schools and provide scholarships that help keep thousands of rural and indigenous students in school every year. Lucia, a 14-year-old girl writes to us that our organisation's scholarship changed her mind and her life. It inspired her to ask her parents to call off her arranged marriage and allow her to stay in school. Her message feels like redemption.

Every time I slow down to spend a few days in a village, I meet a new woman and learn her story. As I age, and as the women I associate with age, their stories only become more tragic. For me, the pivotal turning point that determines their demographic futures is their schooling careers.

I meet Alma in my early twenties when we build our first middle school in the community lands behind her parents' home where she lives. She finished primary school, which is why she can speak Spanish when her mother only knows their native Tzotzil. But Alma never went to middle school and her livelihood comes from subsistence farming. In one return visit, years after the school had been built, I congratulate her on her upcoming marriage to which she simply shrugs. The conversation turns toward childbearing, and she indifferently states that giving birth brings either life or death. In the next seven years, she will have five children, all of whom are stunted from undernourishment. In those same years, I will have two children. My petite four-year-old daughter is the size of her seven-year-old son. Her older children's early schooling careers are already challenged by having to repeat school years because of failed subjects. How can a child learn anything on an empty stomach?

I meet Catarina and Patricia in my late twenties when at another village school build. I act as translator for a visiting nurse. Catarina has a lump in her breast, and breaks down in tears when I convey the nurse's worries and instructions to visit a hospital. Catarina explains that her husband beats her and will not give her money for an examination. Death would be a release, she cries, but she does not want to leave her three children. She herself grew up on the streets and knows first hand the pain of being an orphan. Giving her what cash I have with me does little to ease my conscience. Patricia's husband recently left her. She has no employable skills and nothing from which to make a living to feed and clothe her children. She does not cry during our conversation; there is no heartbreak, only exhaustion from carrying the a burden alone. Local village clinics do not house psychologists that will help her with her depression.

In my mid thirties, I meet Guadalupe. We are the same age and her teen daughters already have their own children. She feeds me hand-pressed tortillas, made with her own corn and freshly toasted over a comal on the open fire in her kitchen (a wooden shack). Next door, the family bedrooms are in a splendidly-coloured cement construction built with remittances from her husband who is working in the United States. I catch scabies, as per usual, when taking up her generous offer to spend the night. I can feel their ill-tempered bites in the early hours before the sunrise. Guadalupe has not seen her husband in five years, and it has been months since she heard from him. She prays that the money will not run out.

Just last month, Maria's daughter was beaten nearly to death by her husband and spent serveral weeks in an unresponsive coma in a hospital bed. Maria is in her late forties, suffers from severe fibromyalgia, never went to school and has eight children. She started a cleaning job some years previous and can now sign her name after attending an adult literacy course. Before her formal employment, she could only afford to feed her children two meals a day of—kilo of tortillas with salt. She lives in the outskirts of San Cristóbal de las Casas, in one of the many surrounding shanty towns. She does not dare leave her abusive husband (who is only home a few weeks out of the year) because he will kick her and their children off his tiny plot of land. Maria's daughter is only now waking up from her coma of several weeks. The doctors did not think she would survive. Nobody intends to press charges.

After all these years, their faces still haunt me. Reina still haunts me. Years after I lost Reina, I found her family in a nearby village. I can still see her father telling me with callous nonchalance that Reina left school because she married. Reina's mother stands silently behind him with down-cast eyes. I wonder, but do not have the nerve to ask, if it was an arranged marriage, as is the custom in the area, or if it had been Reina's choice. At the time, a few crates of Coca-Cola was an acceptable bride price. Was Reina's future traded for so little? Her sweet, timid face flashes in and out of my conscience. Again and again I see the shadow in her eyes when she speaks of her father not wanting her to study.

Over the years, the burning question for me increasingly became how my glimpses of Reinas and Lucias played out in the broader population. I wanted to understand just how widespread their demographic histories might be. My PhD has been a journey to acquire the technical skills I did not have and knew I needed to be able to give voice to the invisible. My first paper draws heavily from my experiences of the pivotal differences between lower- and upper-secondary schooling among the adolescents I work with in Chiapas. The second paper is inspired by all the women and girls I have met both in village and city who started childbearing before existing statistics counted them—at age 14 years and younger. The third paper speaks to the dramatic socioeconomic and cultural differences I encountered across Mexico, as well as a recognition that adolescence spans ten dynamic years of opportunity and change. Mexico is a land of inequality and paradox, and the lives of Chiapan villagers are just as foreign to Mexico City's middle class as they are to the European hippies who now call San Cristóbal de las Casas their home. Nevertheless, the beauty and challenge of adolescence is universal. I have kept my foothold in Chiapas during the PhD. I cannot seem to let the place go. My part-time work with the charity has kept me grounded and sane.

I have long since come to an answer for that once anthropologist. After watching what becomes of the lives of women who leave school too early and start motherhood before they have the skills they need for modernity, I no longer see the issue as a battle between capitalism and culture, between globalisation and tradition. I have more space for ambiguity in my worldview than I did in my youth. Instead, it is the poverty of choice that I cannot stomach. If Reina is happy where she is, fine. But if she could have chosen, freely and without constraint, would her path have been the same? I want all the Reinas, Catarinas, Patricias, Guadalupes and Marias to be able to choose.

To have the freedom to live to their full potential, whatever that might be. Lucia, the girl who stayed in school, is my saving grace.

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