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Geography and Environmental Science

Using statistical modelling approaches to explore the prevalence of cigarette smoking in the Global South

by

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Thesis for the degree of Doctor of Philosophy

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Abstract

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The prevalence of tobacco use is one of the leading causes of preventable deaths. Most tobacco users reside in low- and middle-income countries (The Global South). Current estimations predict a surge in tobacco use and preventable deaths in these countries, which are more economically vulnerable to the variety of problems that tobacco use causes. Data must guide current and future national and international tobacco control measures. Data collection within Global South countries is often irregular, imperfect, or absent. Most prevalence estimates represent national rates, which obscure the variations between demographic and social groups at the small-area level over time. These heterogeneities of prevalence must be understood to plan effective future tobacco control.

This thesis investigates the heterogeneity of cigarette smoking prevalence across the Global South. It uses Demographic and Health Surveys and auxiliary datasets in binary logistic multilevel models to investigate the associations of selected independent variables with current smoking prevalence, the trajectories of these associations over time, and their links to country-level determinants of smoking. A Bayesian geostatistical model is used to predict small-area level smoking prevalence.

The thesis shows considerable variation between countries in the magnitude and direction of individual demographic and social determinants of smoking, varying trends in smoking over time, and the importance of country-level determinants of smoking, including the extent of commitment to tobacco control. Novel small-area predictions highlight areas needing to catch up on tobacco use reduction targets. Collectively, this thesis demonstrates the need to improve the targeting of tobacco control policies in the Global South.

Table of Contents

Table of Tables

Table of Tables

Table of Figures

Table of Figures

Research Thesis: Declaration of Authorship

Print name: Robert Steven Taylor

Title of thesis: Using statistical modelling approaches to explore the prevalence of cigarette smoking in the Global South

I declare that this thesis and the work presented in it are 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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Ethics approval for this research was given by the University of Southampton (Ethics and Research Governance Online (ERGO II) study number 52390). Permission to use DHS datasets was given by becoming a registered DHS data user.

Definitions and Abbreviations

ASH .... Action on Smoking and Health

CDC .... Centres for Disease Control and Prevention

CPI .... Corruption Perception Index

DHS................................ Demographic and Health Surveys

DRC................................ Democratic Republic of the Congo

EA................................... Enumeration Areas

ENDS.............................. Electronic Nicotine Delivery Systems

FCTC .... Framework Convention on Tobacco Control

GATS............................... Global Adult Tobacco Survey

GDP................................ Gross Domestic Product

GHPSS............................ Global Health Professions Student Survey

GLM................................ Generalised Linear Modelling

GPS .... Global Positioning System

GSPS .... Global School Personnel Survey

GTSS............................... Global Tobacco Surveillance System

GYTS............................... Global Youth Tobacco Survey

HDI .... Human Development Index

ICF.................................. Inner City Fund

IGLS................................ Iterative Generalised Least Squares

IHME............................... Institute for Health Metrics and Evaluation

INLA................................ Integrated Nested Laplace Approximation

ITC.................................. International Tobacco Control

LEDC .... Less Economically Developed Countries

MCAR .... Missing Completely at Random

MCMC .... Markov Chain Monte Carlo

PSI .... Political Stability and Absence of Violence/Terrorism Indicator

SAE.................................. Small Area Estimation

SD .... Standard Deviation

SDG................................ Sustainable Development Goal

SETM .... Smoking Epidemic Transition Model

SPDE .... Stochastic Partial Differential Equation

STROBE .... Strengthening the Reporting of Observational studies in Epidemiology

TP .... Tobacco Production

UI .... Urbanisation Index

UK .... United Kingdom

UN .... United Nations

UNDESA .... United Nations Department of Economic and Social Affairs

UNDP .... United Nations Development Programme

US .... United States

WHO............................... World Health Organisation

Chapter 1 Introduction

1.1 The pervasiveness of tobacco use

Public health experts consider the prevalence of tobacco use as the most significant threat to public health globally (WHO, 2023). The World Health Organisation (WHO) estimated in 2023 that there were approximately 1.3 billion people between the ages of 15 and above who use tobacco. Most of these smokers consume “white cigarettes”, which are mechanically manufactured cigarettes with or without a filter (Nichter et al., 2009). Its prevalence alone firmly establishes tobacco smoking as a global issue of significance.

This global prevalence is widely considered an epidemic (WHO, 2023). This designation reflects the health problems and consequences that flow from tobacco consumption. Although there has been a significant relative decline in global tobacco users, from 22.5% of the global population in 2007 to 19.2% in 2017 (WHO, 2019a), deaths attributable to tobacco use are increasing. Estimates suggest that there were approximately 100 million deaths relating to illnesses brought about by tobacco in the 20th century, and almost 450 million deaths are predicted between 2000 and 2050 if current tobacco consumption patterns continue (Jha and Peto, 2014; Jha, 2009). Approximately 50% of all long-term tobacco users are estimated to die from their use of tobacco, making tobacco use the most preventable cause of death globally (Blecher and Ross, 2013). On average, those who use tobacco throughout their lives lose ten years of their life expectancy (West, 2017). In 2023, the WHO reported that each year, more than 8 million people globally die prematurely due to non-communicable diseases caused by tobacco use (WHO, 2023). This figure, which is substantial in any argument for greater tobacco control, includes 1.3 million annual deaths that are indirectly linked to tobacco via second-hand smoke.

The annual mortality currently associated with tobacco use represents a significant increase from the 1990s, when 3 million deaths per year globally were estimated to be associated with tobacco (Peto et al., 1996). Half of all tobacco-related deaths now occur among people during their most economically active years from the ages 35 to 69 (Thakur et al., 2011). The number of premature deaths that are directly linked to tobacco use is expected to rise to over 10 million over the next 20 years (WHO, 2019a; Jha and Peto, 2014). This is due to the ageing of the current number of young smokers; although many will subsequently quit, global averages of 10% of young women and 50% of young men are indicated by current estimates to smoke (Jha and Peto, 2014).

The effects of tobacco use on the health of a smoker during their lifetime have been well-documented. According to Bonnie, Stratton, and Kwan (2015), tobacco use negatively impacts the health of an individual in both the short and long term. It impairs a smoker's overall health, compared to a non-smoker, as tobacco use renders a smoker more susceptible to poorer health outcomes due to a weakened immune system. These poorer health outcomes are wide-ranging, such as a poorer ability for the body to heal wounds, the development of more acute illnesses and diseases compared with non-smokers, and a greater risk of developing tumours that lead to cancer. Moreover, long-term tobacco use hastens the onset of diseases that are associated with old age ten years earlier compared to non-smokers (West, 2017; Jha and Peto, 2014).

Bonnie et al. (2015) note that the diminishing health of a smoker can impact the labour force. This is because smokers, young and old, are significantly more likely to take time off school and work. Consequently, according to Drope and Schluger (2018), tobacco-related illnesses were calculated to have cost the world economy $2 trillion in 2016. This includes the estimated cost of days taken off during employment, the cost of care on health services and the loss of human capital (WHO, 2023). Additionally, tobacco users spend, on average, up to 10% of household income on tobacco products (NCD Alliance, 2011). This can impact spending on food and shelter as the global average hides significant geographical variation: low-income households in Southeast Asia spend up to 40% on tobacco products (WHO, 2011). Tobacco use, therefore, not only impacts health and national economies but can also put people further into poverty (Thakur et al., 2011). Moreover, it enhances a variety of other detrimental social and economic problems in areas as diverse as agriculture, where it is linked to crop dependence, and international trade regulation, where it is strongly associated with illicit tobacco trade and smuggling (Barnett et al., 2016).

1.2 The global distribution of tobacco use

The prevalence of tobacco use presents itself as a significant obstacle to health. The WHO (2019) indicated a decline in global tobacco use rates; however, a vastly increasing global population could be contributing significantly to this decline. From 2000 to 2018, the World Bank (2019) states that the global population increased from 6.1 billion to 7.6 billion. According to the WHO (2018a), however, the number of tobacco users in 2000 was slightly less than current estimates. The number of tobacco smokers is estimated to decrease from 1.366 billion in 2000 to 1.270 billion by 2025 (Trenda, 2023). As such, the relative decline in the prevalence of tobacco use should be treated with caution.

Although tobacco use is gradually diminishing on a global scale, it is increasing at the national level in some countries. The countries that exhibit growth in tobacco use are mainly in the low- to middle-income categories (American Cancer Society, 2018; Hiscock et al., 2012; Pampel, 2008). These countries are in the poorest regions of Africa and specific areas of Asia, Oceania, and Central and South America. These low-income countries are frequently termed the 'Global South' (Dados and Connell, 2012), a term justified in section 1.5 for use in this research. The countries with the current highest rates of tobacco use are generally in the Global South (WHO, 2022). Though mitigating tobacco use is by no means a priority only for the Global South, higher tobacco use prevalence in these countries will be a significant public health burden in the medium- to long-term. The public health challenges of tobacco use in Global South countries, therefore, form a crucial motivation for the research presented in this thesis.

1.3 The internationally adopted framework to reduce tobacco use

Focusing this thesis on tobacco use in the Global South also reflects the challenges in implementing a global strategy to mitigate tobacco use by promoting the WHO's Framework Convention on Tobacco Control (FCTC). The FCTC, the first international public health treaty, was created by the WHO in 2003 to mitigate the demand and supply of tobacco as a response to the tobacco epidemic (Mamudu et al., 2018; Brathwaite, Addo, Smeeth and Lock, 2015). It was implemented in 2005 and has been ratified by 165 countries. The United Nations (UN) set the FCTC as target 3.a of Sustainable Development Goal (SDG) 3 to improve health and well-being with the aim of greater tobacco control (UNDP, 2020). The FCTC provides an internationally coordinated plan for tobacco control by providing governments with steps to follow. These steps include adopting tobacco taxes, banning the advertisement of tobacco, designating tobacco use spaces at work and public spaces, advertising tobacco use's impact on health on tobacco products, and strategies in reducing the illicit tobacco trade (Framework Convention Alliance, 2008). The success of the FCTC would mean that an estimated 200 million deaths could be avoided this century (Jha and Peto, 2014).

Global South countries face considerable challenges in implementing the FCTC. One such challenge is the globalisation and liberalisation of trade that can limit any country's ability to control the supply of tobacco products (Collin, 2020). Another challenge is the heightened presence of communicable diseases in the Global South, which may mean that the tobacco epidemic is not always the highest health priority. The tobacco companies will likely also be a challenge by using their economic leverage to involve themselves in government policy decisions and limit tobacco control (Brathwaite et al., 2015). This could be linked to corruption and may be higher in the Global South, which can influence a government's ability to implement policies and lead to an increase in the illegal tobacco trade (Budak et al., 2021). Political instability, often associated with countries in the Global South, can further impact governmental decisions and is linked with higher rates of tobacco use (Waajid, 2007). Finally, some Global South countries are large tobacco producers (Wallbank et al., 2016); limiting tobacco production in these relatively poorer countries would impact their economies. With such issues in play, the Global South will continue to struggle to reduce tobacco use and face significant challenges implementing the FCTC (Maiyaki and Garbati, 2014; Owusu-Dabo et al., 2010).

1.4 Monitoring the reduction of tobacco use prevalence

Having data to monitor tobacco use is crucial in highlighting the FCTC's progress. This thesis sits broadly within the extensively documented theoretical context provided by the well-established body of research on health inequalities and, more specifically, social inequalities in tobacco consumption. This body of work has shown clear associations between smoking behaviour and demographic, socioeconomic, and other information collected via national censuses and subnational surveys. It has located the roots of these inequalities in structural disadvantages stemming from poverty and has demonstrated clearly that individual health-related behaviours (including smoking) reflect not only individual behavioural decisions but, more importantly, individual socioeconomic constraints and overarching neighbourhood, national, commercial, and governmental factors (Pearce, Barnett, and Moon, 2012; Dahlgren and Whitehead, 1991).

The data collection necessary to monitor health inequalities, including those associated with tobacco consumption, is significantly less robust, less reliable, and untimely in Global South countries compared with Global North countries. Consequently, reliable inferences on current tobacco use prevalence inequalities within Global South countries are less frequent (Hoffman et al., 2019). Most of the literature on inequalities in tobacco consumption is derived from studies conducted in the Global North.

The lack of data collection on tobacco use in the Global South is partly due to possible safety issues in dangerous parts of the world and the lack of necessary resources to conduct nationwide censuses and surveys representative of a country's population (Abdullah and Husten, 2004). There are compatibility issues when comparing countries' tobacco use prevalence rates across different censuses and surveys due to the lack of standardisation in questions, the sample size, and the data collection date (Abdullah et al., 2014). There are, however, databases that endeavour to address these issues. A further motivation for this thesis is the exploitation of these sources to provide robust evidence on the extent of inequality in tobacco consumption across the Global South.

1.5 A note on terminology

Many terms have been used to describe the part of the world on which this thesis will focus: 'Less Economically Developed Countries (LEDCs)', 'developing countries', and 'the third world', to name a few. Many of these are contentious, including the 'Global South', due to its generalisations when describing a heterogeneous group of counties and the sense of hierarchy in which perceived Western countries dominate (Prys-Hansen, 2023). The term 'Global South' is used in this thesis with mutual recognition of the Global North, without any notion of hierarchy between the two regions. Using 'Global South' here is purely a reflection of the current location of the largest proportion of global tobacco users. This thesis recognises that these countries have unique characteristics, which will undoubtedly be apparent in the variation of results expected in these investigations.

1.6 COVID impacts

The impact COVID-19 has had on conducting this thesis has been extensive. Supervision was driven online, which impacted the exchange of ideas and meaning, which is easier to do in person. Additional responsibilities required me to care for sick relatives in Suffolk and Kent throughout each national lockdown who were unwilling to have people nearby to help them. This required time travelling from Portsmouth to help my relatives, which meant a lack of internet access whilst staying outside their homes for safety and delayed progress. Unfortunately, there were deaths in my close family as a result of COVID-19 and other health-related issues, the aftermath of which involved challenging personal priorities. These deaths led to my decision to suspend my thesis twice to allow time to grieve.

1.7 Thesis structure

This thesis is based on three empirical papers structured as chapters addressing the research questions posed in chapter two. The three papers follow the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) framework and are targeted at leading journals for health geography. I conducted the data management and subsequent analysis for these papers with guidance and feedback from my supervisory team, Andy Tatem, Graham Moon, and Chris Jochem. The three empirical studies are book-ended by three initial chapters that set the context for the research and a final chapter summarising the thesis's contribution.

The present introductory chapter has outlined the motivation for the research, providing a general background on the health impacts of tobacco use and highlighting the scale of global tobacco use and its unequal distribution, with most of the global prevalence observed in Global South countries.

Chapter two provides a conceptual framework for this thesis and a scoping literature review to find gaps in our knowledge of the variability of tobacco use prevalence within Global South countries. Following an outline of the conceptual framework, a literature search strategy and accompanying selection criterion are proposed to identify relevant past literature. The critical and central Lopez, Collishaw, and Phia (1994) Smoking Epidemic Transition Model (SETM) is presented and critically evaluated to gauge how the prevalence of tobacco use could change in the Global South. Papers on demographic and socioeconomic determinants of tobacco use in the Global South are then examined. The review concludes by identifying significant gaps in knowledge on tobacco use in the Global South and framing associated research questions to be addressed in the later empirical sections of the thesis.

Chapter three assesses the available data sources to address the research questions identified in chapter two. The benefits and limitations of available databases are explored. This chapter also discusses the measurement of tobacco use, variables capturing inequalities in tobacco use, and, in broad terms, the analytical strategy followed in the empirical elements of the thesis.

Chapters four, five, and six comprise the empirical core of the thesis. Their foci reflect the research questions that emerge from chapter two. In brief, these chapters concern variations in social and demographic inequalities in smoking prevalence across the Global South, spatial-temporal changes in smoking behaviour and the impact of country-level factors, and small-area variation in Global South case-study countries.

The final chapter of the thesis, chapter seven, summarises the thesis findings and their implications for the literature. It also discusses the limitations of this research, policy implications, possibilities for future research, and final thoughts.

Chapter 2 Conceptual Framework and Literature Review

The introduction chapter identified the importance of tobacco use as a topic for research. It particularly highlighted the need for more research on tobacco use in the Global South. The purpose of this literature review chapter is firstly to establish a conceptual framework that can identify and ascribe determinants to the variability of cigarette smoking. Secondly, the limited research on tobacco use in the Global South is examined in depth. Lastly, from the gaps in that existing body of research, research questions are identified that will be pursued in later empirical chapters.

2.1 Conceptual framework

This thesis is conceptually rooted in the theoretical positions associated with research on health inequalities. While there were earlier contributions, the major theoretical foundation for such research in the context of the United Kingdom (UK) is the 1979 Black Report on Inequalities in Health (Townsend and Davidson, 1982). The Black Report contended that health disparities between population groups and places could not be dismissed as mere statistical anomalies, nor were they predominantly attributable to genetics. Instead, these disparities reflected how people chose to behave via health-damaging lifestyles (including smoking) or, more significantly, the broader structural factors people faced, such as poverty and powerlessness. In simpler terms, this thesis translates Black's conceptual position, shifting the focus from health to health-related behaviour; smoking prevalence can be theorised as the result of both individual choices and, more critically, the structural constraints that shape those choices.

In the almost 50 years since the Black Report, there has been a vast expansion of research on health inequalities, documenting their occurrence worldwide and drawing continued conceptual inspiration laid by the Black Report's theoretical framework. Key contributions to this conceptual development, which are central to this thesis, have been provided by Marmot (2010) and Dahlgren and Whitehead (1991), who introduced the idea of social determinants of health. The latter provides a widely cited model that has offered a theoretical framework for researchers on the social determinants of health (Figure 1). This model identifies key determinants and specifies the hierarchical nature and the interaction that these have with each other (Jahnel et al., 2022). The model is a useful conceptual tool by providing a picture of the social determinants that perpetuate health inequalities (Dahlgren and Whitehead (2021).

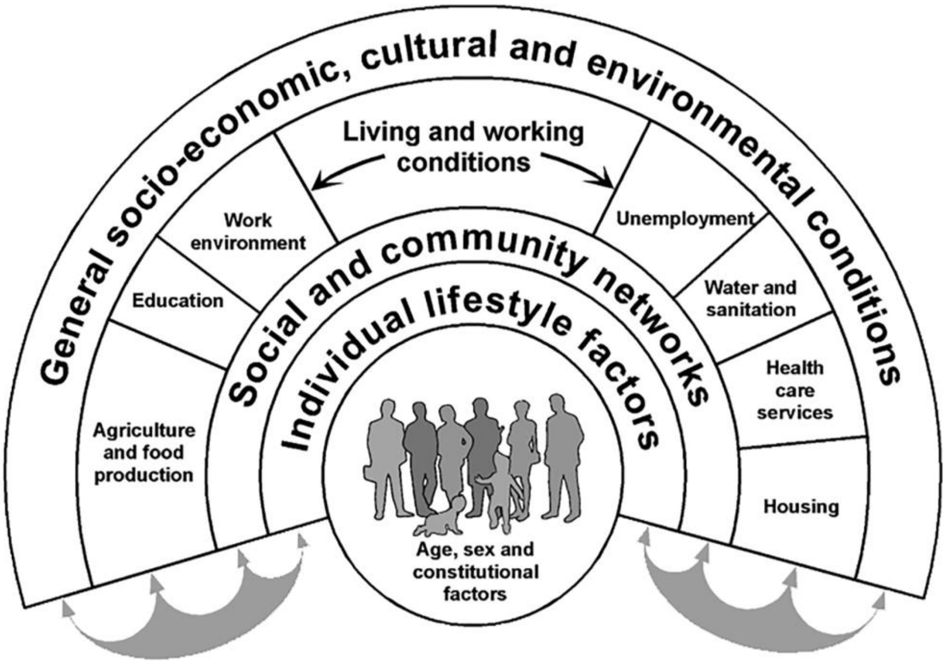

Figure 1. The theoretical framework of the social determinants of health (Dahlgren and Whitehead, 1991).

The Dahlgren and Whitehead model breaks down the factors that conceptually underpin inequalities in health at individual, community, and state levels.

A significant body of research in health geography and social epidemiology has focussed on the inner levels of the model. Early research was provided by what Pyle (1976) described as associative analyses, often relying on cartographic methods or correlation to explore areas-based associations between health outcomes and hypothesised causes. More recent conceptual developments have emerged from the use of multilevel statistical models in the health sciences (Owen, Harris, and Jones, 2016; Duncan, Jones, and Moon, 1993) and debates regarding the impact of place effects on health outcomes (Cummins et al., 2007; Macintyre, Ellaway, and Cummings, 2002). The former offers a methodological and conceptual approach that allows for the simultaneous consideration of health effects, such as individual characteristics and area factors. Multilevel models are employed extensively throughout this thesis. Debates about place effects similarly emphasise that health outcomes result from the dynamic interaction of compositional, contextual, and aggregational/collective effects, reflecting the interaction of individual and place factors. The application of these ideas to smoking behaviour by Pearce, Barnett and Moon (2012) provided an essential conceptual foundation to the research presented in this thesis, as was the research on applying these concepts to the development of small area estimates of smoking behaviour (Twigg, Moon, and Jones, 2000).

This thesis is also conceptually shaped by recent concerns with the outer rings of the Dahlgren and Whitehead model and research that incorporates a temporal dimension to the study of the health inequality determinants. In the former case, significant work has focused on the role of commercial, political, and governmental factors in shaping health outcomes (Gilmore et al., 2023; Maani, Petticrew, and Galea, 2023). In the latter case, Pearce has made important contributions by examining how changes in place characteristics over time affect health (Pearce, 2018). While the influence of commercial factors on smoking behaviour is widely recognised, less attention has been given to governmental factors. It is this neglect that is addressed in this thesis, alongside a consideration of how such national-level factors evolve over time. The subsequent subsections introduce how factors of interest at different levels of the Dahlgren and Whitehead model are operationalised in this thesis, emphasising its focus on the Global South.

2.1.1 Age, sex, and constitutional factors

This thesis focuses on four factors at the lowest, central level of the Dahlgren and Whitehead model: gender, age, marital status, and the presence of children. Although ethnicity is another potentially significant factor, it is not considered as it is not routinely available in the data sources used in the empirical chapters of the thesis.

2.1.1.1 Gender

Gender is one of the core determinants of health inequalities due to its embedded role within society and alters an individual's exposure and experience with healthcare (Miani et al., 2021). Women face higher levels of discrimination and barriers to healthcare compared with men, especially in the Global South, such as social taboos around diseases and health habits, a lack of mobility, lower literacy rates, poorer training among medical staff for treating women, and a lack of agency when making decisions on their health and well-being. When looking at rates of smoking between men and women, however, female smokers represent only 3% of smokers in the Global South, whereas the proportion of female smokers is around 17% in the Global North (Hagen et al., 2016). This change in gender inequality, albeit a relatively small proportional change, could be linked with generally higher levels of female empowerment within the Global North (Hitchman and Fong, 2011). Empowering women to have equal socioeconomic and political status with men will require tobacco control strategies to adapt to account for an increasing proportion of female tobacco users over time as gender inequality changes. It should be noted that, due to the extent of the discrimination against women in the Global South, women may also be inaccurate when recording their use of tobacco.

These gender norms also impact men's health as it elevates the importance of masculinity among men, which can encourage men to use tobacco (WHO, 2021). At the genetic level, tobacco activates the reward pathways in the male brain more than it does in the female brain (Cosgrove et al., 2014). Cravings for nicotine were also found to be more alleviated among men than women, further entrenching tobacco use as a relaxing habit among men (Perkins and Karelitz, 2015).

2.1.1.2 Age

Age is also an important social determinant of health. The United Nations Department of Economic and Social Affairs (UNESA) states that older people require more health care than younger people and are more likely to have lower accessibility to the specific care they need and can afford (UNDESA, 2018). The negative health impacts of long-term health behaviours, such as tobacco use, are much more apparent among older people who start to become sick as they are more exposed to health problems over time, leading to an increasing proportion of older people unable to work and becoming dependant of health care services. Older people have also had greater exposure to past societal norms of tobacco use and misleading tobacco advertisements, which did not inform people of the negative health impacts of tobacco (Lushniak et al., 2024). These beliefs about tobacco use affect people in old age as it has led to a lower recognition of the risks of tobacco use compared to younger people (Roberts et al., 2016).

2.1.1.3 Marital Status

Married people, in general, are more likely to have improved health outcomes than those who are not married. Economically, married people are better off as they can pool resources to afford a stable lifestyle (Kim, Lee, and Park, 2018). Unmarried men are more likely to have poorer health outcomes, although being unmarried is more likely to be a symptom rather than a cause of poorer health (Robards et al., 2012). Those who are single are more likely to use tobacco than those who are married (Pennanen et al., 2014). The lower likelihood of tobacco use among married people is influenced by their spouses, who can provide support with quitting tobacco use (Waldron and Lye, 1989). The social norms of marriage and the expectations of their partners can also reduce the likelihood of using tobacco (Salvatore, Gardner, and Kendler, 2020). Married people live in the same environment, which influences their decisions to reduce or adopt bad health behaviours (Margolis and Wright, 2016). Married people want approval from their spouses, and so will be more likely to quit than to start using tobacco (Britton, Haddad, and Derrick, 2019). A married woman is more likely to stop using tobacco if their partner does not use tobacco (Cobb et al., 2014). Most of the understanding of this inequality, however, comes from Global North countries and may not be found in the Global South.

2.1.1.4 Having children

Having children is also a social determinant of health inequalities. This is because having children is a drain on finances, with poorer families less able to provide the resources their children need regarding quality healthcare and schooling (Loignon et al., 2015; Victorino and Gauthier, 2009). As such, poorer health outcomes are associated with children in less wealthy families (Braveman and Gottlieb, 2014). A drain on parent's finances may incentivise them to find ways to reduce spending, including money spent on tobacco products (Rogers et al., 2019); equally, smoking may be a source of solace in the face of deprivation. Regardless, parents are more motivated to quit or not start using tobacco due to the health risks posed to their children (Kanis and Mahabee-Gittens, 2014). As such, people with children are generally less likely to use tobacco than those who do not have children. This association changes depending on other factors, such as deprivation, where more disadvantaged children are still more likely to use tobacco than more advantaged children (Kock et al., 2022). This is because these children are more likely to have parents and role models who use tobacco and so are more exposed to a normalised culture of tobacco use among family and friends (Lynch and Bonnie, 1994).

2.1.2 Individual lifestyle factors

The primary focus of this thesis is on smoking behaviour, which is an individual lifestyle factor. While there is extensive research, primarily from the Global North, exploring the association between smoking and other health-damaging lifestyle factors, such as poor diet, physical inactivity, and excessive alcohol consumption, these associations are not examined in this thesis. This is due to the lack of consistent, reliable data in the key data sources.

2.1.3 Social and community networks

The third level in the Dahlgren and Whitehead model is social and community networks. Social networks influence attitudes around health, with those more socially excluded and lacking in social support associated with poorer health outcomes than those who are more connected with friends and family (Weyers et al., 2008). This is because a lack of social networks acts as a negative psychosocial factor in affected people, influencing the decision to initiate bad health behaviours. Social networks can help alleviate stress and loneliness, which are more prevalent in the poorest and eldest (Yanguas, Pinazo-Henandis, and Tarazone-Santabalbina, 2018). Moreover, people from disadvantaged groups have weaker social and community networks, especially when they move to a new area because of the lack of job opportunities and suitable housing (Göran and Whitehead, 1991). Disadvantaged groups tend to live in more deprived neighbourhoods, in which there is a higher perception of danger, further adding to any existing stress and leading to a higher likelihood of tobacco use (Denney, Sharp, and Kimbro, 2022). Social networks among the most disadvantaged are more likely to have friends who are unemployed and who are less able to offer the support that is needed (Finney, Kapadia, and Peters, 2015). This lack of support from individuals and the surrounding community, which can be social, emotional, and financial, further increases the risk of adopting and maintaining bad health behaviours, thus enhancing health inequality among those who have weaker social networks and community support.

2.1.4 Living and working conditions

Poor living and working conditions, which may reflect individual, group, or place factors, enhance the impact of the Dahlgren and Whitehead model's more localised levels on health inequalities. These conditions may also be modified or intensified by commercial and political factors.

2.1.4.1 Agricultural and food production

Agricultural and food production is a determinant of health inequalities because of food insecurity's physical and mental impacts (Campanera, Gasull, and Gracia-Arnaiz, 2023). One of the challenges of food security is using tobacco production as a cash crop instead of food (Kim-Mozeleski and Pandey, 2020). Food insecurity increases stress, which leads to people turning to tobacco use to relieve stress. The impact of food insecurity is more greatly felt among disadvantaged groups who already have limited access to food resources, especially in the relatively poorest countries. Poor diets, linked with poor mental and physical health and stress, are risk factors for bad health behaviours, such as smoking (MacLean, Cown, and Vernarelli, 2018; Sutter et al., 2016). The environmental impacts of tobacco production, often in the most rural areas in some Global South countries, lead to higher pollution levels, deforestation, and social erosion (Mentis, 2017; Novotny et al., 2015). These impacts are brought about by using harmful chemicals and unfair labour practices, which negatively affect the local workers and communities to facilitate more cost-effective crops. Tobacco use, along with agriculture and food production health inequalities, further compound each other to deteriorate population health and well-being.

2.1.4.2 Education

People with less education are more likely to have poorer health outcomes (Zajacova and Lawrence, 2018). This is because they are less able to get well-paid jobs to afford a higher standard of living that would include more opportunities to further their skills, improve social networks, access to healthcare, and more financial support for themselves in times of national economic hardship (Zajacova and Lawrence, 2018; Shankar et al., 2013). As such, people with less education have a greater vulnerability to stress, leaving them more reactive to negative events in their lives, meaning they are more likely to choose negative health behaviours to cope (Shankar et al., 2013). Consequently, tobacco use is more likely to be prevalent among those with lower education than those with higher education (Theilmann et al., 2022). Lower educational attainment and negative perceptions about future opportunities are more prevalent in deprived areas, which hinders motivation to acquire qualifications to gain access to future opportunities (Cattell, 2001). Deprived areas also usually have less access to higher-quality schools, with the accessible schools having fewer teaching resources (Bandyopadhyay et al., 2023). This determinant of inequality, therefore, leads to a higher risk of tobacco use in these areas compared with relatively more affluent areas.

2.1.4.3 The work environment

The health risk presented in the work environment is substantially different depending on the type of occupation an individual has. Manual labour employees may be exposed to physical and chemical hazards that increase stress levels as these jobs have relatively lower wages and are less able to financially support themselves if they are physically unable to work (Armenti et al., 2023). Although the risks of these exposures in physically demanding roles have declined over time with workplace regulations and standards, especially in Global North countries, the psychosocial workplace environment has become a more important factor for its influence on health inequalities (Bambra et al., 2009). This changes how an employee perceives their job, as more intensive jobs, for instance, can see an imbalance between the effort they give and the reward they receive. The lack of job security, financial incentives, a work-life balance, and career opportunities in less skilful jobs negatively affects workers' mental health and influences bad decision-making about poor health behaviour, such as tobacco use. Additionally, work often described as "desk jobs" leave people sedentary for long periods of the day, increasing the risk of non-communicable diseases over time and impacting workers' mental health depending on whether there is a lack of financial opportunities (Ball et al., 2015). Workers with lower socioeconomic statuses are more vulnerable to these negative health outcomes in the workplace due to additional external pressures that culminate in bad health behaviours such as tobacco use (Glymour, Avendano, and Kawachi, 2014). Workers with higher socioeconomic statuses, however, are more able to deal with workplace stress by using the benefits of higher-paid jobs, such as more time off and more medical cover, rather than poor health behaviours, to cope.

2.1.4.4 Unemployment

Being unemployed has negative mental and societal impacts (Armenti et al., 2023). Employed people are significantly more likely to report good health and well-being, up to five times more, than unemployed people (The Health Foundation, 2024). Moreover, life expectancy is lower among unemployed people who have a higher mortality rate as they are more likely to make bad health-related decisions and are less likely to find the support they may need mentally and physically through social networks and professional help (Bloomer, 2014). People with lower socioeconomic statuses are more likely to be unemployed, leading to more pressure at home to find ways of financially supporting themselves and their families. Moreover, employment opportunities are often limited for this population group, even more so for younger people with less education and skills and older people who are economically inactive through illness. Having no job and losing a job further limits people in this group to adequate support groups and social networks (The Health Foundation, 2024). The stress induced by unemployment, therefore, further increases the risk of using tobacco.

2.1.4.5 Water and sanitation

Access to safe drinking water and sanitation is key to maintaining and improving public health by reducing exposure to disease (Sheel et al., 2024). Some populations within the Global South are more vulnerable to unsafe water, especially those in lower socioeconomic groups, due to water scarcity along with limited and less maintained water pipes (Pal et al., 2018). Tobacco production uses a substantial amount of water, which is a valuable resource. Growing tobacco crops takes five to eight times more water than growing tomatoes (Zefeiridou, Hopkins, and Voulvoulis, 2018). Moreover, harmful chemicals from tobacco production leach into the local environment and pollute drinking water (Zefeiridou et al., 2018; Novotny et al., 2015). The health inequality between areas with either more or less access to clean water is, therefore, exacerbated in areas where tobacco is produced.

2.1.4.6 Health and care services

The availability of a wide range of healthcare services depends on available funding provided by national governments and local administrations. Accessibility of these services is limited due to barriers such as rurality, geographic obstacles, a lack of understanding of what help is available to people and how to use them, and racism (Dahlgren and Whitehead, 2021; Gulliford et al., 2002). The affordability of using these services, travel arrangements, and time needed to take off work, act as additional barriers. Demand for healthcare is also higher in deprived areas as people are more likely to suffer from long-term illnesses (Barlow et al., 2021). Moreover, men are much less likely to seek healthcare support (Galdas, Cheater, and Marshall, 2005). These factors perpetuate health inequalities, leading to riskier health behaviours, such as using tobacco, and limiting access to tobacco cessation resources (Garrett et al., 2014).

2.1.4.7 Housing

The availability and quality of housing have physical and mental impacts on people's health. The quality of housing is affected by dampness and mould, access to heating, and overcrowding, which increases the risk of disease and stress (Lorentzen et al., 2022). Houses within deprived areas are more likely to face these issues than more affluent areas (Rolfe et al., 2020). Moreover, these houses are more likely to be social and rental houses, giving people a lower perception of home and security with their tenancy. The stress over living conditions, increased rates of diseases, and lower perceptions of living standards influence bad health habits, leading to higher rates of tobacco use (ASH, 2022).

2.1.5 General socioeconomic, cultural, and environmental conditions: commercial and political determinants

The top outermost level of the Dahlgren and Whitehead model includes commercial and political determinants of health. Commercial companies can alleviate some factors of health inequalities by providing more employment, products, and services to areas with demand (Gilmore et al., 2023). Over time, in the case of tobacco, however, there has been a growing power imbalance between commercial companies and people; as the former grows and becomes more affluent, the latter suffer more from poorer health and degraded environments due to the products that tobacco companies sell, leaving governments to tackle the public health inequalities left behind.

The approaches used by tobacco companies to sell their products that have a negative impact on health are clear; they have the power to influence societal norms to encourage demand for their products (Hoek, Edwards, and Waa, 2022). Over time, tobacco companies were able to manipulate social norms via effective advertisements which promoted tobacco by targeting specific populations, such as low socioeconomic status individuals. They were also able to tailor their image to other marginalised population groups by positioning tobacco use as a more positive symbol with unique brands and appearing on the same side to whomever the target group is. For instance, they have bought celebrity endorsements on social media platforms, which are usually overlooked or even approved by governments, to encourage younger people to try their products so that they have a new generation addicted to nicotine. Although they are market competitors, the big tobacco companies have collaborated to manipulate people further to buy their products and to conceal research highlighting the negative impacts of tobacco use (Goel et al., 2023).

Globalisation has given tobacco companies an extended global reach, leading to national governments having less control of the products entering their countries and a global shared culture of health behaviour (Yach and Bettcher, 2000). This has exposed populations of the Global South to products that encourage poorer diets and bad health behaviour, including smoking (Klickbusch, Allen, and Franz, 2016).

Commercial companies have constantly lobbied governments to align regulations, laws, and taxes in their favour. Tobacco companies are doing this by funding research that contradicts our understanding of tobacco's effect on poor health outcomes (Goel et al., 2023). This has had more of an effect on poorer countries with less resources and support to defend against these actions in court. These countries face tremendous legal challenges in implementing tobacco control policies, increasing taxes on tobacco, and curtailing tobacco advertising. Bribery and corruption are perpetuated by tobacco companies with the aim of stalling tobacco control and improving market access; both are linked with an increase in untaxed and unregulated illicit tobacco trade (Gilmore et al., 2023). Those in government who are sympathetic to tobacco companies help improve their public image, which influences people's trust and increases the risk of tobacco use prevalence (Goel et al., 2023). While there have been international tobacco control agreements, there is still evidence of governments' unwillingness to enforce controls due to a lack of resources or political power (Mentis, 2017). This leaves poorer countries less able to deal with health inequalities.

Having set out the conceptual framework for the thesis and outlined its application with respect to individual, local, commercial, and governmental determinants of inequalities in tobacco use, attention now turns to previous research on smoking prevalence in the Global South.

2.2 Literature search strategy

A literature search strategy was created to generate a database of relevant academic papers that have researched the prevalence of tobacco use within the countries of the Global South using Mendeley (Foeckler, Henning, and Reichelt, 2008). This method used multiple online academic databases: Google Scholar, SCOPUS, Delphis, Web of Science, and PubMed. Additional relevant literature was identified from the literature obtained from this search strategy. Grey literature from other sources was also added. The search comprised three key themes: tobacco, the causes of tobacco use, and the research conducted in the Global South. Each theme was investigated by using a Boolean search method, given in Table 1.

Table 1. Boolean search phrases for the literature search on academic databases.

Key themes	Keywords
Tobacco	tobacco OR smoker OR smoking OR smokeless
The causes of tobacco use	“determinants of tobacco use” OR “tobacco use determinants” OR “determinants of smoking” OR “smoking determinants” OR “determinants of smokeless” OR “smokeless determinants” OR “causes of tobacco use” OR “tobacco use causes” OR “causes of smoking” OR “smoking causes” OR “causes of smokeless” OR “smokeless causes” OR “variables of tobacco use” OR “tobacco use variables” OR “variables of smoking” OR “smoking variables” OR “variables of smokeless” OR “smokeless variables” OR “coefficients of tobacco use” OR “tobacco use coefficients” OR “coefficients of smoking” OR “smoking coefficients” OR “coefficients of smokeless” OR “smokeless coefficients” OR “factors of tobacco use” OR “tobacco use factors” OR “factors of smoking” OR “smoking factors” OR “factors of smokeless” OR “smokeless factors”
The Global South	“low-income country” OR “low-income countries” OR “middle-income country” OR “middle-income countries” OR “least developed country” OR “least developed countries” OR “poor country” OR “poor countries” OR “Global South” OR “third world country” OR “third world countries” OR Africa OR African OR Asia OR Asian OR “South America” OR “South American” OR “Latin America” OR “Latin American” OR “Central America” OR “Middle East” OR Afghanistan OR Algeria OR “American Samoa” OR Angola OR Anguilla OR “Antigua and Barbuda” OR Argentina OR Armenia OR Aruba OR Azerbaijan OR Bahamas OR Bahrain OR Bangladesh OR Barbados OR Belize OR Benin OR Bhutan OR Bolivia OR Botswana OR Brazil OR “British Virgin Islands” OR Brunei OR “Burkina Faso” OR Burundi OR Cambodia OR Cameroon OR “Cabo Verde” OR “Cayman Islands” OR “Central African Republic” OR Chad OR Chile OR China OR “Cocos Keeling Islands” OR Colombia OR Comoros OR “Republic of the Congo” OR “Cook Islands” OR “Costa Rica” OR “Côte d'Ivoire” OR Cuba OR Cyprus OR “North Korea” OR “Democratic Republic

Key themes	Keywords
	of the Congo” OR Djibouti OR Dominica OR “Dominican Republic” OR Ecuador OR Egypt OR “El Salvador” OR “Equatorial Guinea” OR Eritrea OR Eswatini OR Ethiopia OR “Falkland Islands” OR Fiji OR “French Polynesia” OR Gabon OR Gambia OR Georgia OR Ghana OR Grenada OR Guam OR Guatemala OR Guinea OR Guinea-Bissau OR Guyana OR Haiti OR Honduras OR “Hong Kong” OR India OR Indonesia OR Iran OR Iraq OR Jamaica OR Jordan OR Kazakhstan OR Kenya OR Kiribati OR “South Korea” OR Kuwait OR Kyrgyzstan OR Laos OR Lebanon OR Lesotho OR Liberia OR Libya OR Macao OR Madagascar OR Malawi OR Malaysia OR Maldives OR Mali OR “Marshall Islands” OR Mauritania OR Mauritius OR Mayotte OR Mexico OR Micronesia OR Mongolia OR Montserrat OR Morocco OR Mozambique OR Myanmar OR Namibia OR Nauru OR Nepal OR “Netherlands Antilles” OR “New Caledonia” OR Nicaragua OR Niger OR Nigeria OR Niue OR “Northern Marianas” OR Oman OR Pakistan OR Palau OR Palestine OR Panama OR “Papua New Guinea” OR Paraguay OR Peru OR Philippines OR “Puerto Rico” OR Qatar OR Rwanda OR “Sao Tome and Principe” OR Samoa OR “Saudi Arabia” OR Senegal OR Seychelles OR “Sierra Leone” OR Singapore OR “Solomon Islands” OR Somalia OR “South Africa” OR “Sri Lanka” OR “Saint Kitts and Nevis” OR “Saint Lucia” OR “Saint Vincent and the Grenadines” OR Sudan OR Suriname OR Syria OR Taiwan OR Tajikistan OR Tanzania OR Thailand OR Timor-Leste OR Togo OR Tokelau OR Tonga OR “Trinidad and Tobago” OR Tunisia OR Turkey OR Turkmenistan OR “Turks and Caicos Islands” OR Tuvalu OR Uganda OR “United Arab Emirates” OR Uruguay OR Uzbekistan OR Vanuatu OR Venezuela OR Vietnam OR “US Virgin Islands” OR Yemen OR Zambia OR Zimbabwe

2.2.1 Selection criteria

After the implementation of the search strategy, any duplicates were removed so that each study was a unique case within the database. This left a database of 1,563 unique studies. The following criteria to select relevant results were adopted to assess each study’s suitability for this scoping review. Firstly, studies that did not have tobacco, smoker, smoking, and smokeless identified in the first theme in their title were excluded from the results via Boolean selection by keyword. The 427 papers excluded at this stage were deemed to lack a primary focus on smoking. Secondly, the abstracts of the remaining papers were read to assess their relevance to smoking in the Global South. A further 930 papers were excluded because their abstracts had a solely clinical, biomedical, or Global North theme. Thirdly, relevant papers cited in the literature already in the database were included (including grey literature), resulting in a comprehensive list of studies for consideration in the literature review. A consort diagram of the paper selection process is given in Figure 2. This process identified 257 unique and relevant papers that could be used to build a literature review on the prevalence of tobacco use within the countries of the Global South.

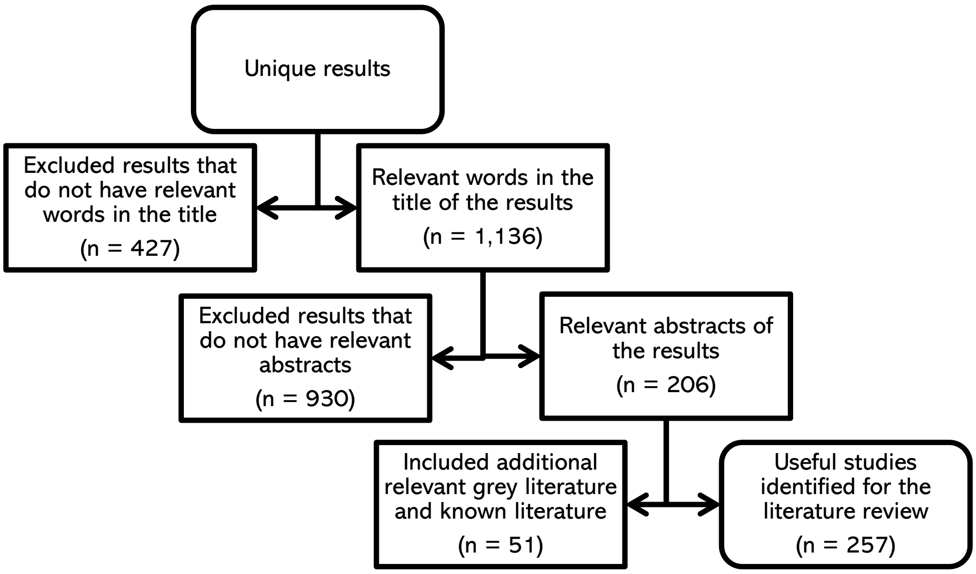

Figure 2. Consort Diagram of the implementation of the literature selection criteria.

2.3 Forms of tobacco use

Tobacco use is a term used by the WHO (2018b) that encompasses both smoked tobacco and smokeless tobacco. The specific ways tobacco is consumed vary in different regions of the world. Globally, the most common form of tobacco consumption was stated by Mackay, Eriksen and Eriksen (2002) and West (2017) to be in the form of smoked tobacco, as manufactured 'white' cigarettes. Of the 1.46 billion tobacco users, only 367 million use smokeless tobacco rather than smoked tobacco (WHO, 2018a). Smokeless tobacco involves tobacco that can be chewed or sniffed (West, 2017). This form of tobacco use is significantly prevalent in Southeast Asia, specifically among women in India, where 56% were found to chew tobacco (Mackay et al., 2002). Mackay et al. (2002) observed that other forms of smoked tobacco, apart from white-manufactured cigarettes, represent the most significant proportion of tobacco smoking in specific regions of the world. Waterpipes, for example, are commonly found in the Mediterranean, North Africa, and some areas of Asia. Bidis are a type of hand-rolled cigarette found throughout Southeast Asia. Kreteks, a type of cigarette made of tobacco and cloves, can be found more specifically in Indonesia. Lawrence and Collin (2004) state that kreteks were used by 88% of tobacco users in Indonesia.

Within the last decade, Electronic Nicotine Delivery Systems (ENDS) have been introduced to the global market as an alternative to tobacco use. Their long-term health impacts have yet to be established. There are significant debates on the effectiveness of ENDS as a cessation tool and the popularity of ENDS among young non-smokers, which could lead to tobacco use in the future (WHO, 2023; Solanki, Kashyap and Kashyap, 2014). Although the prevalence of ENDS continues to grow, they will not be discussed further. This is so that tobacco use, currently the most prevalent form of nicotine delivery in the Global South, can be the focus of this research.

Different types of tobacco use are wrapped in cultural ideas and social norms, becoming an integral part of society for the long term in different places worldwide. In Indonesia, for example, kretek cigarettes have been widely promoted, with backing from the local government, as an indigenous form of tobacco use, compared to the foreign, western style of white cigarettes (Nichter et al., 2009). Kreteks have, therefore, been portrayed as a critical part of their culture and a symbol of Indonesia, which normalised this type of tobacco use (Lawrence and Collin, 2004). Another example is the use of smokeless tobacco in India, where the normalisation of chewing tobacco was brought about mainly by the taboo of tobacco smoking among women and the cosmetic use of chewing tobacco as an ingredient for dying mouths, which is considered an attractive trait in Indian women (Shah et al., 2018).

2.4 The global smoking epidemic transition

The SETM, proposed by Lopez et al. (1994) in Figure 3, highlights the importance of successfully implementing the FCTC. The SETM describes the experience of cigarette smoking prevalence and associated deaths in Global North countries in the 20th century. The SETM highlights how the impacts of tobacco use have long-term effects, as even after successful tobacco control programs, a country can still expect to experience impacts on health in the future due to ageing populations of former tobacco users.

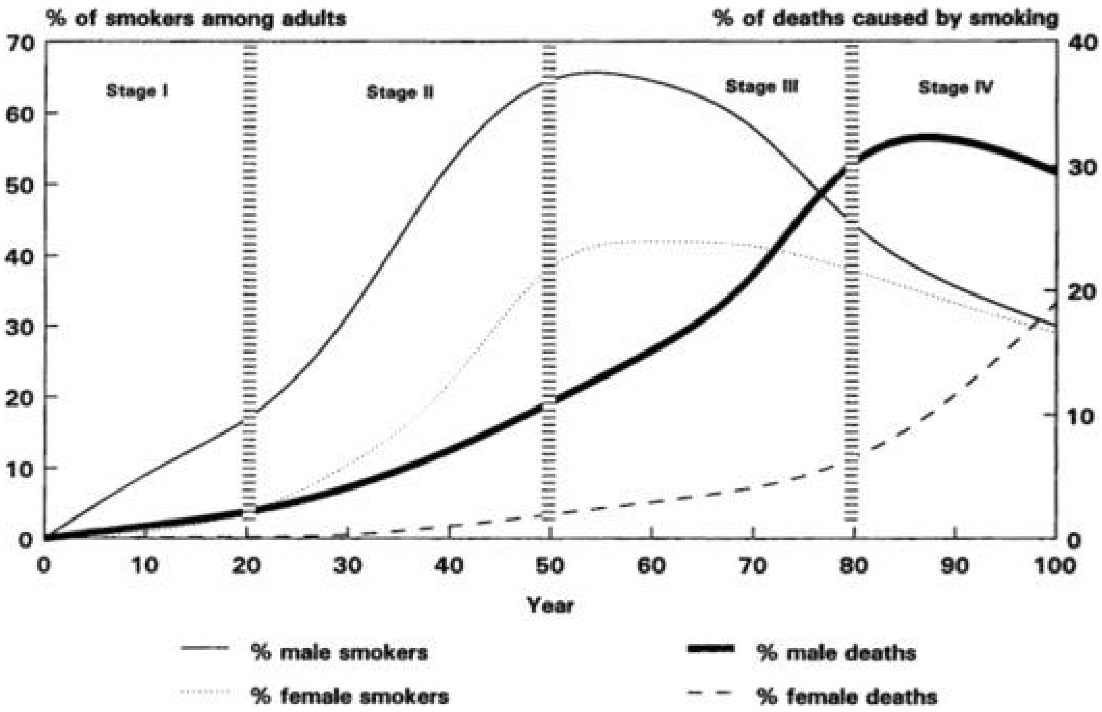

Figure 3.The smoking epidemic transition model (SETM) (Lopez et al., 1994).

The SETM identifies both the percentage of cigarette smokers and the percentage of deaths caused by cigarette smoking in the population in each country for each gender over time. The inclusion of gender into the SETM shows that there is variation in smoking rates amongst males and females throughout the four stages. The first stage shows that smoking rates increase among males and remain low among females. The second stage shows that smoking rates among males reach their peak, and female smoking rates start increasing rapidly, likely indicating when social acceptance and female empowerment grow. The third stage sees a decline in male smoking rates and reaches a peak in female smokers as tobacco control measures are enforced. Social acceptance of smoking habits begins to decline, particularly among those with higher educational attainment. The fourth stage sees the continual decline in gender inequality in smoking rates. Lopez et al. (1994) state that the delayed response of about 30 years, from the rate of smoking prevalence to the rate of associated mortality, is attributable to the time taken for the negative health impacts of a regular smoking habit to take effect.

Countries in the Global South have similar characteristics found in both stages one and two of the SETM because of the absence of effective tobacco control measures, high smoking prevalence in men, and low prevalence in women (Ozbay et al., 2019; Khattab et al., 2012). The countries in stage four of the SETM are the Global North countries, such as the United Kingdom (UK) (Barnett et al., 2016). As such, each stage presented in the SETM can be associated with the country's level of development. This gives health professionals a rough idea of how the issue of tobacco smoking will change over time for each country. The main prediction that can be made from the SETM, therefore, is that the tobacco epidemic in the Global South could get worse over time, with long-term impacts likely if there is no sharp decline in tobacco use early on.

The SETM, however, is only a general classification method for tobacco use transition. Lopez et al. (1994) acknowledged that the SETM does not accurately describe any country's future trends. The stages used to describe the change in smoking prevalence assume that the rates of smoking develop uniformly for both males and females. This may not always be the case, as research by Friedman, Kurtulus and Koc (2017) found evidence that men and women in Turkey were in two different stages of the model. Moreover, as the SETM represents the experience of Global North countries, the model may not accurately represent rates within populations of countries in the Global South. Thun et al. (2012) revisited the model and suggested that separate models for men and women are needed for the Global South as there was no clear sign of a surge in prevalence among women. Revisions to the model were made by Khlat et al. (2016) by conducting separate analyses for men and women and by incorporating a fifth stage. The aim of this is to improve on the limitations of the original model by allowing the model to account for education attainment groups. In doing so, some nuances between socioeconomic factors and smoking could be gauged. Although Khlat et al. (2016) used data from France and the US, their revised model of the tobacco transition concluded that the SETM did not represent the experience of smoking prevalence in all social groups. This was particularly so for the lower education groups, as more were found to smoke in France, and fewer were found to smoke in the United States (US) over time for both men and women. Whilst considering the SETM's use of gender as a determinant that changes in significance over time, there is a need for further exploration of the factors that determine the changes in smoking prevalence over time. Doing so would provide a greater understanding of how to measure smoking prevalence.

2.5 Tobacco use in the Global South

The SETM suggests that smoking prevalence and the consequent burden on public health in the Global South will grow without adequate control measures in the long term. Moreover, infectious diseases within Global South countries will help create a 'double burden' on this region's public health and further outstretch local government's ability to mitigate these issues (Herrick, Reubi, and Brown, 2016). There is already much evidence on a national scale, rather than a global scale, that the burden of tobacco is already unequally distributed as variations in tobacco use can be found between the Global North and Global South countries. 80% of the current tobacco smokers of the world (approximately 1.1 billion) live in Global South countries (WHO, 2023). This is a significant change from the past, as Maiyaki and Garbati (2014) noted that until recently, tobacco was considered to be mostly a health burden for Global North countries. Pampel (2008), however, observed that from 1970 to 2000, cigarette consumption increased by 46% in low-income countries and decreased by 14% in high-income countries. This transition of the smoking epidemic from Global North countries to Global South countries was also noted in other research, such as the American Cancer Society (2018), which found tobacco use reduced by 26% in Europe whilst it increased by 60% in Africa between 1990 and 2009.

This change in the distribution of global tobacco use to the Global South is mainly the result of higher taxation and more tobacco industry regulation in Global North countries (Bramall and Keenlyside, 2017). This has led to tobacco companies expanding into Global South countries, such as Sub-Saharan Africa, where tobacco companies have been capitalising on the region's youthful demographics and economic growth (Brathwaite et al., 2015). Brathwaite et al. (2015) add that government policies further exacerbate the success of tobacco companies in these countries of the Global South. Sub-Saharan African countries, for instance, have lower taxation rates on tobacco, weaker and less enforced smoke-free policies, and fewer restrictions on tobacco advertisement when compared with Global North countries. According to Egbe, Bialous and Glantz (2017), this weaker stance against tobacco use in Global South countries leads to greater susceptibility to legal challenges by the tobacco companies. This is further enhanced by these governments' lack of financial resources, attracting further investment from tobacco companies to expand their markets greatly. Policy implementation, however, does not reflect policymakers' attitudes towards tobacco use but rather their ability and the available resources needed to do so effectively. Furthermore, regions like Africa have more pressing issues dealing with infectious diseases, so tobacco control is a lower priority (Blecher and Ross, 2013). This allows tobacco companies to involve themselves in government policy-making decisions and employ tactics that oppose any policies limiting the growth of the tobacco industry (Brathwaite et al., 2015). The importance of governments and policymakers in persevering on implementing tobacco control policies was highlighted by Brathwaite et al. (2015), as countries that ratified the WHO FCTC earlier were found to have lower smoking prevalences than countries that ratified later or not at all. Smoking rates in the Global South will, therefore, continue to rise, fuelled by an expanding pool of young smokers due to both the tobacco company's tactics in targeting the markets in the Global South and the lack of ability and resources to implement the FCTC in the poorest countries of the Global South (Maiyaki and Garbati, 2014; Owusu-Dabo et al., 2010).

Even though there is considerable evidence of tobacco companies shifting their focus on the markets in the Global South countries, the significance of the prevalence of tobacco use has, thus far, yet to be substantially defined in Global South countries (Owusu-Dabo et al., 2009). This is because there is a lack of up-to-date data, such as census data, that depicts the current rates and the spatial change of tobacco use (Pampel, 2008). As a result, research on tobacco use seldom takes place within the Global South and, therefore, provides a weak knowledge base of the dynamics of tobacco use in Global South countries compared with Global North countries where data is more readily available. Mamudu et al. (2018) described the Global South as a 'research desert' for tobacco control, specifically the Sub-Saharan African region. This is surprising considering that since the almost global ratification of the WHO FCTC, there has been a need for accurate and up-to-date data to frequently inform the implementation of the strategy in the Global South. Continuous surveillance of the tobacco epidemic is crucial in tailoring policies that mitigate tobacco prevalence (WHO, 2023). Although, with only one out of three countries of the world, mainly Global North countries, that monitor tobacco use via surveys every five years, it would be reasonable to presume at this stage that Target 3.a of the SDG 3 will not be achieved at this rate and that the burden of tobacco will grow in the most vulnerable regions.

With the importance of monitoring tobacco use in the Global South in mind and the extent to which gender influences a variation of smoking within the SETM, it would, therefore, be essential to build an understanding of how determinants, like gender, add to the variation of tobacco use within this region specifically. As such, this presents a gap in our knowledge. The SETM also suggests that countries in the Global South are likely to be in stage one. The SETM, however, does not provide much confirmatory evidence or, more importantly, show how countries in the Global South are moving through the transition. It is, therefore, essential to find the extent to which the relationships between the determinants of tobacco use and tobacco use prevalence change within the Global South over time. Doing so would provide insight into the current and possible future trajectory of tobacco use within Global South countries and what socioeconomic and demographic subpopulations are becoming at risk over time, presenting another gap in our knowledge. These gaps must be addressed so that a more comprehensive understanding can be had of tobacco use in regions that will suffer the most in terms of both the economic and human costs. As such, the following section examines the current state of knowledge concerning the demographic determinants of tobacco use in the Global South that could be used to address these gaps.

2.6 Demographic determinants of tobacco use

The significance of demographic determinants of tobacco use is evident from the results of the literature search strategy, as most of the results were found to focus on finding the significance of the association between gender or age with tobacco use in the Global South. The significance of this association and other demographic variables with tobacco use is investigated in this section.

2.6.1 Gender

Much like the SETM, the most notable disparity in tobacco users can be observed between men and women. Recent global estimates suggest that 1.12 billion tobacco users are men while 279 million tobacco users are women (WHO, 2019a). Although there are significantly fewer female tobacco users globally, there are even fewer within Global South countries (ASH, 2019). Hagen et al. (2016) study found that smoking prevalence among women was around 3% in Global South countries compared to around 17% among women in Global North countries.

This pattern can also be seen on a smaller scale. Nejjari et al. (2009), for example, found that over the first decade of this century, Morocco, unlike the Global North countries, had neither a decline in smoking rates overall nor a decline in gender inequality in smoking rates, with rates of 36.3% in men and 3.3% in women. This gender inequality is comparable to the levels experienced by most Global North countries around the end of the 1940s. Similarly to the stigma that was evident among Global North countries for most of the 20th century, the stigma of tobacco use in Morocco fuels this gender disparity, as a smoking habit is seen as shameful among women whilst being considered normal among men. The stigmatisation of female smokers, however, could mean that they were less likely to report that they use tobacco. Therefore, it is likely that there are more female smokers than what was reported. The existence of tobacco smoking among women in Morocco, regardless of the local social norms, manifested from Western influence. This influence led women to use tobacco as a statement of their emancipation. This is what was observed in Global North countries where, over time, gender empowerment helped eliminate societal norms and taboos around a smoking habit for women (Waldron, 1991).

The disparity in tobacco use between men and women remains significantly apparent in Global South countries, with the likelihood of a man smoking being five times greater than the likelihood of a woman smoking (Khattab et al., 2012). Additionally, men also have an increased likelihood of having a more intense use of tobacco compared to women (Ozbay et al., 2019; Ghani et al., 2012; Le et al., 2009). The smoking gender inequality has also been observed in other parts of the Global South, such as Asia, where China was found to have the most significant number of smokers than any other country in the world, with 300 million males and 20 million females that smoke (Yang et al., 2006). The smoking rate in 2011 was estimated to be prevalent among 60% of men and only 4.2% of women in China, according to Hitchman and Fong (2011). This gender difference is likely to reduce as Global South countries develop and women close the gap with men, increasing the burden of tobacco on public health in the future. This gulf in gender smoking rates is common across this region, such as in Malaysia, with smoking as high as 61.7% in men and 5.8% in women (Ghani et al., 2012). This could be linked with the negative stigma of female smokers, as found in Nejjari et al. (2009) research in Africa, as stated previously, or that women prefer to use smokeless tobacco. Gupta and Ray (2003) state that smokeless tobacco was popular among women throughout South Asia, with smokeless tobacco representing a third of all tobacco consumed in this region. Most of the female population in India, for example, were found to use smokeless chewing tobacco (Mackay et al., 2002).

2.6.2 Age

Age is also an important variable to consider when trying to ascertain when a smoker initiates a smoking habit. In general, long-term smokers begin their smoking habit from the ages of 18 to 20 (ASH, 2019). Global South countries are found to have significantly higher rates of smoking among adolescent populations compared to Global North countries (ASH, 2019). Xi et al. (2016) estimated that, on average, 13.6% of 12- to 15-year-olds have smoked in the Global South, although Xi et al. (2016) also stated that this percentage could have been as high as 44.7% in some Global South countries. In contrast, ASH (2019) stated that, on average, 3% of 11- to 15-year-olds have smoked in the UK. Moreover, the rates of tobacco use were also found to be increasing among young people in the Global South. In one of the worst cases, Gurung et al. (2016) found that tobacco use in Bhutan among 13- to 15-year-olds, particularly males, increased 11.5% from 2006 to 30.3% in 2013.

There are several potential reasons for a greater smoking population yield from younger age groups. One is the normalisation of tobacco use around children, which, in turn, encourages children to experiment with smoking or smokeless tobacco to imitate their family members (Gupta and Ray, 2003). The influence posed by family members is significant in Global South countries. As Gupta and Ray (2003) mentioned, between a third and a half of children under the age of 10 in three rural areas in India have used tobacco to imitate family members.

Peer pressure among adolescent friends is another reason for there being a greater smoking prevalence among young people, as this can lead to a dependence on nicotine at a young age due to social pressure among peers who do not want to stop smoking (Panday, Reddy and Bergström, 2003). This could bring about a larger pool of young adults having a long-term smoking habit. As smoking initiation in adolescence continues into adulthood, the impact of tobacco on public health will worsen over time as current adolescents who smoke become victims of tobacco-related illnesses in the future (Rawat, Gouda and Shekhar, 2015).

A further additional reason for the high prevalence among young people is given by Hussain, Zaheer and Shafique (2017), whose research found that in some countries, such as India, Pakistan and Bangladesh, children were encouraged by their parents to use smokeless tobacco. As a result, smokeless tobacco among young people within this region of Asia is prevalent. It has been normalised to such an extent that smokeless products were found to be considered sweets. This smokeless tobacco-friendly environment is compounded further by not only peer pressure but also the media. Hussain et al. (2017) found that 40.2% of those who initiated the use of smokeless tobacco before the age of 15 were influenced by the media. Khattab et al. (2012) found that waterpipes were used by up to 34% of 13- to 15-year-olds in North Africa. Hasnaoui et al. (2012) stated that the lack of enforced tobacco regulations that aim to ban smoking in public places within certain countries of this region contributes to this. Moreover, El Hasnaoui et al. (2012) added that many people living in this region consider tobacco use, primarily via waterpipe, as a socialising factor. This further indicates why tobacco control measures are more lenient within the Global South.

There are, however, examples where tobacco use is higher among older people. For instance, smoking prevalence among elderly males was found to be as high as 84.5% in Indonesia (Marinho et al., 2008). Magati et al. (2018) study in Kenya found that smoking prevalence increased with age. This trend is significantly more extensive in males than females, as males aged 20 to 30 were found to be five times as likely to smoke, whilst those aged 30 to 54 were 13 times more likely to smoke compared with males aged 15 to 19. Magati et al. (2018) highlighted that the relatively low tobacco use among adolescents in Kenya, compared with older generations, may be attributable to an effective ban on tobacco advertising, unlike the tobacco media influence found in India in Hussain et al. (2017) study. Moreover, Oyewole et al. (2018) and Kusumawardani et al. (2018) found that there was a greater smoking prevalence in areas of Nigeria and Indonesia, where younger age groups represent a smaller proportion of the population.

2.6.3 Marital status

The results of the literature search show that very few studies have examined the association between marital status and the prevalence of tobacco use in the Global South. Magati et al. (2018) study in Kenya indicated some association between marriage and a lower likelihood of smoking. They suggested that married men were 15% less likely to use tobacco. In contrast, men who were either separated, divorced, or widowed were 1.4 times more likely to use tobacco. A similar pattern was also found among married women. Women who live with their partner but are not married, on the other hand, were 46% more likely to smoke than those who were married. Moreover, this pattern was not found among unmarried men living with their partners. Marinho et al. (2008) study in Brazil corroborates these findings as smoking prevalence among married individuals was estimated to be 17.6%, whereas smoking prevalence among the unmarried, separated, divorced, and widowed was estimated to be 27.7%. The smoking prevalence disparity between marital statuses, noted by Magati et al. (2018) and Marinho et al. (2008), could be due to the social factors involved, such as married individuals benefitting from additional mutual social support to either refrain from tobacco use or to successfully quit smoking compared to those who are unmarried (Meyler, Stimpson and Peek, 2007).

Jarallah et al. (1999) study in Saudi Arabia, however, contradicts Magati et al. (2018) and Marinho et al. (2008), as they found smoking prevalence was greater among those who were married compared to those who were not. These findings, however, may not convey an actual representation of the truth, as smoking tobacco is not socially acceptable in Saudi Arabia. Therefore, the data collected via interviews may be inaccurate as individuals may not have disclosed truthful answers in the presence of family members, especially for young unmarried women.

2.6.4 Children

The presence of children within a home as a factor that influences tobacco use is also a topic that has limited literature from the Global South. Notwithstanding this, one study in Taiwan found that having children was associated with lower rates of smoking in the household, as having a child led to more parents successfully quitting smoking (Lin, 2010). The remaining studies, however, contradict this relationship.

Arouri, Youssef, and Nguyen-Viet (2016) study in Vietnam observed that there was a strong positive association between the number of children within a household and smoking prevalence as an additional child increased tobacco consumption by 15% within the family home. This was attributable to the additional parental stress caused by having several children. In addition to this, there may be a lack of knowledge on the impact of smoking and second-hand smoke, as tobacco use is mainly accepted as part of the social norms of this country. Although the social norms of smoking in most Global South countries usually only allow men to smoke, it could be said that the health behaviour of parents living in Global South countries that have male children is more likely to have an impact on their children's risk of smoking than parents with female children (Sullivan, Bottorff and Reid, 2010). Jarallah et al. (1999) study in Saudi Arabia observed that parents who continued to smoke increased the risk of their children initiating a smoking habit. Moreover, Ahmed et al. (2008) observed that parental smoking behaviours in Pakistan promoted smoking initiation for the children and an escalation in their child's smoking habit if one already exists.

The existing literature is unclear on the impact of having children in the home on tobacco use. It appears, however, to at least acknowledge the influence of culture and societal norms in this association. Due to the influence of socioeconomic determinants, the significance of this relationship and other demographic determinants is highly likely to vary across the Global South. As such, the socioeconomic determinants of tobacco use are now explored.

2.7 Socioeconomic determinants of tobacco use

This section examines the common socioeconomic determinants found within the Global South literature, such as education, employment status, income, and type of place (rural and urban) that underpin the variation in tobacco use prevalence. In doing so, a more comprehensive understanding of the significance of each socioeconomic factor can be had. This is important as Laaksonen et al. (2005) argued that most research had seldom considered multiple socioeconomic determinants and usually relied on one factor when investigating the change in tobacco use prevalence.

2.7.1 Education

Much of the literature on the association between education and tobacco observed that a lower probability of using tobacco was associated with people who achieved a higher level of education (Lin, 2010). As noted by studies such as Fernando et al. (2019) in Sri Lanka and Marinho et al. (2008) in Brazil, a gulf in smoking prevalence was found between those with high educational attainment and those with low educational attainment, as those with only primary education smoked significantly more than those with either a secondary or higher education. Furthermore, the extent of the significance of education as a determinant of tobacco use was highlighted by Siahpush et al. (2008), whose study on Malaysia and Thailand found that those with no education were six times more likely to smoke, and those with primary and secondary education were three times more likely to smoke, than those that had higher education.

A similar association was found with smokeless tobacco in India and Nigeria, as those with no education used chewing tobacco significantly more than those who were educated (Rawat, Gouda and Shekhar, 2015; Desalu et al., 2010). Additionally, Gupta and Ray (2003) found that regardless of the regional variations of the type of tobacco use, the preference for smokeless tobacco had an inverse relationship with the level of education. This suggests that not only does tobacco prevalence have an inverse relationship with educational attainment, but in India specifically, there was a change in how tobacco was consumed. Consequently, it could be presumed that, due to the popularity of smokeless tobacco within South Asia, similar trends could be found in the change of preference in tobacco use with an individual's educational attainment.

Higher educational attainment was also linked with a higher successful smoking cessation rate (De Walque, 2007; Gupta and Ray, 2003). De Walque's (2007) study on Vietnam found that the impact of the level of education on an individual's decision to smoke dramatically improved access to information on individual health. Fernando et al. (2019) corroborates with De Walque (2007), who observed that those with secondary or higher education had a better awareness of tobacco's impact on their health. Furthermore, Desalu et al. (2010) found that 89.5% of those who used smokeless tobacco and have low educational attainment were not aware of the harm of this type of tobacco. A reason for greater awareness of health impacts with education was given by Lin (2010), whose study established that an individual with more qualifications had a greater motivation to quit a smoking habit successfully. This is due to the greater availability of time and money brought about by improved job opportunities associated with their level of education.

When looking at studies specific to certain areas, such as Ahmed et al. (2008) in Pakistan, there are contradictions to the current understanding of the association between education and tobacco use. Ahmed et al. (2008) observed a high prevalence of smoking among university students and noted that these rates were similar to the rates amongst the less educated populations. This study challenges studies in other Global South countries, such as Iran, where a university education was found to be significantly associated with being a non-smoker (Rajabizadeh et al., 2011).

A study by Gurung et al. (2016) in Bhutan compared the association between education with smoking and smokeless tobacco. According to Gurung et al. (2016), although those with higher educational attainment were less likely to use smokeless tobacco than those with less educational attainment, which corroborates with most literature on the subject, the opposite was true with smoked tobacco. Gurung et al. (2016), however, found this association between smoked tobacco and education in Bhutan to be unique, as their research considered the findings in other studies conducted in other South Asian countries. This is possibly due to the strict tobacco control measures implemented two decades ago in Bhutan (Ugen, 2003). Further contradictions can be found in the level of education of men and women with tobacco use. Khattab et al. (2012) study of the Middle East and North Africa found that although male smokers were associated with lower educational attainment, female smokers were associated with higher educational attainment. This was expected as section 2.6.1 found that the empowerment of females, which in this case may be linked to higher educational attainment, led to a higher smoking prevalence rate among women.

2.7.2 Employment status

There is limited literature on the impact of employment status on tobacco use within the Global South, which provides no clear consensus. The research by Fernando et al. (2019) and Marinho et al. (2008) in Sri Lanka and Brazil, respectively, observed that unemployment was a stressful event in an individual's life. Much like female empowerment and greater awareness of health consequences are different modes in which determinants of smoking, such as education, operate; stress was found to dramatically increase the chance of both initiating the use of tobacco and the intensity of a habit as a coping mechanism. Although Lin (2010) noted that unemployment was a contributing factor for initiating tobacco use, specifically among married women in Taiwan, no significant association was found for married men. This, however, was not the case in China, as Ding et al. (2009) stated that unemployed men in China were found to be associated with high smoking prevalence rates.

Further contradictions are common throughout the literature. In some studies, such as Abdelwahab et al. (2016) and Cheah and Naidu (2012), employment was found to be associated more with smoking prevalence than unemployment. This, therefore, is the opposite of what was found in studies by Fernando et al. (2019) and Marinho et al. (2008). Marinho et al. (2008) suggested that different social factors, such as peer influence, in different work environments resulted in a higher prevalence of tobacco use among those who were employed. Whereas Cheah and Naidu (2012) suggested that job pressure and being more financially independent lead to an increased chance of smoking initiation.

2.7.3 Income

As seen with the previous factors discussed thus far, sociocultural variations across the Global South make it challenging to form a consensus on the significance of income as a determinant of tobacco use prevalence. Some literature found that tobacco use was higher among people with a low income (Marinho et al., 2008; Subramanian et al., 2004; Rani et al., 2003; Steyn et al., 2002; Gilmore, Mckee and Rose, 2001). Moreover, tobacco use has been found to reinforce poverty and further contribute to intergenerational poverty, as those who smoked and lived in socioeconomically deprived areas spend much less on childcare, education, food, and clothes than those who were found not smoke (ASH, 2019; John, Mamudu and Liber, 2012). This is because poor smokers, who are the primary income providers in families, divert a larger share of their income away from these essentials to fund their tobacco use habit. Half of the female spouses that were interviewed in Fernando et al. (2019) study on Sri Lanka stated that smoking was the main reason why their families have little disposable income to spare for household activities. Additionally, this reduction in available income helped create higher stress conditions within households, which further fed the need for smokers to buy more tobacco.

Some literature provides evidence of the opposite association. For example, high levels of socioeconomic deprivation, which was found to be a good indication of people who were on a lower income in an area, was associated with lower smoking intensity and an increased number of smokers attempting to quit in Mexico, according to Fleischer et al., (2015). Moreover, Lau et al. (2018) found that deprivation had a non-linear relationship with smoking prevalence within South African neighbourhoods. There were also instances where those with higher incomes smoked more. Nejjari et al. (2009) observed that women who lived in higher-income communities were three times more likely to smoke than the national average for female smoking prevalence. Moreover, Lebanon exhibited the highest smoking rates among high-income females within the North African and Middle Eastern regions (Khattab et al., 2012). Both Khattab et al. (2012) and Nejjari et al. (2009) stated that this could be attributed to the Western influence in the societies within Lebanon and Morocco.

Variations in the type of tobacco use were also found to be affected by income. Gurung et al. (2016) study on Bhutan found that smokeless tobacco was more affordable than smoked tobacco. This could explain the conclusions made by Gupta and Ray (2003), whose research on India found an inverse relationship between the preference for smokeless tobacco and income. This suggests that the price variation provided a greater level of accessibility of tobacco to smokers and potential smokers. Consequently, this increased accessibility could negate any meaningful attempt to identify the extent of the association between income and tobacco use. This could help explain why Lin (2010) found no strong association between smoking behaviour and income in Taiwan, which was contrary to what they had expected.

There is evidence of the level of income interacting with other determinants of tobacco use. Jha and Peto (2014), for example, indicated that young people had a higher smoking rate in poorer and deprived areas. On the other hand, children, particularly young males who grow up in higher-income families in Saudi Arabia, were found to be more likely to initiate a smoking habit (Al Agili and Park, 2012). Consequently, by considering the points made here and the impact of the varying cultural contexts, the association between income and the prevalence of tobacco use may continue to change in each country of the Global South.

2.7.4 Place

The last determinant of the prevalence of tobacco use found in some of the literature is the environment a person lives in, specifically the association between tobacco use and sparsely populated rural areas or high-density urban areas. In most studies found for this review, this environment, referred to as ‘place’, observed that rural areas were more associated with greater tobacco use than urban areas in the Global South at varying extents. One such example can be found in Kusumawardani et al. (2018) study on Indonesia, where tobacco use prevalence was only marginally higher in rural communities at 53.7% compared with urban communities at 51.9%. Shikha et al. (2014) in their study in India, observed that prevalence was as high as 32.9% in some rural areas and 15.8% in some urban areas. A similar rural and urban disparity can be found in Alam et al.’s (2008) study in Pakistan. Gilani and Leon (2013) observed that tobacco control campaigns in Pakistan targeted those living in rural areas, which had a higher proportion of poor and uneducated individuals who were at a greater risk of initiating tobacco use. Moreover, Smokeless tobacco use was significantly more prevalent in rural areas of Bangladesh, India and Myanmar compared with urban areas (Naznin et al., 2020; Rawat et al., 2015). Women in Sub-Saharan Africa who reside in rural areas were also more likely to smoke than those in urban areas (Sreeramareddy, Pradhan and Sin, 2014a). Gurung et al. (2016) study in Bhutan, however, found that smoking prevalence in urban areas was higher and more statistically significant than in rural areas. Although, it is important to note that Gurung et al. (2016) stated that their findings contrast with other studies conducted within the area.

Some research indicates that the association between place and tobacco use had no noticeable pattern. It was noted by Oyewole et al. (2018) study and Brathwaite et al. (2015) systematic review of existing literature that there was no consistent disparity in smoking prevalence in Sub-Saharan African countries between the rural and urban populations. The estimates for prevalence in Zambia showed the most significant difference and statistical significance, with 22.4% smoking in rural areas and 6.8% in urban areas. This could be due to underlying characteristics, such as subtle differences in socioeconomic status, culture, and tobacco accessibility. Brathwaite et al. (2015), however, observed that some studies that were conducted in the same region at the same time presented different results. Urban areas within Kenya, for example, were estimated in 2010 to have a smoking prevalence of 4% and 13% in different studies. Moreover, two studies in rural areas within Zambia found the smoking prevalence to be 22.4% and 10.8%. This suggests potential data collection errors or different definitions of rural and urban areas. Therefore, place as a predictor may be too complicated for statistical analysis with different datasets. It is also important to consider that many of the determinants discussed previously relate to place, such as income, as wealth disparities between rural and urban areas can be significant across the Global South.

Most of the discussion on the effect of place on tobacco use focuses on comparing national rural and urban prevalence rates. One study that was found, however, examined the wider internal spatial variation of tobacco within Global South countries. Krishnamoorthy and Ganesh (2020) found hotspots of tobacco consumption among women in India using spatial autocorrelation. They observed that areas with high rates of tobacco consumption were associated with areas with larger tribal populations where social norms are different to areas with non-tribal populations. Although there have been different associations between tobacco use and rural or urban settings, with varying significance, the underlying spatial element of place as a determinant of tobacco use is not limited to the differences in prevalence between rural and urban areas. This lack of research on the spatial variation of tobacco use within Global South countries presents a clear gap in our knowledge.

2.8 Country-level determinants of tobacco use

Most of the results from the literature search strategy focused on individual and small-area level determinants. Understanding country-level determinants would be useful as this knowledge can help governments to frame tobacco control policies. As such, additional supporting literature that is not specific to the Global South was used to further guide our understanding of country-level determinants.

Some country-level determinants are political. Low political stability impacts the priorities of the affected government, as both the implementation and enforcement of tobacco control policies may be a less important priority (Jha et al., 2006). Lower rates of political stability have been linked with higher smoking prevalence rates, especially among the younger generation (Waajid, 2007). Another political country-level determinant is corruption. This can challenge government priorities for tobacco control. Corruption is linked with a higher level of crime, which includes tobacco-related crime, like tobacco smuggling across borders, and is, therefore, linked with higher rates of smoking prevalence (Budak et al., 2021). Governments may not be entirely at fault as tobacco companies are known to take advantage of situations in countries that have low political stability and high corruption (Chen et al., 2015). The perception of corruption among a country's population has also been linked to a higher rate of smoking (Bogdanovica et al., 2011). This perception of corruption could be because of a lack of trust in governments and stress responses from a lower social cohesion among communities, particularly in more deprived areas that experience more crime and higher smoking prevalence (Felker-Kantor et al., 2019).

Other country-level determinants of smoking are economic, reflecting the established associations between national wealth, human potential, and tobacco use. Human development is negatively affected by tobacco use due to tobacco's impact on public health and the burden it places on national economies (Ordunez and Campbell, 2020). Human development has been increasing in countries with decreasing smoking prevalence rates (Bogdanovica et al., 2011). Another economic country-level determinant is urbanisation. An increase in urbanisation over time has been linked to a decrease in national smoking rates (Yang and Barnett, 2021; Yu et al., 2021). A reason for this could be that a larger/growing healthcare infrastructure in urbanised/urbanising areas improves accessibility and availability to tobacco control resources compared to rural areas.

Finally, there are tobacco-specific country-level determinants. Tobacco production, both as an agricultural crop and as a manufacturing sector, has been growing in the Global South and has been linked to an increase in smoking prevalence (Wallbank et al., 2026). Another tobacco-specific determinant is the national tobacco control commitment. Successfully implemented and enforced tobacco control policies are directly linked to the decline in smoking prevalence (Ahsan et al., 2022; Islami et al., 2015). This association is found most significant in countries that are suffering from relatively high smoking prevalences (Husain et al., 2021).

2.9 Summary of the gaps in our knowledge

Working within the conceptual framework outlined at the start of this chapter, the studies discussed above present a current understanding of associations between the determinants of tobacco use and the prevalence of tobacco use in the Global South. This understanding indicates that the associations vary significantly across the Global South. Although some variation was expected when comparing research over many countries, the absence of a clear picture of the effect of these determinants on tobacco use across the Global South makes for uncertainty regarding the vulnerability of specific demographic and socioeconomic populations to tobacco use in Global South countries. Removing such uncertainty by finding the significance of each determinant in each Global South country would build an understanding of the factors that lead to tobacco use variation within these populations. This would provide a better opportunity for countries to use such evidence in tobacco control policies to reduce tobacco use. Reitsma et al. (2021) and Ng et al. (2014) have examined the variations in smoking prevalence on an international scale, with 204 countries from 1990 to 2019 and 187 countries from 1980 to 2012, respectively, and stratifying by age and gender. Their results urged monitoring such variations to focus on countries with relatively higher prevalence rates. As these countries are increasingly in the Global South, the first gap in knowledge to be highlighted is a need for an enhanced understanding of the extent to which known social and demographic determinants vary in their influence on smoking prevalence in the Global South.

The reviewed studies highlight the associations within specific Global South countries using data obtained at a specific time. When considering the variation in the relationship between gender and smoking prevalence over time in the SETM, it is likely that the associations discussed thus far will be subject to change. Moreover, Reitsma et al. (2021) and Ng et al. (2014) identified varying trajectories of smoking prevalence by age and gender, which suggests diverging trends from the SETM. Though some inferences can be made about the current importance of some determinants of tobacco use with the existing body of literature, there is little investigation of the changing importance of the current critical determinants of tobacco use. Gaining such an understanding could provide foresight of these associations in the near future. The impact of this would prepare policymakers to adjust current and future tobacco control policies for demographic and socioeconomic populations that are found to have a growing population of tobacco users and those more vulnerable to initiating tobacco use. As such, a second gap in knowledge exists concerning the changing relationship between social determinants and smoking over time.

A longitudinal investigation to address this second gap would benefit from additionally incorporating consideration of country-level determinants. This would highlight the extent to which these neglected determinants affect the variation of tobacco use over time and allow comparisons between countries. This presents a third gap in our knowledge.

A fourth gap in knowledge that emerged from the literature review concerns the role of place in tobacco use. This is because little research exists on the internal spatial variation of tobacco use within Global South countries beyond simplistic comparisons of rural and urban prevalence. Understanding the internal heterogeneity of smoking prevalence within countries and the differences between places would benefit those involved in implementing tobacco control measures by improving efficiency in targeting vulnerable populations with tobacco control resources that are not readily available within these relatively poorer countries.

2.10 Research questions

To address the four gaps in the knowledge that were identified in this literature review, four research questions were proposed:

1. How does the significance of the social determinants of tobacco use vary within the Global South?

2. How has tobacco use changed over time within the Global South?

3. How have the country-level determinants of tobacco use impacted changes in tobacco use prevalence over time in the Global South?

4. How does tobacco use vary within the countries of the Global South?

The results of answering the first question would provide a better understanding of the important determinants of tobacco use both across the Global South and within Global South countries. This would help indicate areas within countries where specific demographic and socioeconomic groups are more at risk of initiating tobacco use if they have not already done so. The results of the second and third questions would highlight the extent to which these determinants influence tobacco use over time. This would provide insight into current and future trends in tobacco use and what determinants may become more important when considering tobacco control policies. The results of the fourth question would highlight subnational areas that indicate an increase or decrease in tobacco use and would improve the allocation of the existing tobacco control resources.

Chapter 3 Data Landscape

The WHO recognised that the continuous surveillance of the tobacco epidemic is the key to mitigating the impact of tobacco use on public health around the world (WHO, 2019a). Only one in every three countries, however, actively monitors tobacco use at regular five-year intervals (WHO, 2019a). Most countries that regularly monitor tobacco use are developed countries due to the resources they have at hand. Data collected from standardised surveys implemented at regular intervals allow for a reliable evaluation of the tobacco epidemic and the effect of tobacco control policies in affected countries over time (WHO, 2008a). Different surveys have been conducted in many Global South countries that primarily measure health indicators, including tobacco use, of a country's population.

This chapter reviews and assesses the suitability of the surveys containing tobacco use data from the Global South, which can be used to address the research questions identified in the previous chapter. Before choosing survey datasets, a comprehensive understanding of the tobacco use data adopted by previous studies is needed. Only publicly available, multinational, multilevel, standardised surveys with data on individual respondents from the Global South are discussed. This is to avoid using unstandardised single-country surveys to draw comparisons of the variation of tobacco use between countries and to observe subnational variations within countries.

This review looks for surveys relevant to the thesis research questions; the surveys must have standardised datasets from multiple Global South countries to draw comparisons between countries and to avoid compiling a database of unstandardised national surveys. The surveys must also have collected data from across a country rather than from specific areas, such as cities. The surveys must have datasets with large sample sizes to make more reliable inferences from the results of each Global South country. The surveys must also include males and females rather than one specific gender. The survey datasets must be stratified into multiple spatial levels so that both subnational and national results can be generated to better inform the variation of tobacco use within and between countries. The datasets must also include variables that can represent the determinants of tobacco use discussed in sections 2.6 and 2.7 of the literature review chapter. Including these determinants in a dataset is important in addressing the first research question of this research as it would allow for statistical analysis of the significance of the associations in the Global South. Datasets collected from countries of the Global South on more than one occasion were also needed. This would allow for an analysis of the associations with tobacco use over time in relation to the Lopez (1994) model to address the second and third research questions. Lastly, Global Positioning System (GPS) coordinates of the sampling locations were needed for each dataset, allowing for statistical analysis at the small-area level so subnational variations of tobacco use can be generated to predict where prevalence is of concern to address the fourth research question.

Sources were initially identified from the research discussed in the previous chapter. A search of the Global Health Data Exchange database of health-related data within the Institute for Health Metrics and Evaluation (IHME) was then conducted to find any additional surveys relevant to this research. After this review, a suitable source of tobacco use data to address the project research questions is identified. An examination of the metadata of the common variables within the chosen database identifies the compatibility of the datasets for cross-sectional comparative analysis and the suitability of the variables to act as indicators of the determinants of tobacco use. Information is also given on the standardisation of the variables available. Following this, criteria were adopted to select specific datasets from the chosen survey with the required data. A brief analytical strategy used in the empirical chapters is then presented. The chapter concludes by acknowledging the limitations presented in the chosen datasets.

3.1 Tobacco use datasets

3.1.1 The GTSS

The Global Tobacco Surveillance System (GTSS) is a leading international data repository for tobacco use (CDC, 2020). The GTSS was developed in 1988 to help implement and monitor the WHO's FCTC and evaluate the impact of tobacco control policies in collaboration with the WHO and the Centres for Disease Control and Prevention (CDC) (CDC, 2018). Within the GTSS, four international surveys contain tobacco data: the Global Health Professions Student Survey (GHPSS), the Global Youth Tobacco Survey (GYTS), the Global School Personnel Survey (GSPS), and the Global Adult Tobacco Survey (GATS).

3.1.1.1 The GHPSS

The GHPSS is a standardised survey of university students in their third year of study for degrees in health disciplines, such as nursing and dentistry (Yang et al., 2015). The GHPSS describes the respondents' attitudes and behaviours towards tobacco use and their demographic attributes, such as age and gender. The GHPSS was developed and implemented from 2005 to 2011 in schools among students in the health profession across 70 countries (Sreeramereddy et al., 2018). The survey is self-administered, anonymous, and contains standardised questions that all respondents answer. Additional questions were added that indicated the local way in which tobacco is consumed (Sreeramareddy et al., 2018). The GHPSS provides representative data at the national level. This survey aims to highlight the prevalence of tobacco use among young health professionals in specific regions, which could describe the respondent's attitudes and motivation to help mitigate the impact of tobacco use on public health. The GHPSS has helped shape these students' education by providing information about smoking cessation support (Yang et al., 2015).

One fundamental limitation of the GHPSS, which was found within all four surveys of the GTSS, is that the GHPSS was self-administered and was, therefore, influenced by response bias (Yang et al., 2015; Palipudi et al., 2013; Farshad et al., 2012). Moreover, the GHPSS scope is limited to students in specific disciplines. It leaves out students of other subjects, such as psychologists, who can educate patients on smoking cessation, meaning the survey may not be wholly representative (Warren et al., 2008). Additionally, the data obtained from this method was limited to third-year university students only and, thus, does not contain data on the majority of a country's population that this research aims to include. Moreover, a reliability study was carried out on the GHPSS in 2005, which was only implemented in the US at the time. Therefore, the reliability of the survey, since it has been conducted internationally, has not been fully gauged (Yang et al., 2015). Another limitation is the date on which the surveys were conducted. Most countries' GHPSS surveys were conducted from 2005 to 2007; this would be an out-of-date database to measure recent trends in tobacco use for this demographic. Nor were there any questions that provided insight into the determinants of tobacco use, so the data would not allow for the exploration of the associations with tobacco use (Warren et al., 2008). Consequently, the datasets from the GHPSS would not help address any of the aims of this research.

3.1.1.2 The GYTS

The GYTS, used in studies such as Reitsma et al. (2021) and Ng et al. (2014), provides systemic global surveillance of the tobacco epidemic amongst the young population, defined as those between the ages of 13 to 15 in schools (WHO, 2008b). By 2020, 181 countries have implemented the GYTS. The GYTS is anonymously self-administered and has been conducted since 1999 in five-year intervals (WHO, 2008b). The sample design of the GYTS produces cross-sectional estimates of tobacco use in students for a given country. The GYTS also attempts to identify regional-level stratification where possible (CDC, 2018). The survey questions on tobacco identify whether a student uses tobacco and how they use it, such as cigars, cigarettes, or chewing tobacco (WHO, 2018b). There are also country-specific questions that identify the local ways of tobacco use, such as bidis and kreteks, along with questions identifying the respondent's demographic information. This survey aims to supply data for the surveillance of tobacco use to enhance a country's ability to effectively implement or redesign tobacco control policies that reduce tobacco use among students (CDC, 2018).

The GYTS suffers from the same limitations as the GHPSS in that it has a limited scope of a specific demographic, with an age range of 13 to 15 in the GYTS. Moreover, the datasets may not be representative of the 13- to 15-year-olds in a given country as the survey was completed only by those who attend school (Itanyi et al., 2008). As with the GHPSS, the GYTS does not include data on the determinants of tobacco use (WHO, 2008b; GYTS Collaborating Group, 2003). Therefore, the datasets from this survey are also unsuitable for addressing the aims of this research.

3.1.1.3 The GSPS

The GSPS provides nationally representative tobacco use data from teachers and other school staff members who participated in a GYTS (WHO, 2008b). This survey, first used in 2000 and has since been implemented in 84 countries, attempts to identify the exposure of tobacco to students that would possibly undermine the student's education on the danger of tobacco and, thus, hinder the reduction of youthful smoking prevalence (GTSS Collaborative Group, 2006). The design of the GSPS includes the same tobacco-related questions as the GYTS, such as the age of tobacco use initiation and the respondent's level of tobacco dependency. The GSPS is self-administered by the teachers, with both student and teacher maintaining anonymity. Due to the flexibility of the framework of the GSPS and GYTS, country-specific questions can be asked about the specific type of local tobacco use within each country at the regional level (WHO, 2008b).

The GSPS is a unique survey within the GTSS, as even though the GSPS is a separate survey, it is conducted only at schools that participated in the GYTS. The GSPS has the same limitations as the GYTS, and consequently, it is dependent on the success of the GYTS (Farshad et al., (2012). Therefore, the GSPS is also not used to address the aims of this research.

3.1.1.4 The GATS

Unlike the previous three databases, the GATS surveys those aged 15 years and above (Palipudi et al., 2013). The GATS was first implemented in 2008 to represent tobacco use in the population aged 15 years and older in 14 low- and middle-income countries. By 2020, 33 countries, all of which are low- or middle-income, have implemented GATS (Asma et al., 2015). This survey uses a standardised survey framework that allows for cross-sectional comparisons of smoking between genders and rural and urban people between countries at the national level, with a minimum sample size of 4,000 with an equal portion between men and women, and rural and urban (GATS Collaborative Group, 2020). The questions at the core of this survey indicate the respondent’s tobacco use behaviour, along with demographic indicators (Palipudi et al., 2013). Similarly to the previous surveys discussed, optional questions can be added to each GATS in a country to adapt to the local tobacco use situation.

GATS datasets were found in Reitsma et al. (2021), Bashir et al. (2018), Lim et al. (2018), Ngaruiya et al. (2018), Hessami et al. (2017), Mbulo et al. (2016), Tee et al. (2016); Ng et al. (2014), Palipudi et al. (2014), Singh and Ladusingh (2014), Minh et al. (2012), and Palipudi et al. (2012) from the results of the literature search in the previous chapter. These studies used GATS datasets to estimate some determinants’ impact on tobacco use via multilevel logistic regression approaches. These studies acknowledged the usefulness of data from the GATS as it allowed researchers to compare data between countries over time due to the regular frequency of surveys in some countries. The minimum sample size of 4,000, however, is insufficient to truly represent subnational populations and has also been argued to be unrepresentative of a national population (Palipudi et al., 2013). The datasets from this survey may be helpful as they include several variables that cover specific determinants of tobacco use, such as educational attainment, marital status, and whether the respondent resides in a rural or urban environment. Some determinants, however, are not included, such as wealth and the number of children per household. Only 33 countries have conducted this survey, with only a few, such as India and Bangladesh, that have conducted the GATS more than once at regular intervals of about ten years (Asma et al., 2015). Consequently, the GATS is also unsuitable for addressing the research questions. It should be noted that the GATS datasets do allow for a cluster-level analysis of tobacco use. Although this data would not be able to address the fourth research question as the GTSS does not make available the GPS coordinates of the GATS clusters.

3.1.1.5 The International Tobacco Control Survey (ITC)

The ITC is a longitudinal household survey of tobacco use among men and women aged 15 years and older (Fong et al., 2006). It is designed to measure the behavioural impact of the implementation of tobacco control policies over time. The standardised ITC has been conducted in 31 countries and contains relevant variables that can represent the determinants of tobacco use (Kaii et al., 2022). The ITC has a multistage clustered sampling design and has been stratified by multiple spatial levels, from the cluster level to the regional level. The data was collected in one-to-one interviews. The sample sizes appear to vary, with some limited to around 5,000 and others almost as low as 1,000 (Nordin et al., 2022; Wu et al., 2010).

The ITC is not nationally representative as it has mainly been conducted in cities. The ITC has only recently collected data from rural areas, such as the ITC in China (ITC Project, 2017). Moreover, due to the longitudinal nature of the survey, the data is unlikely to be reliable for analysis at the sub-national level. No GPS datasets are provided from these surveys to conduct spatial analysis. Lastly, fewer than half of the countries that have conducted the survey are part of the Global South; therefore, there is only limited coverage. This would not provide a reliable overall picture of the variation in the prevalence of tobacco use within the Global South.

3.1.2 The Demographic and Health Survey (DHS)

The DHS provides nationally representative data on health indicators, including tobacco use behaviour among the adult population (ICF, 2020). The DHS is conducted in 112 countries, all of which are low- and middle-income countries (Fabic, Choi and Bird, 2012). The results of the literature search in the previous chapter found that the DHS was the source of tobacco use data for Reitsma et al. (2021), Magati et al. (2018), Okunna (2018), Nketiah, Afful-Mensah and Ampaw (2018), Sreeramareddy et al. (2018), Kwamena and Bright (2017), Sinha et al. (2016), Sreeramareddy and Pradhan (2015), Blecher et al. (2014), Ng et al. 2014, Khanal, Adhikari and Sujan (2013), John et al. (2012), and Ayo-Yusuf and Szymanski (2010). Eight updated phases of the DHS have been implemented over time since the Inner City Fund (ICF) implemented the first survey in 1984, with each occurring in overlapping phases of either five or six years. The fourth, fifth, sixth, seventh and eighth phases of the DHS, from 1997 to present, contain data on tobacco use within the Global South.

The DHS has a two-stage cluster design: Enumeration Areas (EA), usually collected from country census data, and a sample of households surveyed in each EA within a country. The DHS data is sub-nationally and nationally representative within countries and of rural and urban populations. The population-based data provided by the DHS initially focused on highlighting fertility, contraception, and maternal health. More recently, the DHS evolved to include a broader range of questions that cover more adult health topics (Corsi et al., 2012). This also includes data that covers tobacco use and the associated determinants of tobacco use that have been discussed within the literature review chapter.

Unlike the surveys within the GTSS and the ITC, the DHS has considerably more data on tobacco use and the associated determinants within countries of the Global South, covering a more extended period of time (Corsi et al., 2012). The DHS is possibly a more reliable data source than the data collected in the GTSS, as the DHS is conducted by interviewers who have completed a training process of high quality rather than being self-administered. The greater reliability of the data collected allows for a more accurate picture of the tobacco use landscape within the Global South. In addition to this, the data collection framework is standardised across all countries and has remained consistent each time a DHS is conducted. Although additional questions have been added over time to cover more health topics, the standardisation of the DHS provides researchers with data that can be used in a comparative cross-sectional analysis at different points in time. Moreover, the DHS data collection method allows researchers to use the data in multilevel logistic regression analysis to create estimates of prevalence rates at different spatial levels, as the data can be stratified from the household level to the country level. Unlike the surveys within the GTSS and the ITC, the DHS supplies GPS datasets for some of the DHS surveys that can be used for additional small-area level spatial analysis of the variation of tobacco use.

3.1.3 The selected dataset source: the DHS

This review has identified that the DHS provides the most suitable datasets to address the thesis research; the DHS datasets can be used to explore the significance of the associations of tobacco use and the associated determinants at multiple spatial levels for the first research question. For some Global South countries, the DHS datasets are obtained more than once, which helps find the change in the importance of the determinants of tobacco use over time for the second research question. Country-level data can also easily be linked to the DHS. Lastly, the DHS has a suitable coverage of populations across countries and provides the location of clusters where data was recorded; thus, it can be used to investigate the variation of tobacco use within Global South countries for the fourth research question. Table 2 summarises the findings of the review of candidate datasets.

Table 2. Summary of candidate survey characteristics.

Survey	Number of countries surveyed	Minimum sample size	Sample focus	Spatial focus	Survey dates (oldest, newest)	GPS coordinates for cluster locations
GHPSS	70	N/A	University students	Schools	2005, 2011	No
GYTS	181	N/A	School children	Schools	1999, 2024	No
GSPS	84	N/A	School children	Schools	2000, 2024	No
GATS	32	4,000 respondents	adults	National	2008, 2023	No
ITC	31	1,000 respondents	adults	Selected cities	2002, 2022	No
DHS	112	5,000 households	adults	Local	1984, 2024	Yes

3.2 Investigating the metadata of common DHS variables

This section indicates the common variables within the DHS datasets across multiple DHS phases that represent tobacco use and the associated tobacco use determinants. The section assesses the suitability of the variables chosen, including their potential for comparison across datasets and over time. Although Corsi et al. (2012) stated that the DHS is standardised across all the datasets, this investigation is necessary to check and identify datasets that are missing essential data for this research.

Phases four, five, six, and seven of the DHS are used as they include tobacco use questions. At the time of writing, no phase eight of the DHS was available. Publicly available DHS datasets provide recoded files as raw data, which is inconvenient for analysis because some questions are repeated. The recoded files are labelled as births recode, couples recode, household recode, individual recode (consisting of data for women only), children's recode, men's recode, and household member recode. Some of these datasets are missing, particularly from the older DHS phases when the DHS focused primarily on women. This research only uses surveys with the individual recode files of women and men. This is because these files represent each respondent as an individual case in the survey dataset, whereas other recode files have multiple people in each case.

3.2.1 Tobacco use variables

The DHS four was conducted between 1997 and 2003 and contains nine variables associated with tobacco use (ICF, 2008). Variables in DHS four cover the basics of smoking tobacco but appear to lack variables dedicated to representing forms of smokeless tobacco. The variables described as country-specific, or the variable for “other tobacco”, could provide data on smokeless tobacco use. These variables could also provide a better understanding of the local differences in how tobacco is consumed, such as Kreteks and chewing tobacco, that are more specific in certain countries than the widespread popularity of cigarette use.

The DHS five, conducted between 2003 and 2008, has ten variables related to tobacco use (ICF, 2012). The additional V463X variable labelled as “smokes other” would help identify responders who smoke but do not already categorise themselves as using other forms of tobacco.

The DHS six, conducted between 2008 and 2013, also has ten variables related to tobacco use (ICF, 2013). Variables V463C, V463D, and V463E, however, were set as chewing tobacco, using snuff, and smoking cigars, respectively, instead of being generalised as country-specific. DHS six added variables representing smokeless tobacco use, which appears unrepresented in DHS four and DHS five.

The DHS seven, conducted between 2013 and 2018, started to include more questions relating to tobacco use, providing up to 17 variables related to tobacco use (ICF, 2018). The variable V463D from the previous DHS is broken down into two variables (V463D and V463H) in DHS seven, which provided specific information on whether the respondent snuffs by nose or mouth. Although additional information on types of tobacco use is essential to capture a reliable picture of the tobacco use landscape, the DHS seven appears to have switched the meaning of the variable V463E to represent kreteks instead of it representing cigars as it did in the previous DHS six. Table 3 summarises the tobacco variables available across these DHS datasets.

Table 3. The tobacco use variables that are present in Phases 4, 5, 6 and 7 of the DHS.

Variable name	**Variable description**			
	DHS 4	**DHS 5**	**DHS 6**	**DHS 7**
V463A	Smokes cigarettes	Smokes cigarettes	Smokes cigarettes	Smokes cigarettes
V463B	Smokes with a pipe	Smokes with a pipe	Smokes with a pipe	Smokes with a pipe
V463C	Other tobacco	Other tobacco	Chewing tobacco	Chewing tobacco
V463D	Country specific	Country specific	Uses snuff	Snuff by nose
V463E	Country specific	Country specific	Smokes cigars	Smokes Kreteks
V463F	Country specific	Country specific	Country specific	Smokes cigars
V463G	Country specific	Country specific	Country specific	Uses a water pipe
V463H	N/A	N/A	N/A	Snuff by mouth
V463I	N/A	N/A	N/A	Uses betel quid
V463J	N/A	N/A	N/A	Country specific
V463K	N/A	N/A	N/A	Country specific
V463L	N/A	N/A	N/A	Country specific
V463X	N/A	Smokes other	Smokes other	Smokes other
V463Z	Does not smoke	Does not smoke	Does not smoke	Does not smoke

Cigarette smoking is the dependent variable of my research due to the consistency of cigarette smoking data (variable V463A) and the prevalence of this specific type of tobacco use, acknowledged by both the WHO (2019) and the trends in the DHS data. Although this excludes other forms of tobacco use, including them would likely cause some unreliability in the results due to the varying social, cultural, and geographical differences associated with each type of tobacco use.

3.2.2 Demographic variables

3.2.2.1 Number of children

Two variables indicate the number of children in the household, which are named V202 and V203. The former indicates the number of sons the respondent has living at home, and the latter indicates the number of daughters the respondent has living at home. When the data was cleaned, an additional variable was created to represent the total number of children living at the respondent's home. In doing so, the analysis can investigate both the associations between the number of children in a household of the respondent and the respondent's tobacco use.

3.2.2.2 Gender

There is no such gender variable in the DHS recode, as men and women are separated into two files. As such, a dummy variable was created in each male and female dataset so that the analysis could differentiate between the male and female data records when the datasets merged.

3.2.2.3 Age

Only two variables within each DHS identified the respondents' age in the years they completed the survey. The first variable, V012, is a continuous variable that identifies how many years old the respondent is. The second variable, V013, is a categorical variable that groups the age of the respondents into five-year groups. This research uses V013 to help answer research question one to allow for a more efficient cross-tabulation analysis in investigating the associations with tobacco use, which can identify the nature of any non-linear associations between age and smoking. This research uses V012 to help answer research question two to investigate how the likelihood of smoking changes with an increase in age. This variable could also be squared to investigate possible non-linearities associated with age.

It should be noted that the DHS datasets of women have an age range of 15 to 49, whereas most of the datasets for males have an age range of 15 to 59, and a few datasets have a range of 15 to 54. To avoid potential data loss when merging the datasets with fewer age categories, during the data cleaning process using R, all male and female datasets contained five-year groups ranging from 15 to 59 within V013.

3.2.2.4 Marital status

The variable within the DHS that indicates the respondent's marital status is V501. This variable has options for the respondent to be either of the following: never in a union, married, living with a partner, widowed, divorced, or no longer living together/separated. This is standardised in both the male and female datasets throughout the DHS.

3.2.3 Socioeconomic variables

3.2.3.1 Education

Three variables within the DHS identify the respondent's level of education. Variable V106 indicates the highest level of education attained, variable V107 indicates the number of years the respondent has been in education, and variable V149 indicates the respondent's level of education, complete or incomplete. This research uses variable V106, which has categories representing no education, primary, secondary, and higher, to provide a simpler variable for analysis.

3.2.3.2 Employment status

The variable of interest to represent employment status is V714, which indicates whether the respondent is employed. Another variable, V732, identifies how often the respondent works in the following categories: temporary, occasional, seasonal, and all year. This variable, however, has more missing data than V714, and the additional categories would add complexity to an already complex set of variables for modelling.

3.2.3.3 Income

No variables within the DHS directly identify a respondent's income. There is, however, an alternative. The wealth index was introduced to the DHS around the same time as data on tobacco use. The wealth index represents a household's cumulative living standard (DHS, 2020). This considers what amenities and commodities are in a household and the accessibility to water. The DHS has two categorical variables, V190 and V190A, that indicate the respondent's wealth index. V190A is a separate wealth index that takes account of households in rural or urban settings. This was made in response to V190 possibly being too focused on living standards in urban environments specifically. V190, however, is used instead of V190A in this research as this variable is nationally standardised and so represents common indicators of the wealth of all households within a country (DHS, 2008).

3.2.4 Place variable

The variable V025 is used to identify the type of environment the respondent lives in. This categorical variable identifies whether the respondent resides in a place that is considered rural or urban. The interviewer, not the respondent, inputs the data for this variable. This decision is based on whether the data collection point is within an area defined as a rural or urban setting.

3.3 Selected countries

According to Clarke (2018), the term 'Global South' refers to the group of countries considered low- or middle-income countries. Therefore, the World Bank (2020) has defined 167 countries as part of the Global South. 81 countries out of the 167 Global South countries have DHS datasets available from phases four to seven. The stages taken in the data selection method can be seen in the consort diagram in Figure 4.

Two datasets (male and female) and a corresponding GPS dataset make up the complete DHS survey requirement for a country. A survey was removed if it did not include tobacco use data and all variables of interest. Surveys without GPS datasets were not removed but separated from complete DHS surveys as they could still be used for analysis where GPS data was not needed.

Stage one of the consort diagram indicates 521 male, female, and GPS datasets available to download from DHS four, five, six, and seven. Of these datasets, 137 are GPS datasets, and 364 are male and female datasets. The remaining stages of this consort diagram identify which surveys are fully viable for this research.

Stage two removes 64 female datasets that are missing a corresponding male dataset. These were removed as male datasets are needed to investigate the research questions. The 22 GPS datasets that provide spatial data for surveys missing a male dataset were also removed. This stage resulted in finding 150 complete surveys containing male and female datasets and 115 GPS datasets that provide spatial data for some of the remaining datasets.

Stage three removes 87 complete surveys missing data on tobacco use and variables of interest, such as the wealth index, within the male or female datasets. 55 of these 87 surveys have corresponding GPS datasets, and so these 55 GPS datasets were also removed. At the end of this stage, there are 63 complete surveys, each providing data on both males and females in a country, with 60 relevant GPS datasets also remaining.

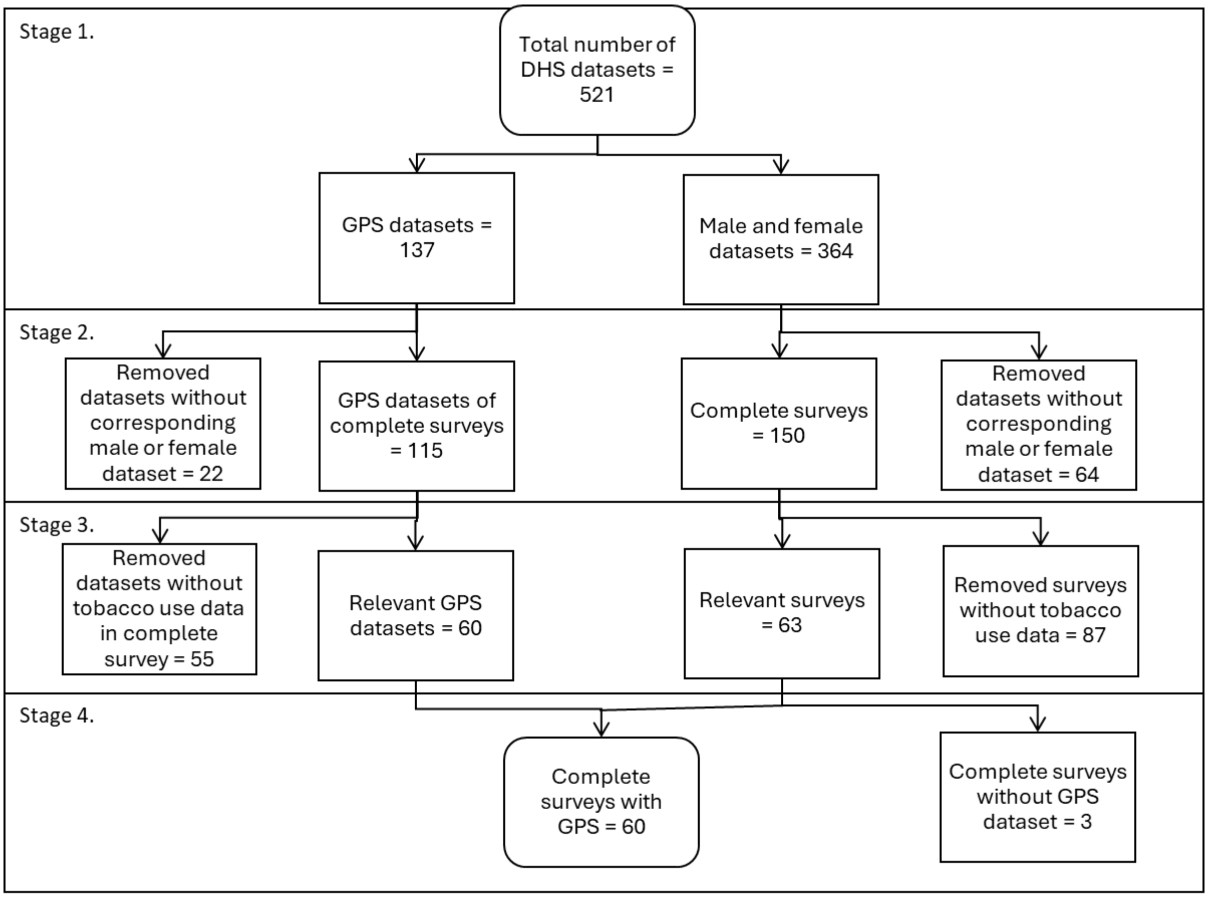

Figure 4. The data selection process that identifies complete surveys that contain data on tobacco use and the determinants of tobacco use.

The remaining 63 surveys represent 40 of the original 81 countries, with data from phases four to seven and data from 41 countries removed throughout the four stages of the data selection method. Of these remaining 40 countries, 24 have only one complete survey available, nine have two complete surveys available, and seven have three complete surveys available. Table 4 identifies the number of surveys in the selected countries, the years in which the surveys were conducted, and the sample sizes. The countries with multiple surveys have a time interval of five to six years between each survey. The three surveys that do not have GPS datasets are for Indonesia.

Table 4. The selected countries and the year in which surveys were conducted, along with the surveys sample size.

Country	Year of survey	Sample size
Angola	2015	20,063
Benin	2011	21,779
Burkina Faso	2010	24,357
Burundi	2010	13,661
Cambodia	2010	26,993
	2014	22,758
Cameroon	2011	22,617
Comoros	2012	7,496
Cote d'Ivoire	2011	15,195
DRC[1]	2013	27,483
Eswatini	2006	9,143
Ethiopia	2005	20,103
	2011	30,625
Gabon	2012	14,076
Ghana	2003	10,706
	2008	9,479
	2014	13,784
Guatemala	2014	37,059
Guyana	2009	8,518
Haiti	2012	23,780
Honduras	2011	29,877
India	2015	234,472
Indonesia	2007	41,653
	2012	54,913
	2017	59,636
Kenya	2003	11,773

[1] DRC is an abbreviation of the Democratic Republic of the Congo.

Country	Year of survey	Sample size
	2008	11,909
	2014	27,530
Lesotho	2004	9,892
	2009	10,941
	2014	9,552
Liberia	2007	13,101
	2013	13,357
Madagascar	2008	25,961
Malawi	2004	14,959
	2010	30,195
Mali	2012	14,823
Mozambique	2011	17,780
Myanmar	2015	17,622
Namibia	2006	13,719
	2013	14,499
Nepal	2006	15,190
	2011	16,795
Nigeria	2003	9,966
	2008	48,871
	2013	56,307
Philippines	2003	18,399
Rwanda	2005	16,141
	2010	20,000
	2014	19,714
Senegal	2010	20,617
Sierra Leone	2008	10,654
	2013	23,920
Tanzania	2010	12,666
Timor-Leste	2009	17,213

Country	Year of survey	Sample size
Togo	2013	13,956
Uganda	2000	9,208
	2006	11,034
	2011	10,969
Zambia	2007	13,646
	2013	31,184
Zimbabwe	2005	16,082
	2010	16,651

3.4 Analytical strategy

The analysis conducted in this thesis uses the DHS data explored in this chapter and proceeds sequentially through the thesis research aims. The first empirical chapter focuses on the individual and small-area determinants using a binomial four-level multilevel model. A multilevel modelling approach was chosen because, as discussed earlier in the conceptual framework section, multilevel modelling has become a standard approach in health geography and social epidemiology for analyses seeking to examine place effects. While alternative approaches, such as fixed effects modelling and generalised estimating equations (Huang, 2016; Subramanian and O'Malley, 2010), were considered, they were ultimately rejected. The fixed effects modelling approach would result in over-parameterised and uninterpretable models with excessive fixed terms to effectively capture area variability, while generalised estimating equations were rejected as cluster and region membership are known in the DHS data.

The same rationale also informed the choice to use multilevel models in the second empirical chapter, where the analysis shifts to examine change over time with respect to determinants at the country level, addressing the second and third thesis objectives. The inclusion of time and country-level determinants adds novelty to the analysis, extending beyond what is offered in the context of the Global South.

The final empirical chapter focuses on small-area estimations, addressing the final thesis objective and exploring within-country spatial heterogeneity in smoking prevalence. The chapter employs a geostatistical approach to small-area estimation rather than approaches using multilevel models (Twigg, Moon, and Jones, 2000) or microsimulation (Smith, Pearce, and Harland, 2011). Although these alternative approaches have been used to explore local geographies of smoking, their data requirements are not fully compatible in the Global South context. A more detailed discussion of methods is provided in the respective empirical chapters.

3.5 Conclusion

Using secondary data within research is an inexpensive and time-efficient approach to meet the scale of the data needed for statistical analysis (Cheng and Philips, 2014). As with all secondary data, however, the original aim of the data collection process usually does not completely align with the aims of the research it is used in. Therefore, care must be given when choosing the data so that the data is correctly used and understood in the analysis. With DHS datasets from only 40 Global South countries selected, the results of this research cannot be said to represent all of the Global South. This is most obvious in South America, with only four countries (Guatemala, Guyana, Haiti, and Honduras) that provide relevant DHS datasets.

An additional limitation is that although the DHS surveys may have standardised questions, the way in which some answers are recorded is not always standardised. For example, the names of regions within countries have been found, in some cases, to be spelt differently between male and female datasets, which would make comparisons more difficult. Moreover, some of the options in the categorical variables are misspelt. Checking on the spelling in the datasets limits this issue.

Notwithstanding the selected dataset’s limited representation of the Global South and the issues with spelling or different languages used in the results, reasonable inferences are still made from the results generated from this research and can suggest what the tobacco use landscape may look like in countries that have no data available. To this end, the data limitations emphasise the importance of filling in the data gaps of tobacco use within the Global South with a standardised data collection approach to build upon the results of this investigation.

Chapter 4 Investigating the determinants of cigarette smoking in the Global South: a multilevel analysis

4.1 Abstract

Tobacco use is one of the main burdens on global public health. Little is known about the extent to which social determinants of smoking vary in their effect across the Global South. Understanding these associations would highlight key determinants of smoking within countries that can be used to identify areas that could have a higher likelihood of smoking.

Demographic and Health Survey (DHS) datasets from 39 Global South countries were used. Each dataset had data on cigarette smoking and variables that indicate determinants of smoking found in the literature (gender, age, marital status, number of children in the home, educational attainment, employment status, wealth index, and type of place). Individual, household, cluster, and region DHS identifiers enabled binomial logistic multilevel analysis of these associations. Global and Local Moran's I statistics were generated to identify any grouping of residuals in the sampling cluster units that could indicate spatial autocorrelation where other factors influence smoking prevalence that are not included in the model.

In most countries, people who are male, older, single, had fewer children, had less education, were employed, less wealthy, and who lived in urban areas were more likely to smoke. There are some countries whose people who are married, unemployed, or who live in rural areas are more likely to smoke, contradicting the general Global South associations. Spatial autocorrelation statistics identify statistically significant clustering of cluster-level residuals (P <0.01) in Kenya, Nigeria, and Timor-Leste.

This research finds that not all countries in the Global South conform to expectations regarding the associations with social determinants of smoking. Some local level variation is left unexplained by the standard determinants, highlighting a need for additional data collection. Further research is needed to examine the change of these associations over time to draw more reliable conclusions on the current and future relationships so that the allocation of tobacco control resources can adjust accordingly.

4.2 Background

The tobacco epidemic is one of the biggest problems for public health (WHO, 2021). The WHO states that the tobacco epidemic kills over 8 million people a year globally, either by direct use or via second-hand smoke. The ill-health that is brought about by tobacco use kills half of all long-term tobacco users. As of 2023, there were estimated to be around 1.3 billion tobacco users worldwide (WHO, 2023).

There has been a gradual decline in global tobacco use, from 22.5% in 2007 to 19.2% in 2017 (WHO, 2019a). This decline may indicate that recent tobacco control initiatives are making an impact. The rate of decline, however, is slow and will not be sufficient to reach the WHO FCTC target of a 30% reduction of tobacco users by 2025 (WHO, 2018a). Moreover, the decline in global tobacco use masks an increasingly unequal distribution of tobacco users between countries, 80% of whom are currently living in the Global South (WHO, 2023). These countries saw a 47% increase in tobacco use from 1970 to 2000 (Pampel, 2008). High-income countries, in contrast, saw a 14% decrease in tobacco use during the same period. More recently, tobacco use in Africa grew by 60% and declined in Europe by 26% from 1990 to 2009 (American Cancer Society, 2018).

To reduce tobacco use in Global South countries, it is important to understand the demographic and social determinants of tobacco use in the Global South. This is because having a comprehensive understanding of these associations, such as that between gender and smoking in the SETM, where men are significantly more likely to smoke than women (Lopez et al., 1994), could help tailor tobacco control policies to improve the targeting of the limited resources to specific population groups that are more vulnerable to tobacco use. There is, however, a lack of research within the Global South context, which has been noted as a ‘research desert’ compared with the sizable volume of literature that has investigated the significance of the determinants in high-income countries (Mamudu et al., 2018). As such, the determinants of tobacco use prevalence have yet to be fully defined in Global South countries (Owusu-Dabo et al., 2009).

There are both commonalities and contradictions in the existing research on tobacco use in the Global South. A common theme is that men are significantly more likely to use tobacco than women (WHO, 2019a; ASH, 2019; Ghani et al., 2012; Khattab et al., 2012; Hitchman and Fong, 2011; Nejjari et al., 2009; Yang et al., 2006; Lopez et al., 1994). Tobacco use also appears to be more associated with younger age groups (ASH, 2019; West, 2017; Xi et al., 2016). According to Magati et al. (2018), however, older people were more likely to use tobacco in Kenya. Generally, those who are single are more likely to use tobacco (Magati et al., 2018; Marinho et al., 2008;

Meyler, Stimpson and Peek, 2007), although Jarallah et al. (1999) noted that it is a possibility that married people in Saudi Arabia, males especially, are more likely to use tobacco. The number of children in the home has a more tentative link with tobacco use, with no clear consensus on whether children in a household lead to a greater chance of the parent using tobacco (Arouri et al., 2017; Chassin et al., 2002).

The literature, in most cases, shows that those who have less formal education have a greater chance of using tobacco (Fernando et al., 2019; Rajabizadeh et al., 2011; Lin, 2010; Marinho et al., 2008; Siahpush et al., 2008). Ahmed et al. (2008), however, noted that there were individuals in higher education in Pakistan who used tobacco more. The association between employment status and tobacco use in the Global South is less clear as there is literature that shows a higher rate of tobacco use among the unemployed (Fernando et al., 2019; Lin, 2010; Ding et al., 2009; Marinho et al., 2008), and other literature that shows a higher rate of tobacco use among the employed (Abdelwahab et al., 2016; Cheah and Naidu, 2012). The literature on the association of wealth with tobacco use in the Global South is clearer: less wealth leads to a higher likelihood of tobacco use (Marinho et al., 2008; Subramanian et al., 2004; Rani et al., 2003; Steyn et al., 2002; Gilmore, McKee, and Rose, 2001). Rural areas, rather than urban areas, also tend to be associated with higher rates of tobacco use (Kusumawardani et al., 2018; Shikha et al., 2014; Sreeramareddy, Pradhan and Sin, 2014a; Alam et al., 2008). Gurung et al. (2016), however, find that urban areas within Bhutan have a higher smoking prevalence than rural areas.

The commonalities and contradictions surrounding the determinants of tobacco use in the Global South present a knowledge gap that needs to be addressed. This chapter aims to identify key themes in the associations of the determinants of tobacco use across the Global South by modelling available tobacco use and determinant datasets. It steps beyond single-country studies to offer a comparative multi-country study providing insight into the extent to which determinants influence tobacco use differently across the Global South.

4.3 Methodology

4.3.1 Data

This chapter uses data from the DHS on smoking behaviour and variables capturing the determinants of smoking (ICF, 2004-2017). The DHS are nationally representative household surveys conducted approximately every three to five years. It contains data on health and development indicators from countries in the Global South. The DHS usually include a men's dataset, an individual (women's) dataset, and a GPS dataset. The GPS datasets record the centroid location of the primary sampling units, referred to as clusters. Knowledge of cluster locations facilitates the identification of localised impacts on smoking prevalence. To boost the anonymity of respondents, the GPS coordinates are displaced by up to two kilometres in urban areas and up to five kilometres in rural areas (Burgert et al., 2013).

The most recent DHS surveys from 39 Global South countries, defined as such by the World Bank (2020), were initially selected (Table 5). Included surveys featured a men's dataset, an individual (women's) dataset, and a GPS dataset. The data collection date for the selected DHS surveys varies by country, with the oldest data collected in 2003 and the newest data collected in 2017. All selected DHS datasets include a binomial variable for cigarette smoking. This is used as the dependent variable as this is the most common type of tobacco use (WHO, 2023). The chosen independent variables were gender, age, marital status, the presence of sons and daughters at home, education, employment status, wealth index, and type of place (rural and urban). These are standard determinants of smoking, as identified in the literature. The wealth index acts as a proxy for income, as income is not included in the DHS datasets. The wealth index measures the ownership of assets, which is important in expressing the relative differences in socioeconomic status (Rutstein and Kiersten, 2004).

Variables indicating a respondent's household, cluster, and region were also collected. Using these variables allowed for an analysis of geographical variations in cigarette smoking behaviour at different spatial scales and ensured that the analysis took account of the cluster-randomised design of the DHS.

The selected male and female datasets of the DHS were aggregated and cleaned using R programming (R Core Team, 2020a), using the foreign (R Core Team, 2020b), dplyr (Wickham et al., 2020), and haven packages (Wickham and Miller, 2020), to create a uniform dataset format with compatible variable definitions across countries. For instance, the categories in the marital status variable were aggregated into either 'living with partner' or 'single'. Data on the number of sons and daughters at home variables were aggregated to represent the total number of children that live at home.

Little's (1988) Missing Completely at Random tests (MCAR) were conducted to investigate patterns in missing data. The MCAR test was significant for India and Namibia, indicating that the missing data is not random and may be biased. As such, India and Namibia were removed from this research, leaving a working database of 37 countries. The MCAR test was insignificant for the remaining countries, indicating randomness in the missing values. For these countries, cases with missing values were removed from the datasets (Table S 1 in Appendix A).

4.3.2 Descriptive statistics

Information is provided on the most recent DHS survey for each country used in this chapter, along with the corresponding sample sizes and descriptive statistics on all of the variables with smoking across all surveys. Using IBM SPSS Statistics 27 software (2020), weighted regional cigarette smoking prevalence rates were calculated using the survey weights supplied within each DHS dataset. These weights were used as a household's probability of being selected is not constant throughout each survey. The weighted data minimises the impact of survey bias and improves the accuracy of population representation. These weighted values were then aggregated to calculate the total of men and women who smoke cigarettes within each region, which, in turn, were mapped using ArcMap Version 10.8 software to illustrate the variation of cigarette smoking prevalence at the subnational level (Esri, 2020).

4.3.3 The models

The independent variables and spatial levels control the non-uniform probability of being selected for the surveys. As such, the multilevel models developed in this chapter are unweighted. A binomial multilevel regression model is adopted as this research measures the likelihood that an individual is a cigarette smoker whilst accounting for the hierarchal nature of the dataset. MLwiN Version 3.04 software was used to produce models for each country and to identify the extent of the variance of cigarette smoking between each of the spatial levels (Charlton et al., 2019). The model generated results using Iterative Generalised Least Squares (IGLS). Other Markov Chain Monte Carlo (MCMC) and bootstrapping methods could also be used, but these are more computationally intensive. IGLS is preferred as a simpler method for reproducibility, and the sample size is suitable at the country and regional levels. The statistics created by the model, described in the equation below, include a logit for the constant (β_0); the variance of smoking at the regional (f_{0l}), cluster (v_{0kl}), and household levels (u_{0jkl}), with the individual level (*i*) constrained to 1; and the logits for the categories of the independent variables ($\beta_{1\ldots21}$). The model was built up by adding each independent variable separately to identify the extent to which they influence the model. The constant (β_0) for the full model represents a woman, aged between 15 and 19, single, with no children at home, no education, unemployed, in the poorest wealth index category, and living in an urban environment.

$$\begin{aligned} smokes_{ijkl} = {} & \beta_0 + \beta_1 gender_{ijkl} + \beta_{(2\ldots10)} age_{ijkl} + \beta_{11} marital\ status_{ijkl} + \beta_{12} children_{ijkl} \\ & + \beta_{(13\ldots15)} education_{ijkl} + \beta_{16} employment\ status_{ijkl} + \beta_{(17\ldots20)} wealth\ index_{ijkl} \\ & + \beta_{21} place_{ijkl} + f_{0l} + v_{0kl} + u_{0jkl} \end{aligned}$$

Bosker's and Snijder's (1999) R-squared formula was used to identify which country has the poorest or best fit in the model.

4.3.4 Spatial autocorrelation analysis

Global Moran's I and local Moran's I statistics are spatial autocorrelation tools in ArcGIS, which were used to assess residual clustering at the small area level (Moran, 1950; Anselin, 1995). Standardised residuals of the full model were calculated using MLwiN at the cluster level. These residuals indicate whether the model has under- or over-predicted cigarette smoking in specific locations. Spatial autocorrelation analysis assesses the statistical significance of clustering of residuals, compared to a random distribution, and can suggest that other unmeasured risk factors influence smoking.

Global Moran's I statistics describe clustered, random, or dispersed patterns among the residuals of clusters of each country (Moran, 1950). The global Moran's I values that are generated identify the extent to which clusters within each country differ from surrounding clusters. A global Moran's I value closer to -1 indicates the dispersion of positive or negative residuals around opposing values; a value closer to zero suggests a spatially random assortment of residuals with no clustering; a value closer to +1 shows significant clustering of residuals of similar values. The local Moran's I statistic identifies areas with statistically significant clustering in the residuals (Anselin, 1995). Local Moran's I index values identify areas where residuals with above-average values are concentrated (high-high) and areas where residuals with below-average values are concentrated (low-low). This shows areas where the model underestimates or overestimates smoking prevalence, respectively.

To conceptualise the spatial relationships of the residuals with global and local Moran's I, an inverse distance method was used in ArcGIS (Charlton et al., 2019). Doing so allows each residual to potentially be a neighbour of any other residual in that dataset, with a minimum distance calculated to allow each residual to have at least one neighbour.

4.4 Results and Discussion

Table 5 shows the names of 37 countries included in this analysis, including the year when the recording began, the number of respondents, and the weighted proportion of cigarette smokers in each country. Nationally, the prevalence of cigarette smoking among the respondents is lower in Benin at 2.12% and higher in the Philippines at 19.03%.

Table 5. The proportion of respondents in each survey that smoke cigarettes in each sampled country.

Country (year of survey)	Number of respondents	
	Smokes cigarettes (%)	Total respondents
Angola (2015)	1109 (5.53)	20,063
Benin (2011)	461 (2.12)	21,779
Burkina Faso (2010)	1494 (6.13)	24,357
Burundi (2010)	582 (4.26)	13,661
Cambodia (2014)	2106 (9.25)	22,758
Cameroon (2011)	1161 (7.95)	14,600
Comoros (2012)	497 (6.67)	7,447
Cote d'Ivoire (2011)	1229 (8.12)	15,136
DRC[2] (2013)	1931 (7.05)	27,411
Eswatini (2006)	635 (6.97)	9,117
Ethiopia (2011)	1721 (5.63)	30,582
Gabon (2012)	1669 (11.90)	14,020
Ghana (2014)	258 (1.87)	13,773
Guatemala (2014)	2727 (7.37)	37,026
Guyana (2009)	1194 (14.15)	8,439
Haiti (2012)	1358 (5.72)	23,757
Honduras (2011)	2028 (6.80)	29,837
Kenya (2014)	2221 (8.07)	27,520
Lesotho (2014)	1203 (12.59)	9,552
Liberia (2013)	541 (4.06)	13,323
Madagascar (2008)	2552 (14.91)	17,116
Malawi (2010)	1358 (4.51)	30,127
Mali (2012)	738 (4.98)	14,823
Mozambique (2011)	952 (5.35)	17,780

[2] DRC is an abbreviation of the Democratic Republic of the Congo.

Country (year of survey)	Number of respondents	
	Smokes cigarettes (%)	Total respondents
Myanmar (2015)	1870 (10.62)	17,615
Nepal (2011)	2451 (14.59)	16,794
Nigeria (2013)	1226 (2.19)	55,870
Philippines (2003)	3496 (19.03)	18,368
Rwanda (2014)	678 (3.45)	19,678
Senegal (2010)	784 (3.80)	20,615
Sierra Leone (2013)	2684 (11.25)	23,853
Tanzania (2010)	489 (3.87)	12,625
Timor-Leste (2009)	3119 (18.13)	17,204
Togo (2013)	473 (3.39)	13,941
Uganda (2011)	373 (3.40)	10,959
Zambia (2013)	3084 (9.92)	31,079
Zimbabwe (2010)	1616 (9.71)	16,651

Table 6 provides a further overview of the demographics of the respondents in all the surveys used for this chapter to summarise the population characteristics. The table shows that, in general, smoking is greater among men, older people, and people in rural areas who are less educated, poorer, have more children, are employed, and are married. These generalisations obscure the substantial differences between countries, as shown in later analysis.

Table 6. Descriptive statistics of the independent variables and cigarette smoking in the dataset.

		Smokes cigarettes		Total
		No (%)	Yes (%)	
Total		685,188 (92.7)	54,068 (7.3)	739,256
Gender	Female	493,277 (98.6)	6,865 (1.4)	500,142
	Male	191,911 (80.3)	47,203 (19.7)	239,114
Age group	15 to 19	154,534 (97.7)	3,619 (2.3)	158,153
	20 to 24	121,954 (94.5)	7,130 (5.5)	129,084
	25 to 29	110,536 (92.6)	8,813 (7.4)	119,349
	30 to 34	91,462 (91.5)	8,520 (8.5)	99,982
	35 to 39	78,588 (90.5)	8,217 (9.5)	86,805
	40 to 44	61,890 (89.7)	7,099 (10.3)	68,989
	45 to 49	52,108 (89.1)	6,389 (10.9)	58,497
	50 to 54	8,443 (75.0)	2,819 (25.0)	11,262
	55 to 59	5,402 (79.4)	1,401 (20.6)	6,803
	60 to 64	271 (81.6)	61 (18.4)	332
Place	Urban	259,600 (93.4)	18,387 (6.6)	277,987
	Rural	425,588 (92.7)	54,068 (7.3)	461,269
Education	No education	167,051 (93.2)	12,097 (6.8)	179,148
	Primary	241,430 (91.7)	21,844 (8.3)	263,274
	Secondary	234,221 (93.1)	17,260 (6.9)	251,481
	Higher	42,486 (93.7)	2,867 (6.3)	45,353
Wealth Index	Poorest	130,787 (90.6)	13,620 (9.4)	144,407
	Poorer	128,979 (91.8)	11,466 (8.2)	140,445
	Middle	132,841 (92.7)	10,430 (7.3)	143,271
	Richer	137,477 (93.6)	9,437 (6.4)	146,914
	Richest	155,104 (94.4)	9,115 (5.6)	164,219
Number of children[3]	0	274,703 (92.7)	21,525 (7.3)	296,228
	1	109,621 (93.5)	7,656 (6.5)	117,277

[3] Number of children has been categorised for the purpose of this table only.

		Smokes cigarettes		Total
		No (%)	Yes (%)	
	2	100,118 (92.7)	7,889 (7.3)	108,017
	3	78,736 (92.6)	6,301 (7.4)	85,037
	4+	122,010 (91.9)	10,687 (8.1)	132,697
Marital status	Not married	271,872 (94.2)	16,815 (5.8)	288,687
	Married	413,316 (91.7)	37,253 (8.3)	450,569
Employment status	Not employed	262,142 (97.1)	7,840 (2.9)	269,982
	Employed	423,046 (90.1)	46,228 (9.9)	469,274

The weighted sub-national spatial variance of the prevalence of cigarette smoking has been mapped, showing the Americas (a), Africa (b), and Asia (c) regions of the Global South in Figure 5. This provides further insight into the substantial variation of cigarette smoking prevalence within each country during data collection. Comparisons between countries must, however, consider the year the data was collected. (a) shows a higher smoking prevalence in Guyana in South America, with a relatively lower smoking prevalence in Central America. (b) shows a more significant variation in smoking prevalence, with higher rates found more in the East of Africa, such as in Madagascar and Ethiopia. (c) shows high prevalence rates throughout Nepal and the Philippines, with more variation in Myanmar and Cambodia. The reliability of these cross-region comparisons is limited due to the gaps in time in which data for each country was collected.

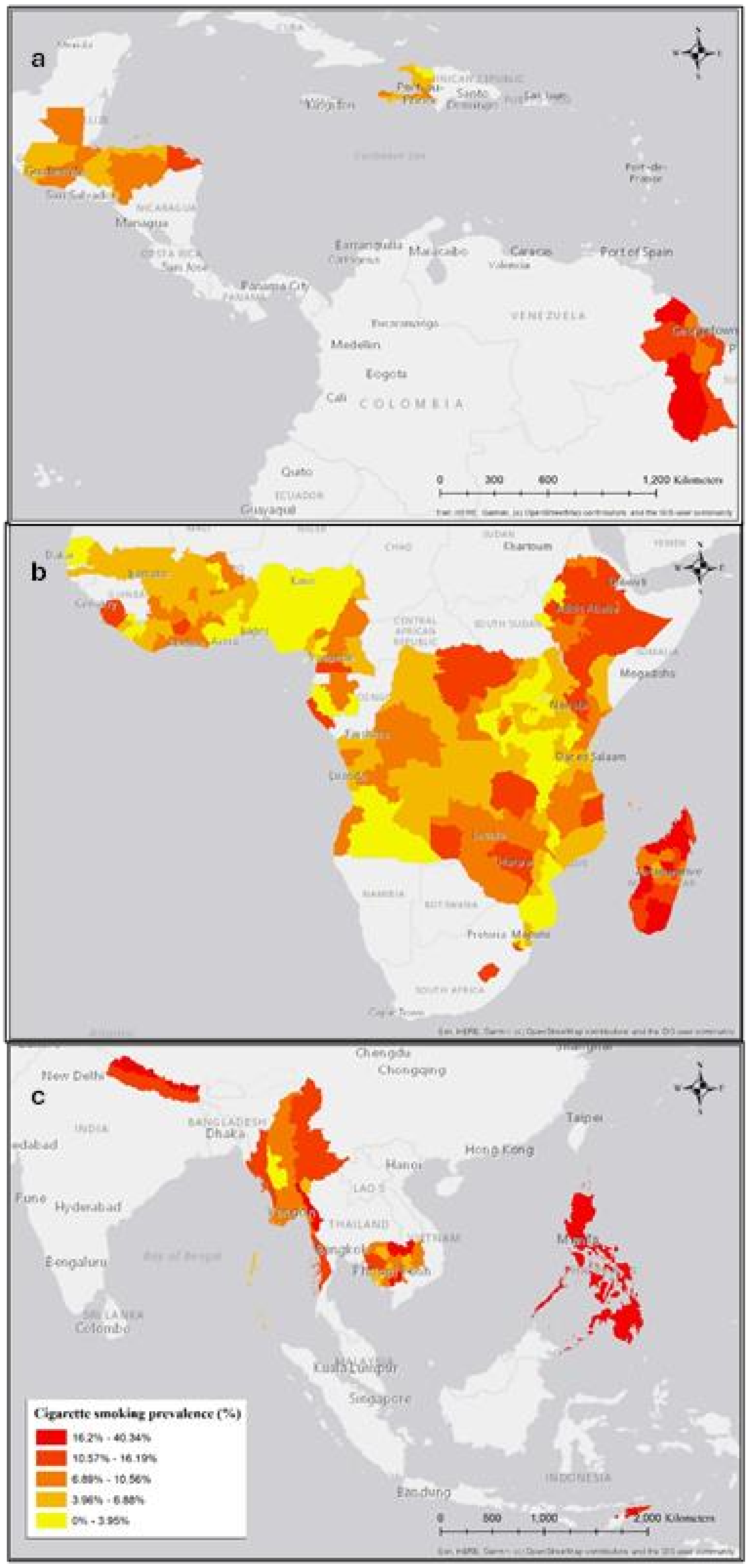

Figure 5. The weighted regional variance of cigarette smoking prevalence amongst the respondents of each most recent DHS survey for 39 countries.in the Americas (a), Africa (b), and Asia (c).

4.4.1 The model results

Table 7 shows the constant variable as a logit and a transformed constant as a percentage of prevalence, along with the random residual variance variables from the model for each country. The constant values indicate the likelihood of the baseline to smoke cigarettes. The constant value for Angola, for instance, is -5.154. The inverse logit identifies a 0.57% chance of smoking for a woman, aged between 15 and 19, single, with no children at home, no education, unemployed, considered to be in the poorest wealth index category, and living in an urban environment in Angola. The smoking prevalence percentage of the baseline population across all 37 countries varies from close to zero in Togo to 5.34% in Nepal.

The variance values for the region, cluster, and household variables provide information on the apportionment of variation around the constant at each level. This test shows that more countries have a significant variation in cigarette smoking at the cluster level, whereas fewer values indicate significant variation at the region level.

Table 7. The binomial regression model logits for the constant and spatial level variance of cigarette smoking prevalence[4][5]. Positive logits for the spatial variance variables indicate a greater likelihood of smoking at different spatial levels.

Region of the world	Country	Constant (*S.E.*)	Constant (%)[6]	Region variance (*S.E.*)	Cluster variance (*S.E.*)	Household variance (*S.E.*)
Africa	Angola	-5.154 (0.207)	0.574	**0.059 (0.030)**	0.303 (0.059)	**0.066 (0.122)**
	Benin	-7.344 (0.349)	0.065	**0.161 (0.081)**	0.416 (0.110)	**~0**
	Burkina Faso	-8.711 (0.367)	0.016	**0.014 (0.012)**	0.168 (0.042)	**0.035 (0.092)**
	Burundi	-5.837 (0.323)	0.291	**~0 (0.008)**	**0.152 (0.069)**	**0.169 (0.167)**
	Cameroon	-6.575 (0.306)	0.139	0.160 (0.073)	0.211 (0.049)	**~0**
	Comoros	-5.088 (0.314)	0.613	**0.067 (0.065)**	**0.069 (0.080)**	0.781 (0.201)
	Cote d'Ivoire	-7.198 (0.287)	0.075	**0.006 (0.010)**	**0.067 (0.040)**	0.335 (0.102)
	DRC[7]	-6.758 (0.225)	0.116	**0.073 (0.038)**	0.323 (0.045)	**0.001 (0.081)**
	Eswatini	-5.640 (0.318)	0.354	**0.014 (0.020)**	0.362 (0.080)	**0.010 (0.143)**
	Ethiopia	-6.307 (0.308)	0.182	0.614 (0.268)	0.405 (0.044)	**~0**
	Gabon	-4.846 (0.207)	0.780	**0.047 (0.026)**	0.080 (0.032)	0.338 (0.089)
	Ghana	-8.571 (0.720)	0.019	**~0**	**0.264 (0.135)**	**~0**
	Kenya	-8.423 (0.304)	0.022	**0.283 (0.145)**	**0.063 (0.034)**	**~0**

[4] When applying the Wald test, values that are ≥ 2 when divided by their associated standard errors indicate significant variance in cigarette smoking. The insignificant values are in bold.
[5] Spatial variance values given as zero do have statistically small values but are effectively zero.
[6] The inverse logits of the constant as a percentage of smokers in the baseline group of each country.
[7] DRC is an abbreviation of the Democratic Republic of the Congo.

Region of the world	Country	Constant (*S.E.*)	Constant (%)[6]	Region variance (*S.E.*)	Cluster variance (*S.E.*)	Household variance (*S.E.*)
	Lesotho	-6.927 (0.360)	0.098	**0.002 (0.010)**	0.146 (0.058)	**0.038 (0.113)**
	Liberia	-8.334 (0.427)	0.024	**0.023 (0.027)**	0.366 (0.092)	**0.025 (0.171)**
	Madagascar	-5.239 (0.192)	0.528	0.144 (0.050)	0.164 (0.031)	**0.092 (0.065)**
	Malawi	-6.954 (0.252)	0.095	**0.014 (0.015)**	0.154 (0.050)	**0.005 (0.109)**
	Mali	-7.870 (0.361)	0.038	**0.003 (0.010)**	0.200 (0.062)	**~0**
	Mozambique	-5.788 (0.277)	0.305	**0.075 (0.042)**	0.363 (0.074)	**0.008 (0.132)**
	Nigeria	-8.381 (0.286)	0.023	**0.119 (0.075)**	0.655 (0.068)	**~0**
	Rwanda	-6.567 (0.375)	0.140	**0.089 (0.063)**	0.067 (0.063)	**0.228 (0.172)**
	Senegal	-7.627 (0.317)	0.049	0.157 (0.072)	0.165 (0.064)	0.228 (0.114)
	Sierra Leone	-5.286 (0.185)	0.534	**0.019 (0.017)**	0.215 (0.032)	0.167 (0.066)
	Tanzania	-7.796 (0.468)	0.041	**0.080 (0.045)**	**0.114 (0.090)**	**~0**
	Togo	-9.510 (0.665)	~0	**0.005 (0.016)**	0.315 (0.094)	**0.021 (0.190)**
	Uganda	-6.543 (0.548)	0.144	**0.242 (0.129)**	0.301 (0.119)	**~0**
	Zambia	-6.222 (0.198)	0.198	**0.034 (0.019)**	0.141 (0.026)	**0.019 (0.066)**
	Zimbabwe	-7.921 (0.370)	0.036	**0.025 (0.016)**	0.071 (0.032)	0.232 (0.093)
Americ-as	Guatemala	-4.409 (0.154)	1.202	**0.072 (0.039)**	0.130 (0.027)	0.269 (0.065)
	Guyana	-3.692 (0.306)	2.432	**0.046 (0.028)**	**0.036 (0.037)**	**0.145 (0.105)**
	Haiti	-4.757 (0.224)	0.852	**0.103 (0.052)**	0.239 (0.047)	0.812 (0.120)

Region of the world	Country	Constant (*S.E.*)	Constant (%)[6]	Region variance (*S.E.*)	Cluster variance (*S.E.*)	Household variance (*S.E.*)
	Honduras	-3.767 (0.173)	2.260	0.133 (0.049)	0.134 (0.035)	**~0**
Asia	Cambodia	-4.166 (0.208)	1.528	0.180 (0.068)	0.391 (0.052)	**0.063 (0.086)**
	Myanmar	-3.699 (0.206)	2.415	0.228 (0.090)	0.177 (0.035)	**~0**
	Nepal	-2.875 (0.163)	5.340	**0.011 (0.013)**	0.280 (0.039)	**0.116 (0.068)**
	Philippines	-3.067 (0.184)	4.449	**0.006 (0.007)**	0.138 (0.031)	0.221 (0.065)
	Timor-Leste	-4.935 (0.179)	0.714	0.114 (0.053)	0.306 (0.047)	**~0**

Table 8 shows the values for the demographic variables (gender, age, marital status, and number of children). Gender has a clear and significant association with cigarette smoking in all surveyed countries. The positive logits indicate an increase in the likelihood of smoking for men. These results support our current understanding that gender has a significant impact on smoking, with men considerably more likely to smoke cigarettes than women (WHO, 2019a; ASH, 2019; Ghani et al., 2012; Khattab et al., 2012; Hitchman and Fong, 2011; Nejjari et al., 2009; Yang et al., 2006).

The categories for the age variable also have only positive logits, which show an increased likelihood of smoking over the baseline category for age. The variation of values across the age categories in each country is more interesting. The age logits for 23 countries, such as the countries in Asia, half of the Americas, and half of Africa, show that the lowest increase in the likelihood of smoking occurs in the youngest age group, whereas the highest increase occurs in the oldest age group. On the other hand, 12 countries in Africa observe the lowest increase in the likelihood of smoking in the youngest and oldest age groups, with the peak in likelihood occurring in those that are in the middle age groups. Additionally, there are three countries (Madagascar, Guatemala, and Honduras) that show the highest increase can be found among the lowest age group and a decline in cigarette smoking in older age groups. Cigarette smoking has been found in most of the literature to be more associated with younger people than older people (ASH, 2019; West, 2017; Xi et al., 2016). The complex nature of the association age has with smoking, when compared to the literature, indicates that generalisations about the impact of age on smoking should not be made in the Global South.

Marital status appears to be of limited significance as a predictor of cigarette smoking relative to gender and age (Table 8). Of the 24 countries with significant logits, 18 have negative values. This suggests that, in most countries, smoking is higher among those who are single. These results support current literature that finds single people are more likely to smoke than those who are married (Magati et al., 2018; Marinho et al., 2008; Meyler et al., 2007). Surprisingly, there are countries, however, such as Comoros and Haiti, where married people are more likely to smoke than those who are single.

The number of children at home is a continuous variable, which means that the logit is multiplied by the number of children living with an adult. A clear negative association between the number of children at home and cigarette smoking emerges among 27 countries with significant logits. These significant values indicate that the more children an individual has, the less likely they are to smoke cigarettes when compared with the baseline category of having no children. Previous literature did not provide a clear association between children in the home and smoking (Arouri et al., 2017; Chassin et al., 2002). Cambodia was the only case in the present research where parents had a statistically significant higher likelihood of smoking with an increase in the number of children. The research by Arouri et al. (2017) in Vietnam, alongside this anomaly, may indicate that this atypical association could be specific to Southeast Asia.

Table 8. The binomial regression model logits for the demographic predictor variables of cigarette smoking[8]. Positive logits indicate an increased likelihood in cigarette smoking.

Region of the world	**Country**	**Gender (*S.E.*)**	**Age (*S.E.*)**[9]									**Marital status (*S.E.*)**	**Number of children (*S.E.*)**
		Male	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-64**	**Living with partner**	
Africa	Angola	2.483 (0.083)	1.138 (0.162)	1.696 (0.164)	2.035 (0.172)	2.441 (0.173)	2.581 (0.176)	2.710 (0.176)	2.660 (0.200)	0	0	**-0.126 (0.089)**	-0.097 (0.019)
	Benin	4.018 (0.194)	1.048 (0.292)	1.489 (0.292)	1.949 (0.297)	2.122 (0.298)	2.286 (0.301)	2.481 (0.307)	2.099 (0.325)	2.162 (0.333)	1.613 (0.374)	-0.397 (0.161)	**-0.032 (0.022)**
	Burkina Faso	6.029 (0.305)	1.558 (0.139)	2.154 (0.148)	2.318 (0.157)	2.254 (0.165)	2.139 (0.175)	1.949 (0.186)	1.828 (0.196)	1.015 (0.241)	0	-0.211 (0.097)	-0.092 (0.019)
	Burundi	3.015 (0.142)	1.325 (0.211)	1.683 (0.227)	1.934 (0.240)	1.703 (0.258)	1.695 (0.27)	2.084 (0.265)	1.792 (0.285)	1.536 (0.321)	0	**-0.176 (0.138)**	**-0.08 (0.030)**
	Cameroon	3.582 (0.167)	1.497 (0.173)	1.981 (0.177)	2.223 (0.187)	2.632 (0.189)	2.838 (0.192)	2.844 (0.198)	2.875 (0.206)	2.410 (0.219)	0	**-0.135 (0.091)**	-0.100 (0.019)
	Comoros	2.615 (0.145)	0.909 (0.225)	1.131 (0.236)	1.183 (0.250)	1.301 (0.253)	0.887 (0.287)	1.376 (0.286)	1.163 (0.345)	0.922 (0.424)	0	0.587 (0.158)	-0.089 (0.035)

[8] When applying the Wald test, values that are ≥ 2 when divided by their associated standard errors indicate significant values in the model. The values that did not pass the Wald test and are, therefore, unlikely to be statistically significant. The insignificant values are in bold.
[9] Values given as zero in some age categories are due to no available data for that age group in each specific country.

Region of the world	Country	Gender (*S.E.*)	Age (*S.E.*)[9]									Marital status (*S.E.*)	Number of children (*S.E.*)
		Male	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-64**	**Living with partner**	
	Cote d'Ivoire	4.689 (0.198)	1.414 (0.164)	1.988 (0.170)	2.201 (0.179)	1.962 (0.193)	1.927 (0.202)	1.972 (0.207)	1.756 (0.223)	1.546 (0.255)	0	-0.249 (0.098)	-0.093 (0.024)
	DRC[10]	4.217 (0.113)	1.395 (0.143)	1.938 (0.149)	2.165 (0.154)	2.097 (0.162)	2.318 (0.165)	2.310 (0.167)	2.081 (0.175)	1.891 (0.185)	0	**-0.091 (0.084)**	-0.058 (0.015)
	Eswatini	2.721 (0.145)	1.937 (0.211)	2.450 (0.221)	2.910 (0.231)	3.364 (0.236)	3.366 (0.249)	3.338 (0.254)	0	0	0	-0.377 (0.115)	-0.158 (0.036)
	Ethiopia	3.426 (0.116)	1.106 (0.118)	1.615 (0.120)	1.851 (0.129)	1.878 (0.133)	2.029 (0.139)	1.928 (0.146)	2.016 (0.154)	1.893 (0.167)	0	**-0.141 (0.074)**	**-0.004 (0.015)**
	Gabon	2.677 (0.084)	1.151 (0.129)	1.695 (0.136)	1.793 (0.142)	1.817 (0.146)	1.853 (0.149)	1.859 (0.150)	1.350 (0.175)	1.313 (0.188)	0	-0.210 (0.077)	-0.088 (0.020)
	Ghana	4.954 (0.461)	1.519 (0.606)	3.218 (0.563)	3.088 (0.585)	3.422 (0.580)	3.553 (0.580)	3.855 (0.581)	3.747 (0.585)	4.411 (0.582)	0	-0.817 (0.196)	**-0.008 (0.037)**
	Kenya	4.089 (0.152)	1.757 (0.164)	2.619 (0.164)	3.076 (0.166)	3.144 (0.170)	3.218 (0.174)	3.389 (0.177)	3.372 (0.180)	0	0	-0.468 (0.068)	-0.070 (0.015)
	Lesotho	5.839 (0.284)	1.285 (0.138)	1.725 (0.156)	1.506 (0.168)	1.563 (0.178)	1.544 (0.193)	1.602 (0.208)	1.336 (0.214)	0.949 (0.224)	0	-0.274 (0.107)	**0.012 (0.038)**

[10] DRC is an abbreviation of the Democratic Republic of the Congo.

Region of the world	Country	Gender (*S.E.*)	Age (*S.E.*)[9]									Marital status (*S.E.*)	Number of children (*S.E.*)
		Male	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	Living with partner	
	Liberia	3.993 (0.199)	1.223 (0.403)	2.224 (0.380)	2.975 (0.376)	3.193 (0.379)	3.420 (0.379)	3.648 (0.388)	0	0	0	**0.008 (0.148)**	-0.118 (0.031)
	Madagascar	3.263 (0.094)	0.872 (0.095)	0.908 (0.104)	0.830 (0.111)	0.897 (0.117)	0.893 (0.124)	0.878 (0.126)	0.634 (0.139)	0.450 (0.151)	0	**0.083 (0.069)**	-0.088 (0.016)
	Malawi	4.171 (0.116)	1.868 (0.182)	2.763 (0.187)	3.035 (0.191)	3.237 (0.194)	3.248 (0.204)	3.490 (0.202)	3.467 (0.212)	0	0	-0.316 (0.098)	-0.079 (0.020)
	Mali	4.672 (0.259)	1.197 (0.231)	1.918 (0.236)	1.906 (0.258)	2.187 (0.263)	2.168 (0.270)	1.981 (0.280)	1.881 (0.288)	1.804 (0.309)	0	**0.057 (0.163)**	-0.071 (0.021)
	Mozambique	3.109 (0.111)	1.560 (0.243)	2.587 (0.234)	3.062 (0.237)	3.102 (0.241)	3.328 (0.248)	3.379 (0.249)	2.890 (0.278)	2.590 (0.294)	2.934 (0.295)	**-0.117 (0.106)**	-0.108 (0.023)
	Nigeria	3.480 (0.114)	1.652 (0.201)	2.598 (0.196)	2.915 (0.202)	2.860 (0.208)	2.844 (0.215)	2.966 (0.215)	0	0	0	-0.372 (0.086)	-0.053 (0.018)
	Rwanda	3.370 (0.150)	1.226 (0.275)	2.210 (0.264)	2.354 (0.271)	2.709 (0.282)	2.697 (0.291)	2.785 (0.294)	2.891 (0.301)	3.105 (0.298)	0	-0.260 (0.125)	-0.076 (0.031)
	Senegal	4.794 (0.229)	1.312 (0.166)	2.004 (0.176)	2.007 (0.194)	2.417 (0.207)	1.855 (0.228)	2.105 (0.237)	1.552 (0.269)	1.705 (0.278)	0	**-0.101 (0.122)**	-0.103 (0.026)
	Sierra Leone	2.271 (0.054)	1.649 (0.145)	2.076 (0.145)	2.561 (0.150)	2.729 (0.150)	2.746 (0.155)	2.772 (0.155)	2.926 (0.181)	2.654 (0.188)	0	**0.077 (0.072)**	-0.101 (0.016)

Region of the world	Country	Gender (*S.E.*)	Age (*S.E.*)[9]									Marital status (*S.E.*)	Number of children (*S.E.*)
		Male	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	Living with partner	
	Tanzania	4.257 (0.187)	1.579 (0.276)	2.467 (0.283)	2.559 (0.290)	2.935 (0.298)	2.941 (0.306)	3.072 (0.311)	0	0	0	-0.463 (0.147)	-0.183 (0.036)
	Togo	5.260 (0.390)	2.191 (0.489)	3.080 (0.489)	3.241 (0.499)	3.263 (0.504)	3.544 (0.503)	3.663 (0.506)	3.884 (0.508)	3.405 (0.530)	0	**-0.260 (0.152)**	**-0.052 (0.027)**
	Uganda	3.389 (0.170)	2.438 (0.436)	3.108 (0.436)	3.682 (0.439)	3.983 (0.441)	3.908 (0.457)	4.366 (0.450)	4.246 (0.489)	0	0	**-0.288 (0.167)**	-0.128 (0.033)
	Zambia	4.207 (0.121)	1.72 (0.120)	2.620 (0.123)	2.796 (0.128)	2.865 (0.132)	3.159 (0.134)	3.428 (0.139)	3.180 (0.147)	3.132 (0.154)	0	-0.318 (0.067)	-0.082 (0.013)
	Zimbabwe	4.919 (0.228)	1.739 (0.145)	2.609 (0.149)	2.532 (0.158)	2.624 (0.164)	2.448 (0.177)	2.856 (0.183)	2.835 (0.187)	0	0	**-0.115 (0.085)**	-0.083 (0.023)
Americas	Guatemala	2.854 (0.064)	0.528 (0.074)	0.650 (0.085)	0.435 (0.094)	0.416 (0.101)	0.238 (0.111)	0.243 (0.114)	**0.166 (0.125)**	**-0.116 (0.139)**	0	**-0.036 (0.062)**	-0.076 (0.018)
	Guyana	2.555 (0.107)	1.244 (0.161)	1.276 (0.171)	1.607 (0.171)	1.745 (0.171)	1.959 (0.172)	1.769 (0.176)	0	0	0	**-0.193 (0.097)**	**-0.011 (0.026)**
	Haiti	1.788 (0.080)	1.276 (0.157)	1.542 (0.164)	1.709 (0.170)	1.911 (0.174)	2.037 (0.176)	2.265 (0.176)	2.268 (0.189)	2.316 (0.193)	0	0.247 (0.083)	-0.075 (0.021)
	Honduras	2.932 (0.070)	0.697 (0.093)	0.619 (0.102)	0.448 (0.108)	0.316 (0.115)	0.272 (0.123)	0.502 (0.123)	**0.236 (0.142)**	**0.098 (0.156)**	0	-0.329 (0.066)	**-0.023 (0.020)**

Region of the world	Country	Gender (*S.E.*)	Age (*S.E.*)[9]									Marital status (*S.E.*)	Number of children (*S.E.*)
		Male	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	Living with partner	
Asia	Cambodia	3.430 (0.070)	1.015 (0.143)	1.355 (0.150)	1.511 (0.153)	1.974 (0.161)	2.003 (0.159)	2.089 (0.158)	0	0	0	**0.090 (0.090)**	0.068 (0.025)
	Myanmar	3.214 (0.073)	0.848 (0.115)	0.981 (0.121)	0.783 (0.128)	1.017 (0.131)	1.076 (0.131)	1.110 (0.134)	0	0	0	**-0.078 (0.080)**	**-0.032 (0.025)**
	Nepal	2.086 (0.064)	0.998 (0.126)	1.498 (0.131)	1.670 (0.138)	1.921 (0.138)	2.217 (0.137)	2.359 (0.138)	0	0	0	-0.222 (0.085)	**-0.009 (0.020)**
	Philippines	2.879 (0.052)	1.135 (0.093)	1.176 (0.103)	1.264 (0.110)	1.496 (0.112)	1.630 (0.116)	1.610 (0.118)	1.519 (0.153)	0	0	-0.240 (0.070)	**-0.005 (0.016)**
	Timor-Leste	4.210 (0.072)	1.486 (0.102)	1.870 (0.121)	1.813 (0.136)	1.744 (0.138)	1.763 (0.146)	1.817 (0.149)	0	0	0	**-0.099 (0.097)**	**0.012 (0.021)**

Table 9 shows the statistics for the socioeconomic variables (educational attainment, employment status, wealth, and place). In most cases, the education variable indicates that individuals with higher educational attainment are less likely to smoke cigarettes compared with the base category of no education. This supports a common theme in the literature, which finds that the more education a person has, the lower the chance of smoking (Fernando et al., 2019; Rajabizadeh et al., 2011; Lin, 2010; Marinho et al., 2008; Siahpush et al., 2008). It should be noted that there are several statistically insignificant logits, particularly in the primary education category. Amongst the significant logits, there are eight countries in which those who are in, or who have finished, primary school education have a greater chance of smoking than those with no education; three of which (Cameroon, Kenya, and Senegal) also show that the chances of smoking are still higher in those who are doing, or who have completed, secondary school education. Though there is a downward trend in these countries with higher education levels, having higher smoking rates among those with primary and secondary levels than those with no education suggests that, much like age, marital status, and number of children, this association is not as clearly linear in all countries of the Global South.

Employment status shows 22 significant positive logits. This supports literature that finds that individuals who are employed are more likely to smoke cigarettes than those who are unemployed (Abdelwahab et al., 2016; Cheah and Naidu, 2012). This is particularly the case in Nepal, as the transformed employment variable logit increases the likelihood of smoking among the baseline by 2.39%.

Although there are several statistically insignificant logits for the wealth index variable, there are 30 countries that have some, if not all, significant logits with negative values that get larger with an increase in wealth. This indicates that ‘richer’ people have a lower likelihood of smoking cigarettes than those who are relatively poorer than them. This supports our current understanding of how wealth interacts with the likelihood of smoking (Marinho et al., 2008; Subramanian et al., 2004; Rani et al., 2003; Steyn et al., 2002; Gilmore, McKee, and Rose, 2001).

The final variable in Table 9 indicates that the type of place a person lives in provides statistically significant negative logits for 20 countries. This suggests that those living in rural areas are less likely to smoke cigarettes than those in urban areas. This contradicts current literature on the subject that has found rural areas to be more significantly associated with a higher smoking prevalence (Kusumawardani et al., 2018; Shikha et al., 2014; Sreeramareddy, Pradhan and Sin, 2014a; Alam et al., 2008). Gabon was the only exception to this trend in the results, supporting the contrasting literature (Gurung et al., 2016).

Table 9. The binomial regression model logits for the socioeconomic predictor variables of cigarette smoking prevalence[11]. Positive logits indicate an increased likelihood in cigarette smoking.

Region of the world	Country	Education (*S.E.*)			Employment status (*S.E.*)	Wealth Index (*S.E.*)				Type of place (*S.E.*)
		Primary	Secondary	Higher	Employed	Poorer	Middle	Richer	Richest	Rural
Africa	Angola	**-0.124 (0.096)**	-0.648 (0.115)	-1.606 (0.252)	**0.177 (0.094)**	**-0.089 (0.107)**	-0.436 (0.142)	-0.616 (0.173)	**-0.368 (0.187)**	**0.024 (0.117)**
	Benin	**-0.088 (0.130)**	-0.625 (0.174)	-1.487 (0.490)	**0.119 (0.149)**	**-0.153 (0.140)**	-0.399 (0.148)	-0.961 (0.187)	-0.958 (0.252)	**0.203 (0.142)**
	Burkina Faso	**0.092 (0.083)**	-0.224 (0.106)	-1.083 (0.256)	**0.243 (0.168)**	**-0.133 (0.105)**	**-0.132 (0.108)**	**-0.144 (0.110)**	**-0.203 (0.133)**	-0.230 (0.099)
	Burundi	**-0.251 (0.107)**	-0.962 (0.183)	-1.126 (0.288)	0.623 (0.217)	**-0.107 (0.149)**	-0.339 (0.160)	-0.485 (0.164)	-0.398 (0.180)	-0.481 (0.160)
	Cameroon	0.433 (0.122)	0.288 (0.132)	**-0.097 (0.201)**	0.320 (0.115)	-0.559 (0.118)	-0.912 (0.140)	-1.395 (0.170)	-1.610 (0.188)	**-0.183 (0.122)**
	Comoros	**0.290 (0.157)**	**-0.279 (0.163)**	-1.321 (0.242)	0.375 (0.140)	**-0.098 (0.195)**	**0.063 (0.201)**	**-0.146 (0.214)**	**-0.049 (0.223)**	-0.568 (0.130)
	Cote d'Ivoire	0.176 (0.087)	**-0.106 (0.100)**	-0.825 (0.198)	0.625 (0.144)	-0.262 (0.110)	-0.410 (0.129)	-0.612 (0.151)	-0.644 (0.172)	-0.399 (0.125)

[11] When applying the Wald test, values that are ≥ 2 when divided by their associated standard errors indicate significant values in the model. The values that did not pass the Wald test and are, therefore, unlikely to be statistically significant. The insignificant values are in bold.

Region of the world	Country	Education (*S.E.*)			Employment status (*S.E.*)	Wealth Index (*S.E.*)				Type of place (*S.E.*)
		Primary	Secondary	Higher	Employed	Poorer	Middle	Richer	Richest	Rural
	DRC[12]	**-0.056 (0.113)**	-0.602 (0.115)	-1.628 (0.205)	0.598 (0.099)	-0.216 (0.079)	-0.336 (0.083)	-0.535 (0.101)	-0.956 (0.163)	**-0.073 (0.106)**
	Eswatini	**-0.088 (0.155)**	**-0.205 (0.158)**	**-0.331 (0.216)**	**-0.153 (0.108)**	-0.363 (0.169)	-0.354 (0.164)	-0.600 (0.176)	-0.838 (0.196)	-0.299 (0.145)
	Ethiopia	**0.037 (0.062)**	**-0.160 (0.105)**	-0.516 (0.122)	**-0.008 (0.066)**	**-0.066 (0.083)**	-0.190 (0.088)	-0.185 (0.090)	-0.388 (0.129)	**-0.127 (0.135)**
	Gabon	0.430 (0.146)	**0.157 (0.140)**	-0.494 (0.194)	**0.094 (0.077)**	-0.543 (0.093)	-0.781 (0.115)	-0.894 (0.129)	-0.690 (0.141)	0.197 (0.087)
	Ghana	-0.726 (0.203)	-1.313 (0.184)	-2.523 (0.542)	**-0.014 (0.372)**	-0.493 (0.194)	-0.594 (0.228)	-1.366 (0.305)	-1.868 (0.407)	-0.442 (0.193)
	Kenya	0.691 (0.119)	0.297 (0.128)	**-0.097 (0.151)**	0.624 (0.114)	**0 (0.079)**	-0.209 (0.082)	-0.551 (0.088)	-0.839 (0.106)	-0.298 (0.060)
	Lesotho	-0.341 (0.138)	-0.763 (0.158)	-1.349 (0.229)	0.326 (0.087)	**0.058 (0.133)**	**0.047 (0.138)**	**-0.120 (0.152)**	**-0.278 (0.170)**	**0.022 (0.119)**
	Liberia	**-0.172 (0.130)**	-0.889 (0.136)	-1.44 (0.403)	0.517 (0.193)	**-0.070 (0.125)**	**-0.072 (0.156)**	-0.512 (0.224)	-1.090 (0.321)	**0.202 (0.160)**
	Madagascar	**0.014 (0.073)**	**0.067 (0.089)**	**-0.256 (0.149)**	0.807 (0.107)	**-0.013 (0.085)**	**-0.054 (0.091)**	**0.091 (0.095)**	**-0.027 (0.119)**	-0.420 (0.092)

[12] DRC is an abbreviation of the Democratic Republic of the Congo.

Region of the world	Country	Education (*S.E.*)			Employment status (*S.E.*)	Wealth Index (*S.E.*)				Type of place (*S.E.*)
		Primary	Secondary	Higher	Employed	Poorer	Middle	Richer	Richest	Rural
	Malawi	-0.289 (0.103)	-0.787 (0.132)	-1.297 (0.300)	**0.087 (0.098)**	-0.313 (0.096)	-0.490 (0.098)	-0.700 (0.105)	-1.091 (0.132)	**-0.123 (0.123)**
	Mali	0.434 (0.123)	**0.246 (0.129)**	-0.578 (0.244)	**0.232 (0.172)**	**-0.191 (0.149)**	**0.013 (0.145)**	**0.075 (0.157)**	**-0.011 (0.195)**	-0.448 (0.158)
	Mozambique	**0.002 (0.100)**	-0.657 (0.158)	-0.750 (0.316)	**0.035 (0.115)**	**-0.065 (0.127)**	**-0.248 (0.134)**	-0.727 (0.149)	-1.273 (0.191)	-0.493 (0.127)
	Nigeria	0.367 (0.099)	**-0.086 (0.103)**	-0.684 (0.135)	0.328 (0.109)	**0.182 (0.113)**	**0.159 (0.128)**	**0.011 (0.142)**	**-0.070 (0.162)**	**-0.087 (0.101)**
	Rwanda	**-0.205 (0.114)**	-0.579 (0.184)	-1.858 (0.403)	0.551 (0.228)	-0.450 (0.130)	-0.404 (0.129)	-0.860 (0.140)	-1.227 (0.173)	-0.617 (0.135)
	Senegal	0.452 (0.107)	0.297 (0.130)	**-0.513 (0.300)**	**0.258 (0.135)**	**-0.248 (0.133)**	-0.374 (0.147)	-0.509 (0.174)	-0.611 (0.203)	-0.557 (0.126)
	Sierra Leone	**0.094 (0.075)**	-0.488 (0.071)	-1.069 (0.150)	0.515 (0.082)	**-0.019 (0.076)**	-0.170 (0.079)	-0.277 (0.090)	-0.790 (0.125)	**-0.029 (0.095)**
	Tanzania	**0.062 (0.171)**	**-0.415 (0.231)**	-1.346 (0.746)	1.525 (0.358)	**-0.231 (0.171)**	-0.503 (0.180)	-0.771 (0.188)	-1.037 (0.235)	-0.548 (0.179)
	Togo	**-0.105 (0.135)**	-0.877 (0.154)	-1.218 (0.334)	**0.461 (0.236)**	**-0.115 (0.149)**	**-0.317 (0.169)**	-1.021 (0.293)	-1.118 (0.342)	**-0.278 (0.279)**
	Uganda	**0.174 (0.210)**	**-0.230 (0.255)**	-0.958 (0.386)	**0.213 (0.249)**	-0.513 (0.179)	-0.971 (0.206)	-1.255 (0.219)	-2.417 (0.309)	-0.852 (0.221)

Region of the world	Country	Education (*S.E.*)			Employment status (*S.E.*)	Wealth Index (*S.E.*)				Type of place (*S.E.*)
		Primary	Secondary	Higher	Employed	Poorer	Middle	Richer	Richest	Rural
	Zambia	**-0.171 (0.097)**	-0.526 (0.102)	-1.186 (0.150)	0.172 (0.070)	-0.545 (0.066)	-0.947 (0.075	-1.273 (0.090)	-1.784 (0.114)	-0.446 (0.071)
	Zimbabwe	**0.197 (0.246)**	**-0.135 (0.248)**	-0.957 (0.290)	0.190 (0.071)	-0.213 (0.102)	**-0.149 (0.104)**	-0.378 (0.118)	-0.674 (0.135)	**0.029 (0.112)**
Americas	Guatemala	**0.015 (0.077)**	-0.239 (0.091)	-0.313 (0.123)	0.514 (0.065)	**-0.149 (0.075)**	-0.203 (0.079)	-0.291 (0.087)	-0.232 (0.100)	**-0.119 (0.062)**
	Guyana	**-0.310 (0.250)**	**-0.391 (0.247)**	-1.313 (0.307)	0.305 (0.108)	-0.508 (0.110)	-0.868 (0.121)	-1.062 (0.126)	-1.420 (0.146)	-0.210 (0.103)
	Haiti	-0.396 (0.083)	-0.671 (0.102)	-0.985 (0.190)	**0.012 (0.084)**	**-0.110 (0.097)**	**-0.110 (0.120)**	-0.325 (0.148)	-0.547 (0.173)	-0.248 (0.121)
	Honduras	**-0.142 (0.103)**	-0.500 (0.122)	-0.408 (0.163)	0.284 (0.077)	**-0.011 (0.075)**	**-0.131 (0.087)**	-0.499 (0.106)	-0.390 (0.119)	-0.501 (0.072)
Asia	Cambodia	-0.779 (0.088)	-1.286 (0.104)	-2.446 (0.209)	0.256 (0.097)	-0.369 (0.087)	-0.604 (0.097)	-0.919 (0.105)	-1.264 (0.130)	**-0.186 (0.108)**
	Myanmar	-0.430 (0.092)	-0.420 (0.099)	-0.826 (0.154)	**-0.076 (0.085)**	**-0.175 (0.091)**	-0.336 (0.095)	-0.270 (0.101)	-0.584 (0.122)	-0.242 (0.091)
	Nepal	-0.681 (0.076)	-1.260 (0.084)	-1.587 (0.128)	0.396 (0.069)	-0.358 (0.080)	-0.523 (0.089)	-0.807 (0.099)	-1.051 (0.118)	**-0.074 (0.099)**
	Philippines	**-0.078 (0.163)**	-0.345 (0.166)	-0.818 (0.173)	0.151 (0.055)	**-0.033 (0.078)**	-0.228 (0.086)	-0.362 (0.091)	-0.472 (0.100)	-0.222 (0.064)

Region of the world	Country	Education (*S.E.*)			Employment status (*S.E.*)	Wealth Index (*S.E.*)				Type of place (*S.E.*)
		Primary	**Secondary**	**Higher**	**Employed**	**Poorer**	**Middle**	**Richer**	**Richest**	**Rural**
	Timor-Leste	**-0.038 (0.086)**	-0.337 (0.087)	-0.773 (0.177)	0.491 (0.077)	**0.095 (0.097)**	**0.063 (0.099)**	**0.081 (0.103)**	**0.106 (0.124)**	**-0.112 (0.108)**

Table 10 presents the selected countries in order of model effectiveness as measured by R^2. The least effective model was for Haiti at 27.54%, and the most effective model was for Lesotho at 70.47%. The results show an apparent variation in the model's effectiveness for each country. What should be noted is the relatively poor effectiveness of the model for countries from the Americas and Asia compared to most of the sampled African countries. Therefore, the model may be more generally suited to countries in Africa. Future DHS surveys and further investigations into other determinants of smoking could improve the effectiveness of modelling countries in the Americas and Asia.

Table 10. The R^2 values that indicate the effectiveness of the model's explanatory power in each surveyed country, ordered from highest to lowest.

Region	country	R^2 (%)
Africa	Lesotho	70.47
	Burkina Faso	69.99
	Togo	68.84
	Ghana	68.38
	Zimbabwe	66.33
	Zambia	63.83
	Kenya	63.07
	Cote d'Ivoire	61.49
	Mali	61.16
	Liberia	60.95
	Tanzania	59.16
	Malawi	57.36
	DRC	57.26
	Senegal	57.16
	Cameroon	56.45
	Uganda	54.33
Asia	Timor-Leste	53.53
Africa	Rwanda	51.73
	Benin	50.02
Africa	Nigeria	48.92
	Mozambique	48.02
Asia	Cambodia	46.87
Africa	Ethiopia	45.31
	Eswatini	45.21
	Madagascar	44.97
	Sierra Leone	44.50
	Burundi	44.15
Americas	Guyana	42.54

Region	country	R^2 (%)
Africa	Gabon	39.46
Asia	Nepal	38.04
Africa	Angola	37.52
Asia	Myanmar	37.19
	Philippines	36.95
Americas	Guatemala	35.39
	Honduras	34.43
Africa	Comoros	34.35
Americas	Haiti	27.54

4.4.2 The spatial autocorrelation results

The global Moran's I values from the standardised residuals of the model at the cluster level, reported in Table 11, all appear to have a value close to zero. This suggests that clear geospatial residual patterns are not generally present.

When adopting a 95% confidence level, only Kenya, Nigeria, and Timor-Leste have <0.05 P-values, with global Moran's I values of 0.028, 0.083 and 0.056, respectively. These positive values suggest that the residuals in these countries are slightly spatially clustered after controlling all the independent variables.

Table 11. Global Moran's I values of the model for each surveyed country.

Region	Country	Moran's Index	p-value
Africa	Angola	0.020	0.498
	Benin	0.013	0.261
	Burkina Faso	-0.022	0.687
	Burundi	-0.018	0.829
	Cameroon	0.000	0.956
	Comoros	0.005	0.831
	Cote d'Ivoire	0.024	0.615
	DRC[13]	0.062	0.074
	Eswatini	-0.039	0.325
	Ethiopia	0.001	0.936
	Gabon	0.011	0.707
	Ghana	0.014	0.539
	Kenya	0.032	0.000
	Lesotho	-0.008	0.840
	Liberia	0.027	0.465
	Madagascar	-0.046	0.178
	Malawi	-0.030	0.352
	Mali	-0.057	0.063
	Mozambique	-0.010	0.790
	Nigeria	0.101	0.000
	Rwanda	-0.008	0.806
	Senegal	-0.007	0.939
	Sierra Leone	0.014	0.634
	Tanzania	-0.055	0.129
	Togo	-0.206	0.268
	Uganda	-0.021	0.443

[13] DRC is an abbreviation of the Democratic Republic of the Congo.

Region	Country	Moran's Index	p-value
	Zambia	0.003	0.860
	Zimbabwe	-0.033	0.251
Americas	Guatemala	0.003	0.745
	Guyana	-0.030	0.242
	Haiti	0.021	0.323
	Honduras	0.008	0.421
Asia	Cambodia	0.029	0.197
	Myanmar	-0.040	0.204
	Nepal	0.101	0.114
	Philippines	-0.006	0.985
	Timor-Leste	0.091	0.000

The statistically significant spatial autocorrelations in Kenya, Nigeria, and Timor-Leste were examined further by calculating the local Moran's I values (Figure 6). The circles in Figure 6 are positive local Moran's I values that indicate a statistically significant cluster of above-average residuals where the model is underestimating smoking (red) or below-average residuals where the model is overestimating smoking (blue). This spatial autocorrelation could indicate missing variables in the model.

In Figure 6, Kenya's underestimation clusters are in the South and East, where cities such as Nairobi and Mombasa are located, with most of the overestimation clustered in the centre of the country. Nigeria appears to have more underestimation than overestimation, with the former mostly clustering in the Northern and more Islamic part of the country, and the latter spread more evenly across the country compared with Kenya, with some small clustering in the South. Timor-Leste has the fewest clusters due to the relatively small size of the country and the dataset. There is, however, a large cluster of overestimations in the centre of the country near the capital, Dili, whilst most underestimation is on the coast and the island to the North and the exclave to the West.

Significant clusters of spatially autocorrelated residuals suggest either an incorrect functional form in the underlying model or where unaccounted variables are having an effect. The potential for an incorrect functional form, such as non-linear associations with certain variables, can be discounted as each model was checked during model development. The identified spatial autocorrelation, therefore, most likely points to the locations within each country where there are missing variables in the models. Identifying these variables is an area for future research. Likely possibilities include the localised effects of the illicit tobacco trade, corruption, and bribery of government officials by criminals and tobacco companies, political instability, and lower social cohesion (Gilmore et al., 2023; Felker-Kantor et al., 2019; Barnet al., 2016; Chen et al., 2015). These commercial and governmental factors have local impacts that likely influence the variation of residuals in the models.

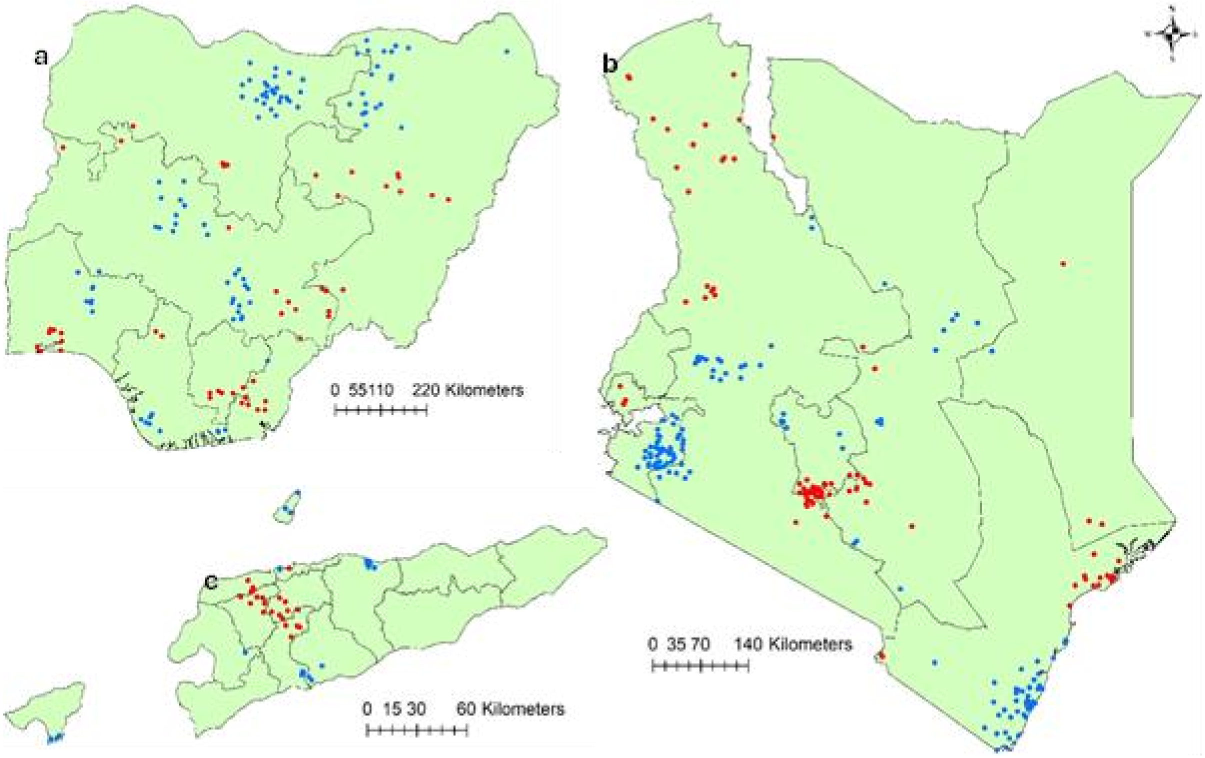

Figure 6. Local Moran's I maps that indicate where there is residual clustering of similar values within A) Nigeria, B) Kenya, and C) Timor-Leste.

4.5 Conclusion

The chapter offers a novel multi-country examination of the social determinants of smoking across the Global South. Most previous research on smoking in the Global South has been limited to one-country studies, meaning that past findings have been less accurate when making generalisations across the Global South. Being male, employed, less educated, and less wealthy was found across the Global South countries to be associated with smoking, which fits within the wider literature of the conceptual framework of social determinants of health inequalities.

Statistically significant contradictions highlighted in the results show that oversimplifying generalisations may not be useful for some countries. Comoros and Haiti were the only countries that had a higher likelihood of smoking among those living with their partner, which is contradictory to the theme found in the literature (Magati et al., 2018; Marinho et al., 2008; Meyler et al.,2007). Cambodia was the only country that had a higher likelihood of smoking with more children in the household. Gabon was the only country with a higher likelihood of smoking in urban areas. There were also contradictions in variables where linear associations were expected. Several countries had a higher likelihood of smoking at primary level education than those who have no education, which does not support the wider literature (Fernando et al., 2019; Lin, 2010; Marinho et al., 2008; Siahpush et al., 2008). Several countries also showed that there was a decline in the likelihood of smoking with age after initially increasing. This could be because older smokers have succumbed to tobacco-related health issues. Modelling these determinants has helped identify areas in countries where the models are overestimating and underestimating, meaning that more local-level determinants have not been accounted for. Conducting the same analysis with future DHS data to confirm that these areas still affect the models should be investigated to identify the missing variables and improve the models.

Understanding the extent of the existing associations between determinants and the prevalence of cigarette smoking is dependent on the integrity of data collection for the DHS for this research. The DHS surveys provide a broad scope of information on tobacco use and multiple known risk factors, allowing for multilevel analysis. The definition of some variables, however, may differ to a certain extent in each survey. For instance, the type of place variable relies on the decision of those collecting data. Therefore, it is possible that whether a place is categorised as urban or rural depends on either the size of the population or the level of infrastructure at each data collection point (ICF, 2018). An additional issue would be that the age variable is usually limited to represent ages between 15 and 59. Therefore, any conclusions drawn on the prevalence of cigarette use throughout age groups are limited to this specific age range. The cluster displacement brings some degree of random error for anonymity, which can affect the results from the spatial autocorrelation analysis. Another limitation is that this research uses 37 Global South countries, most of which are in Africa, which is not representative of the Global South as a whole. Moreover, causal interpretations are not advised with cross-sectional analysis, such as what is presented in this chapter. Therefore, the conclusions made on the significance of the determinants of smoking cannot be purported as the reasons why people smoke, but only that the determinants may change the likelihood of smoking.

The impact of smoking is one of the main challenges for global health. In terms of policy implications, the results of this research on the determinants of smoking contributed by highlighting subpopulations of the Global South that are most at risk of smoking and by finding some determinants in the results that did not support the wider literature. This highlighted the urgency of tailoring tobacco control policies and the allocation of tobacco control resources to specifically the most at-risk subpopulations to reduce the impact of tobacco use; in general, the most significant subpopulations at risk were found to be men, those who are employed, those who have less education, and those who are poorer. Regarding spatial autocorrelation, countries with statistically significant values should be researched further to find the missing determinants of smoking so that the model can improve the targeting of most at-risk subpopulations. With tobacco use prevalence in general set to increase further in the Global South, according to current trends, the enforcement of comprehensive evidenced-based tobacco control policies is needed. Global South countries, therefore, need the support of Global North countries and international bodies to maximise the ability to reduce the impact of tobacco use in countries that are also dealing with relatively high rates of communicable diseases.

This chapter indicates future research possibilities, such as continuing the regular surveillance of smoking prevalence and the associated determinants when datasets become available. Regular repeated surveys would enable an assessment of the changes to the association between different determinants and smoking over time. Targeted epidemiological research with these population groups should also be explored, for instance, type of employment, to find if there is a variation in smoking prevalence and how significant these variations are within these general determinants. Quantitative and qualitative approaches should be used to compare results for specific variables in future research. Other methods must also be considered, such as MCMC and Bootstrapping, as these could provide an opportunity to replicate and check the results of this research using an alternative modelling strategy.

Chapter 5 Investigating the trajectories and national determinants of cigarette smoking in the Global South: A multilevel model approach

5.1 Abstract

More than 80% of the current 1.3 billion tobacco users live within the Global South. The SETM suggests that tobacco use prevalence will continue to grow within this region at changing rates depending on gender. Understanding the extent to which other determinants influence the variation of smoking prevalence in the Global South over time would estimate future trajectories of prevalence and highlight areas that are most vulnerable to the tobacco epidemic. There is little understanding of the extent to which determinants of smoking at the country level affect the trajectory of tobacco use over time within the Global South. Understanding the country-level determinants is important as these are more suitable for indicating what governments can do to reduce national smoking rates.

40 DHS datasets from 17 countries from 2003 to 2017 containing cigarette smoking data and possible national determinants of smoking prevalence were used. A binomial mixed logistic regression multilevel model was used to generate estimates of associations between country-level variables and smoking trajectories whilst accounting for variation at different spatial levels.

There is little variation in the independent, household, and community-level variable associations on the trajectory of smoking prevalence between countries, with only a few variables diverging from Global South trends in a few countries. An increase in implementing MPOWER strategies and human development is associated with a reduction in national smoking prevalence within countries over time, but an increase in tobacco production is associated with an increase in smoking prevalence within countries over time.

The cross-sectional multilevel variable associations with smoking prevalence in the Global South are also evident in the change in smoking prevalence over time. The country-level variables highlight the importance of governments and other interested parties in committing to MPOWER and national human development programmes. The results can be used to tailor current tobacco control policies and improve the preparedness of future policies and initiatives that target specific population groups that are likely to suffer the growing effects of the tobacco epidemic. Constant surveillance is needed to update our understanding of future smoking prevalence trajectories when new datasets become available.

5.2 Background

Tobacco use causes 8 million global deaths each year (WHO, 2021). Long-term tobacco users are more likely to suffer from ill health earlier on in life, leading to a greater strain on national health infrastructures (WHO, 2023; West, 2017). This increased risk of ill health diminishes the size of domestic workforces and negatively impacts national economies (WHO, 2023). The global cost of tobacco use in 2019 was estimated to be 1.85 trillion US dollars, equivalent to 1.8% of the global Gross Domestic Product (GDP) (Vulovic, 2019).

Progress has been made in reducing tobacco use, with global prevalence estimates decreasing from 22.5% to 19.2% from 2007 to 2017 (WHO, 2019a). Tobacco use, however, still presents a significant problem for public health. This problem is compounded by the unequal distribution of tobacco users, with 80% of the 1.3 billion current tobacco users residing in the Global South (WHO, 2023). As a result, Global South countries will bear the brunt of the economic and health burden of tobacco use over time as tobacco users age. The disparity in the prevalence of tobacco use between the Global South and the Global North has grown substantially in the recent past, with the American Cancer Society (2018) stating that tobacco use increased in Africa by 60% from 1990 to 2009, during which time tobacco use reduced in Europe by 14%. This growing disparity is, in part, fuelled by tobacco companies' activity, expanding in growing markets in the Global South that have fewer tobacco control measures, such as taxes, than in the Global North (Brathwaite et al., 2015).

The SETM, created by Lopez et al. (1994), anticipated the increase in tobacco use in Global South countries. This model indicated the trajectory of cigarette smoking prevalence among men and women, including deaths associated with smoking, in Global North countries over the 20th century, separated into four stages. Initially, smoking prevalence and deaths are dominated by men. Prevalence continuously rises and peaks before declining as tobacco control policies take effect and social norms around smoking change, whilst deaths lag prevalence. Women mirror this pattern with a lag period of some decades. The Global North is in the latter stages of the SETM, with prevalence similar among men and women, with both declining, but with death rates among women continuing to grow due to the lag. The patterns exhibited within this model of the Global North indicate what the Global South might expect to experience with smoking prevalence in the future.

Currently, Global South countries, in general, exhibit early-stage characteristics of the SETM, with growing male prevalence, low female prevalence, and low rates of smoking-related deaths. More specifically, most countries within Sub-Saharan Africa exhibit attributes of the first stage, whereas most countries within Southeast Asia and Latin America exhibit attributes of the second and third stages (Ali et al., 2012). There has yet to be a noticeable increase in smoking among women in most Global South countries (Thun et al., 2012). The first objective of this chapter is, therefore, to answer research question two by adding detail to the current understanding of varying national trajectories of smoking prevalence across the Global South.

While the SETM focuses on the changing trajectory of smoking prevalence by sex, much recent research has stressed how health issues, including smoking, are impacted by factors operating at multiple spatial levels (Dahlgren and Whitehead, 1991). Research on smoking behaviour has emphasised the impact of personal characteristics and the characteristics of the local environment (Barnett et al., 2016). It is also evident that, at a national level, important commercial and political factors also impact prevalence (Drope et al., 2018). Comprehending the country-level determinants of smoking is important, as governments are usually responsible for framing tobacco control policies. These determinants should be more suited to indicate what a country can do to influence national smoking rates. Research on multilevel determinants has again focussed primarily on Global North countries. Identifying the importance of such determinants and change over time in the Global South could help prepare tobacco control policies by public health officials and third parties in countries more vulnerable to predicted growth in tobacco use. The second objective of this chapter is to answer research question three by assessing how such national factors impact the trajectory of smoking prevalence in the Global South. The following sub-section assesses the limited literature on national-level determinants of smoking prevalence trajectories.

5.2.1 Determinants of smoking

The literature on country-level determinants of smoking within the Global South is not extensive. What does exist does not clearly indicate general associations specific to the Global South. Therefore, supporting literature from the Global North offers guidance on potentially important country-level determinants of smoking. Three types of country-level determinants may be hypothesised: political, economic, and tobacco-specific.

There are several different dimensions of political determinants. Low levels of political stability in a country are associated with higher rates of smoking, particularly so among young people (Waajid, 2007). Political stability influences government priorities, so implementing tobacco control policies is less important in countries with low political stability (Jha et al., 2006). Higher levels of corruption also influence government priorities as there is more crime, including illegal tobacco smuggling, which can bring about an increase in smoking prevalence (Budak et al., 2021). The level of corruption a population perceives is associated with higher smoking rates within the European Union (Bogdanovica et al., 2011). This could be due to the breakdown in social cohesion among communities that experience more crime, evoking stress responses that are detrimental to health, such as smoking (Felker-Kantor et al., 2019). More simply, corruption may be associated with a reduced commitment to government-led tobacco control.

Economic determinants are reflective of national wealth and human potential. They are the collective national manifestation of established but variable associations between tobacco use and wealth. Human development, measured via the Human Development Index (HDI), identifies national well-being, education, and standard of living (WHO, 2019b). The impact of smoking prevalence in the Global South on public health and national economies threatens human development (Ordunez and Campbell, 2020). Observations in developed countries find that an increase in HDI is associated with a decrease in smoking prevalence (Bogdanovica et al., 2011). Similarly, urbanisation has been associated with lower smoking rates (Yang and Barnett, 2021; Yu et al., 2021). This is possibly due to the greater accessibility and availability of smoking cessation resources and more health awareness in urban areas compared to areas that are urbanising at a slower rate, and the economy is advancing less rapidly.

Tobacco-specific factors take two forms: those related to tobacco production and those related to tobacco control. Tobacco production has increased overall in the Global South (Wallbank et al., 2016). This growth was found to increase the likelihood of smoking, although there are some countries, such as Zimbabwe, that are large tobacco producers but have low rates of smoking relative to countries that produce less tobacco (Martins-da-Silva et al., 2022). Tobacco control policies are, unsurprisingly, associated with a decline in national smoking rates (Ahsan et al., 2022; Islami et al., 2015). This association is more significant in countries that have a relatively high rate of smoking prevalence (Husain et al., 2021).

The association between cigarette smoking and country-level determinants, however, needs to control for individual, household, and community-level determinants that predispose to smoking. In the context of the Global South, the evidence of the extent of such associations of individual determinants varies.

Gender appears to be the most significant determinant of smoking, as men are more likely to smoke than women (WHO, 2023; ASH, 2019; Khattab et al., 2012; Hitchman and Fong, 2011; Nejjari et al., 2009). Age is also important, as younger people are more likely to smoke (ASH, 2019; West, 2017; Xi et al., 2016). Magati et al. (2018) did, however, observe that older people in Kenya were more likely to smoke. The likelihood of smoking was also found to increase among those who are single compared to those who are married (Magati et al., 2018; Marinho et al., 2008; Meyler, Stimpson, and Peek, 2007). Jarallah et al. (1999) present contradictory findings as married men in Saudi Arabia smoke more than those who are single. Being less educated also increases the chances of smoking (Fernando et al., 2019; Rajabizadeh et al., 2011; Lin, 2010;

Marinho et al., 2008; Siahpush et al., 2008). Although Ahmed et al. (2008) found that highly educated people at universities in Pakistan are more likely to smoke. Unemployment was found in some research to be associated with smoking (Fernando et al., 2019; Lin, 2010; Ding et al., 2009; Mariho et al., 2008). Other literature, however, observed a higher likelihood of smoking among those who were employed (Abdelwahab et al., 2016; Cheah and Naidu, 2012), which mentions the increased level of stress among those looking for employment and among those with stressful jobs that facilitate an increased risk of smoking. Income was found to be interlinked with education and employment. So, literature tends to observe a higher smoking prevalence among those with low incomes (Marinho et al., 2008; Subramanian et al., 2004; Rani et al., 2003). Gender has also been found to influence income as a determinant of smoking, as high income is associated with a higher likelihood of smoking among women in Lebanon and Morocco (Khattab et al., 2012; Nejjari et al., 2009). Arouri, Ben-Youssef, and Nguyen Viet (2017) observed that more children increase a parent's likelihood of smoking in Vietnam, whereas Lin (2002) finds the opposite to be true in Taiwan. Lastly, rural areas in some literature have higher rates of tobacco use (Kusumawardani et al., 2018; Shikha et al., 2014; Sreeramareddy, Pradhan, and Sin, 2014a; Alam et al., 2008). Whereas literature, such as Gurung et al., 2016, observed higher rates in urban areas. There is also evidence in some literature, however, that the type of place is not a significant determinant of smoking (Oyewole, Animasahun, and Chapman, 2018; Brathwaite et al., 2015).

5.3 Methodology

This chapter aims to examine the varying temporal trajectories of smoking prevalence across the Global South and identify the importance of national-level determinants of smoking.

5.3.1 Data

Data are drawn from the DHS (ICF, 2004-2017). The DHS are nationally representative surveys of 5,000 to 30,000 households (ICF, 2022a). They provide comparable datasets of people aged 15 and up to 64 from Global South countries (ICF, 2022b). These are standardised surveys that use a two-stage sample design with clusters used as sampling units, with 25 to 30 households for each cluster (Croft et al., 2018). These data are stratified further by government administrative regions and an urban-rural classification of the clusters for each country. Since the DHS's inception, the focus has been on collecting data on the reproductive health of women. This focus, however, has since expanded to include men and other health issues, including tobacco use.

This research uses DHS datasets for 17 Global South countries: Cambodia, Ethiopia, Ghana, Indonesia, Kenya, Lesotho, Liberia, Malawi, Mozambique, Namibia, Nepal, Nigeria, Rwanda, Sierra Leone, Uganda, Zambia, and Zimbabwe. These countries were chosen because they had at least two surveys with data on cigarette smoking for both men and women at the time of writing. The DHS provided data on individual, household, and community-level social determinants of smoking. That served as control variables in subsequent analyses. The national DHS datasets were merged so that general patterns in the determinants of smoking over time could be identified across the Global South. The final dataset comprised 834,343 respondents from 40 surveys conducted in 17 countries between 2003 and 2017. Little's MCAR tests (1998) were conducted to assess randomness in missing values. Cases with missing values were removed. Table S 2 in Appendix B identifies the data-cleaning process for the combined survey dataset for each country.

5.3.2 Dependent variables

Cigarette smoking is the main form of tobacco use internationally (West, 2017). For this research, a binomial 'yes' or 'no' variable for cigarette smoking status was adopted as the dependent variable. This question was asked in the DHS, so no recoding was needed.

5.3.3 Independent variables

DHS variables that control for the individual, household, and community-level demographic determinants of smoking included a continuous variable for age, an aggregated binomial 'married' or 'not married' variable for marital status, and an aggregated continuous variable for the number of children in a respondent's household. A gender variable was researcher-generated as the DHS surveys originate as separate datasets for men and women.

Additional individual-level variables indicate socioeconomic determinants of smoking. An ordinal variable for educational attainment categorised a respondent's education as 'no education', 'primary', 'secondary', or 'higher', whether completed or not. A binomial 'employed' or 'not employed' variable identified whether the respondents were currently working during the survey. Further variables included a household-level ordinal wealth index and a community-level urban-rural indicator. The DHS wealth index measures the relative economic status of each household. This wealth index is more suited to represent household economic status than household income or expenditure, which can vary significantly in the short term in less developed countries (Rutstein and Johnson, 2004; Filmer and Pritchett, 2001). The respondents were categorised as poorest, poorer, middle, richer, and richest for this variable. A 'rural' or 'urban' binomial variable accounted for urban-rural differentials in smoking. Labelling a cluster as either rural or urban is defined by population size and the level of infrastructure the surveyor observed (ICF, 2018).

5.3.4 Country-level determinants

Six indices indicating the determinants discussed in section 5.2 were used (Table 12). Although some could sometimes be measured at the subnational level, datasets on these determinants were generally available only at the country level for specific years. There is no specific data for the percentage of tobacco smuggled into a country. The Corruption Index was used as an indicator of smuggling due to the link between corruption and smuggling in the literature (Budak et al., 2021). The selected indicators were based on the literature review in section 5.2.1 and are in line with the country-level themes highlighted in successive editions of the internationally recognised Tobacco Atlas (Mackay and Eriksen, 2002). Specific measures were chosen by identifying the most cited measure or index for each theme.

Table 12. Indices used as country index variables in the model, along with the source and a corresponding hypothesis of its effect in the model.[14]

Country index variables (Source)	**Hypothesis**	**Range**
Corruption Perception Index (CPI)[15] (Transparency International, 2021)	An increase in CPI is associated with an increase in smoking prevalence.	0 to100 (0 = most corrupt)
Political Stability and Absence of Violence/Terrorism Indicator (PSI) (World Bank, 2021)	An increase in public stability is associated with a decrease in smoking prevalence.	-2.5 to 2.5 (-2.5 = least politically stable)
MPOWER[16] (World Health Organisation, 2020)	An increase in MPOWER is associated with a decrease in smoking prevalence.	0 to 1 (0 = no tobacco control found)
Urbanisation Index (UI) [17](United Nations, Department of Economic and Social Affairs, Population Division, 2019)	An increase in urbanisation is associated with a decrease in smoking prevalence.	0% to 100% (0% = no urban population)
Human Development Index (HDI) (United Nations Development Programme, 2019)	An increase in HDI is associated with a decrease in smoking prevalence.	0 to 1 (0 = least human development)
Tobacco Production (TP) [18](Food and Agriculture Organisation of the United Nations, 2022)	An increase in TP is associated with an increase in smoking prevalence	0% to 100% (0% = no land for growing tobacco)

[14] Website addresses for where these datasets were downloaded and recorded from are available in the List of References.

[15] CPI values pre-2012 were out of 10. The metrics have not changed so values given to countries at the time DHS surveys were conducted pre-2012 were multiplied by 10.

[16] The seven indicators of MPOWER (Monitoring tobacco use and prevention policies; Protecting people from tobacco smoke; Offering smoking cessation help; Warning about the dangers of smoking; Enforcing bans on tobacco advertisements; Raising taxes on tobacco; and Anti-tobacco media campaigns) values were aggregated and divided by the number of available values given for each DHS survey year to give an MPOWER index.

[17] UI is the converted percentage of a country's population living in urban areas at the time of a DHS survey. This is a similar variable to the cluster-level place variable, but with a focus on the country-year urbanised population. This could provide insight as to how the association of the rate of urbanisation affects the trajectory of smoking within and between countries.

[18] TP is the converted percentage of a country's total land mass in Hectares that is used to produce tobacco crops at the time of a DHS survey.

The country-level index variables were collected for each country from when the DHS survey was conducted. Not all variables were available for each survey year. Missing values were interpolated using data from before and after the survey year. If no index data exists before or after the survey year where data is missing, the index value for that survey year is marked as missing.

The within-between formulation was used (Bell and Jones, 2015; Fairbrother, 2014) to model longitudinal and cross-sectional effects as separate functions. The longitudinal effect is the change in a particular variable over time within each country (a within effect). The cross-sectional effect is the association between smoking and the variable in question, with longitudinal change held constant (a between effect). The within-between formulation calculates the between effect ($\bar{x}$) as the mean value of each variable for each country (a country-level variable). The within effect ($x - \bar{x}$) is calculated as the difference between the occasion-specific variables and the new country-level variables (a country-year variable).

A test of multicollinearity between country-year and country-level determinants was conducted. Significant multicollinearity in Table S 3 in Appendix B was found only within countries for HDI, with variance inflation factor values >10. Centring the country-level indices reduced the presence of multicollinearity.

5.3.5 The models

The multiple spatial levels in the dataset allow for a multilevel modelling approach that can generate explanatory variable estimations while simultaneously controlling for other variables that are measured at different spatial levels. This approach also allows for a longitudinal component. This research utilises a 6-level (respondent, household, cluster, region, country-year, and country) binomial logistic multilevel regression model. Three such models were generated using MLwiN version 3.4 (Charlton et al., 2019). The models used IGLS to generate estimates from the dataset of the associations between national determinants of smoking and the observed prevalence of cigarette smoking within and between each country over time whilst controlling for relevant individual, household, and community factors. MCMC could also be used here; however, IGLS has been chosen to keep the approach simple and more easily reproduced. Model 1 was a null model identifying the patterns in cigarette smoking over time between countries in the dataset:

$$smokes_{ijklmn} = \beta_0 + h_{0n} + g_{0mn} + f_{0lmn} + v_{0klmn} + u_{0jklmn} + e_{0ijklmn}$$

Smoking is measured for individuals (*i*), households (*j*), clusters (*k*), regions (*l*), country-years (*m*), and countries (*n*). β_0 is the constant for the null model, giving the likelihood of a respondent smoking. The random effects of each level of the model are given as h_{0n}, g_{0mn}, f_{0lmn}, v_{0klmn}, and u_{0jklmn}. As this is a binomial model, the random effect of the individual level $e_{0ijklmn}$ is constrained to 1.

Model 2 adds the mean-centred year and age variables to account for the survey year and age trend, including the gender variable, with females as the baseline. The survey year and age variables were centred by their grand mean, the rounded values of which were 2010 and 30, respectively. A preliminary test of the model observed linearity in the results, so quadratic terms for the continuous variables for age and survey year were not needed. Model 2 can be written as:

$$smokes_{ijklmn} = \beta_0 + \beta_1 year_{mn} + \beta_2 age_{mn} + \beta_3 gender_{ijklmn} + h_{0n} + g_{0mn} + f_{0lmn} + v_{0klmn} + u_{0jklmn}$$

β_1 and β_2, the coefficients for survey year and age, respectively, along with β_3, the gender coefficient, identify how the likelihood of smoking changes with time, age, and gender. β_0 is the constant that identifies the likelihood of a female respondent aged 29 in 2010 being a cigarette smoker.

Model 3 adds the explanatory variables at the individual, household, community, country-year, and country levels. No education, poorest, no children, single, and unemployed were used as the baseline along with the grand means of the country-years and country-level variables CPI, PSI, MPOWER, UI, HDI, and TP, were added to the model at the country-year level and the country level, respectively, and were centred by the mean. The resulting model has variables at five spatial levels (respondent, household, cluster, country-year, and country). A simple equation that summaries the levels at which the variables are nested in Model 3 is written as:

$$smokes_{jklmn} = \beta_0 + \Sigma_{r=1}^{n}\beta_r x_{jklmn}(r) + \Sigma_{h=1}^{n}\beta_h x_{klmn}(h) + \Sigma_{c=1}^{n}\beta_c x_{lmn}(c) + \Sigma_{y=1}^{n}\beta_y x_{mn}(y) + \Sigma_{t=1}^{n}\beta_t x_n(t) + h_{0n} + g_{0mn} + f_{0lmn} + v_{0klmn} + u_{0jklmn}$$

The variables for each spatial level are denoted in the equation as $x^{(r)}$ at the respondent level, $x^{(h)}$ at the household level, $x^{(c)}$ at the cluster level, $x^{(y)}$ at the country-year level, and $x^{(t)}$ at the country level. The corresponding spatial level constants (β) are estimates of the increase or decrease in the likelihood of smoking when added to the model's constant (β_0). Moreover, the constants of the continuous variables (age and the number of children) indicate an increase or decrease in likelihood with every one-unit increase.

5.4 Results

Table 13 provides descriptive statistics on the control variables. These statistics indicate that men, older people, people in rural areas, people with less education, people who are poorer, people who have more children, people who are married, or people who are employed are proportionally more likely to smoke.

Table 13. Descriptive statistics for the control variables and cigarette smoking in the dataset.

		Smokes cigarettes		**Total**
		No (%)	Yes (%)	
Total		767,205 (91.95)	67,138 (8.05)	834,343
Gender	Male	190,857 (77.16)	56,500 (22.84)	247,357
	Female	576,348 (98.19)	10,638 (1.81)	586,986
Age group[19]	15 to 24	294,887 (97.07)	8,889 (2.93)	303,776
	25 to 34	231,239 (91.23)	22,217 (8.77)	253,456
	35 to 44	165,035 (88.37)	21,722 (11.63)	186,757
	45 to 54	71,925 (84.54)	13,158 (15.46)	85,083
	55 to 64	4,119 (78.14)	1,152 (21.86)	5,271
Place	Urban	282,592 (92.41)	23,215 (7.59)	305,807
	Rural	484,613 (91.69)	43,923 (8.31)	528,536
Education	No education	146,774 (91.58)	13,499 (8.42)	160,273
	Primary	283,656 (91.38)	26,748 (8.62)	310,404
	Secondary	279,226 (92.33)	23,204 (7.67)	302,430
	Higher	57,549 (93.98)	3,687 (6.02)	61,236
Wealth Index	Poorest	147,509 (89.68)	16,969 (10.32)	164,478
	Poorer	139,667 (90.89)	13,997 (9.11)	153,664
	Middle	143,714 (91.70)	13,002 (8.30)	156,716
	Richer	155,206 (92.62)	12,369 (7.38)	167,575
	Richest	181,109 (94.37)	10,801 (5.63)	191,910
Number of children[19]	0	299,563 (93.74)	19,995 (6.26)	319,558
	1	137,451 (91.45)	12,859 (8.55)	150,310
	2	126,981 (90.35)	13,555 (9.65)	140,536
	3	87,827 (90.37)	9,357 (9.63)	97,184
	4+	115,383 (91.03)	11,372 (8.97)	126,755

[19] Age and number of children have been categorised for the purpose of this table only.

		Smokes cigarettes		Total
		No (%)	Yes (%)	
Marital status	Not married	338,943 (95.10)	17,469 (4.90)	356,412
	Married	428,262 (89.61)	49,669 (10.39)	477,931
Employment status	Not employed	296,701 (97.13)	8,755 (2.87)	305,456
	Employed	470,504 (88.96)	58,383 (11.04)	528,887

Figure 7 identifies the trends in cigarette smoking prevalence over time for each of the 17 countries used in this study. The Figure was generated using the results of model 1 (the null model) and model 2, which includes variables for year, age, and gender. Figure 7(a) uses the null model to show the general change in smoking prevalence for each country between the years the DHS surveys were conducted. Figure 7(b) uses model 2 to show the estimated smoking prevalence over time for women aged 30 in the year 2010. Figure 7(c) changes the gender to men for comparison with Figure 7(b). As such, men exhibit a more significant change in rates. Moreover, in most countries, smoking prevalence among women is far lower than among men. Nepal, Cambodia, Sierra Leone, and Namibia had the highest rates among men and women, which declined over time. Indonesia had a high smoking prevalence that peaked around 2012 and then started to decline. The prevalence among men and women in Lesotho, on the other hand, is growing. Most countries are low and level over time over the relatively short period data is available. The random part variance results of the spatial levels in the models are presented in Table S 4, with the results for models 1 and 2 in Table S 5 of Appendix B.

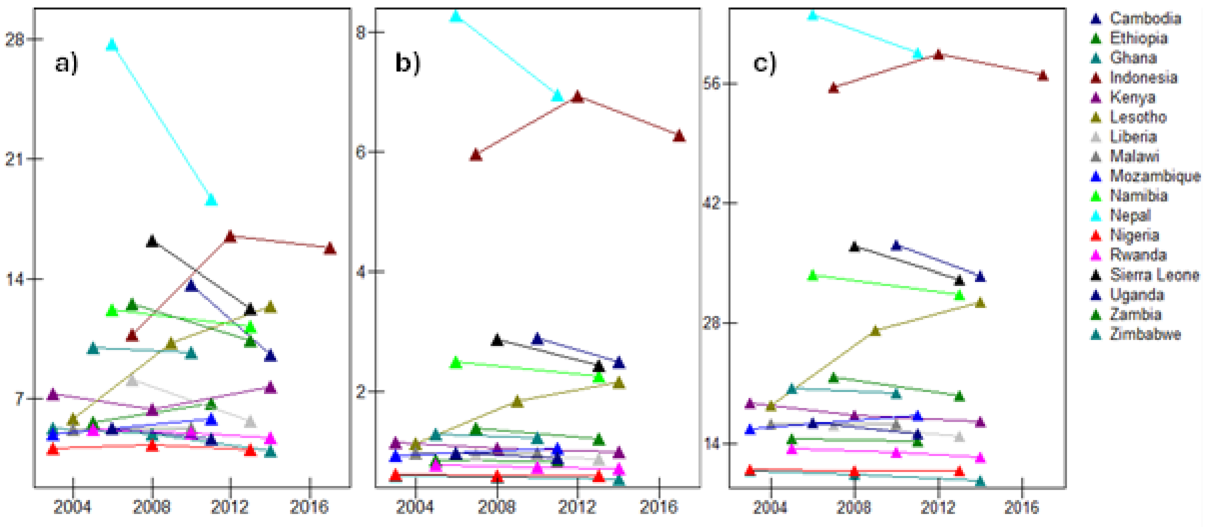

Figure 7. Estimated change in smoking prevalence between countries over time a) Model 1 (null model) estimated change in smoking prevalence (%) in countries over time between DHS surveys b) Model 2 estimated change in smoking prevalence among 30-year-old women in 2010 countries over time between DHS surveys c) Model 2 estimated

change in smoking prevalence among 30-year-old men in 2010 in countries over time between DHS surveys.

5.4.1 The individual and small area determinant results

Table 14 of Model 3 suggests that the likelihood of smoking increases with age, being a man, being married, and being employed. The likelihood of smoking decreases among those who have more education, more wealth, more children, and who live in rural areas.

Table 14. Model 3 results for the individual and small-area level coefficients, including the standard error values.

Variables			Model 3
	Constant		-4.023 (0.158)
Individual and Household level	Age		0.036 (0.001)
	Gender	Male	3.319 (0.015)
	Education	Primary	-0.420 (0.017)
		Secondary	-0.690 (0.019)
		Higher	-1.128 (0.028)
	Wealth	Poorer	-0.160 (0.016)
		Middle	-0.310 (0.018)
		Richer	-0.464 (0.019)
		Richest	-0.758 (0.023)
	Children		-0.031 (0.003)
	Married		0.159 (0.015)
	Employed		0.536 (0.016)
Cluster level	Place	Rural	-0.180 (0.017)

5.4.2 The within- and between-country results

There are three statistically significant within-effect country-year level coefficients for MPOWER, HDI, and TP in Table 15. Both MPOWER and HDI variables indicate that as MPOWER or HDI increases, the likelihood of smoking among men and women in the selected countries decreases over time. The TP variable indicates that the likelihood of smoking among men and women in the selected countries increases over time as TP increases. No statistical significance was found in the between-effect country-level coefficients.

Table 15. The within- and between- country coefficient results of model 3, including the standard error values.[20]

	Variables	Model 3
Country-year level (Within effects)	Year	0.192 (0.100)
	CPI	-0.138 (0.149)
	PSI	0.094 (0.158)
	MPOWER	**-2.373 (0.951)**
	UI	0.073 (0.064)
	HDI	**-31.071 (10.498)**
	TP	**0.614 (0.293)**
Country Level (Between effects)	CPI	-0.237 (0.305)
	PSI	0.386 (0.248)
	MPOWER	3.712 (2.685)
	UI	-0.018 (0.013)
	HDI	0.243 (3.819)
	TP	0.013 (0.138)

5.5 Discussion

Seven individual-level determinants, one small-area level determinant, and six country-level determinants were examined in relation to a person's decision to smoke within the Global South. The model supports the suggestion by Ali et al. (2012) that Southeast Asia is further along the SETM than African countries. This is because Figure 7 identifies that smoking prevalence among men and women in Nepal and Indonesia is already well established, with the former steadily decreasing and the latter increasing to a point before showing signs of a gradual decline relative to other Global South countries. Though most of the African countries also show a small decline in smoking prevalence, there is no evidence in the data of a rapid increase or high prevalence among men and women to suggest that these countries are later in the SETM. This, instead, could be evidence that tobacco use has yet to take root across these countries' populations. Lesotho, on the other hand, appears to be in the early stages of the SETM, with substantial growth in smoking prevalence over time among men, with smaller growth among

[20] When applying the Wald test, values that are ≥ 2 when divided by their associated standard errors indicate significant variance in cigarette smoking. The significant values are in bold.

women. Significantly lower smoking prevalence among women compared with men across the selected countries, particularly in Africa, supports Thun et al.'s (2012) suggestion that it may be more beneficial to model men and women separately as there is no suggestion of smoking prevalence increasing among women.

The results in Table 14 of the model highlight which demographic and socioeconomic groups are more likely to smoke than others over time. Some of these associations were expected. Men were more likely to smoke than women, supporting the general findings in the literature (WHO, 2023; ASH, 2019; Khattab et al., 2012; Hitchman and Fong, 2011; Nejjari et al., 2009). An increase in education was associated with a decreasing likelihood of smoking, which supports the themes in the literature (Fernando et al., 2019; Rajabizadeh et al., 2011; Lin, 2010; Marinho et al., 2008; Siahpush et al., 2008). An increase in wealth was found to lower the likelihood of smoking, which is further evidence for the supporting body of literature (Marinho et al., 2008; Subramanian et al., 2004; Rani et al., 2003; Steyn et al., 2002; Gilmore, McKee, and Rose, 2001). Additionally, rural areas were usually found to have more smoking prevalence than urban areas in the literature generally Kusumawardani et al. (2018), Shikha et al. (2014), Sreeramareddy et al. (2014a), and Alam et al. (2008), which is supported by this research as the likelihood of smoking was found to decrease in rural areas over time.

The literature shows no clear or significant theme of the relationship between smoking prevalence and the number of children at home (Arouri et al., 2017; Chassin et al., 2002). This research, however, found that an increase in the number of children in the respondent's household is linked with a decrease in the likelihood of smoking, which supports Lin's (2002) research. There is no consensus on the relationship between smoking prevalence and employment status in the literature. This research, however, found that being employed increased the likelihood of smoking, and so supports research such as Abdelwahab et al. (2016) and Cheah and Naidu (2012).

Some of the determinants provided surprising associations with smoking prevalence over time. The likelihood of smoking was found to increase with age, which supports Magati et al. (2018) findings that older Kenyans smoke more than younger Kenyans but contradicts the more common theme found in the literature (ASH, 2019; West, 2017; Xi et al., 2016). Being married was associated with a higher likelihood of smoking, which supports Jarallah et al. (1999) research, which found that smoking prevalence was higher in Saudi Arabian couples, especially the husbands, but contradicts the general literature (Magati et al., 2018; Marinho et al., 2008; Meyler, Stimpson and Peek, 2007).

Table S 6 and Table S 7 of Appendix B highlight the variation of these associations at a country level. These results show that a few countries do not follow the general trends in Table 14.

Cambodia, Namibia, and Nepal show that an increase in the number of children increases the likelihood of smoking. Moreover, results for Ghana, Indonesia, Kenya, Liberia, Namibia, and Rwanda show that married people are less likely to smoke.

There were three statistically significant within-effects at the country-year level, providing expected results after controlling individual, household, and community determinants of smoking. An increase in MPOWER over time is associated with a decrease in smoking prevalence within countries, which supports the literature and demonstrates the effectiveness of tobacco control policy (Ahsan et al., 2022; Islami et al., 2015; Husain et al., 2021). An increase in HDI over time is associated with a decrease in smoking prevalence within countries, similar to the findings in literature from developed countries, such as Bogdanovica et al. (2011). This also supports the observation made by Ordunez and Campbell (2020) that the growth of smoking prevalence negatively impacts national human development. An increase in TP over time is associated with an increase in smoking prevalence within countries, which supports the literature on the growth of tobacco production and its association with increasing rates of smoking in the local area (Martins-da-Silva et al., 2022). The between-effects at the country level showed no statistical significance and are of little importance. The importance of the between-effects is primarily related to longitudinal change rather than enduring country effects.

There are limitations to this study. Firstly, the DHS data collection focuses primarily on women, so men are not as well represented. For instance, the Nepal DHS survey in 2011 included men in every second house of the study (Ministry of Health and Population, 2012). Secondly, some variables' categories were aggregated to simplify the already complex model. Although the model provided some significant results by including these variables, the underlying contextual factors that influence these determinants become less meaningful in models that include a time trend. Employment status, for instance, was aggregated to employed or not employed. Excluding data on the type of jobs neglects the possibility that different jobs may have a higher risk of smoking than others, which is also likely to change over time as economies develop. Thirdly, this research does not account for other forms of tobacco use, such as chewing tobacco and bidis, which are more common in certain countries, particularly in Southeast Asia (West, 2017; Sreeramareddy, Pradhan, and Sin, 2014b). As a result, conclusions drawn from this on the prevalence of general tobacco use are likely to underestimate the actual situation. The data used in this research was collected over 14 years. As such, the reliability of the inferences made from the results needs to be improved by adding more data when it becomes available. Lastly, this research attempted to avoid over-complicating the model by only including variables that indicate the determinants of smoking discovered in the literature. Other variables not considered in this research could better explain the variation of smoking in the model. This can be explored further when additional data from more countries becomes available.

5.6 Conclusion

The key findings from the research in this chapter are that using a temporal effect in the model showed that there is no inclination of a rapid increase in smoking rates among men or women within the Global South, except for Lesotho, that the Lopez et al. (1994) SETM suggested that could happen over time. The results, however, did find that some countries were likely to be in a later stage of the SETM, such as Nepal and Indonesia, which had the highest rates of smoking among men. This supports Ali et al. (2012) that Southeast Asia is likely to be further in the SETM than other Global South countries. This would suggest that the tobacco industry at the time when the DHS survey was conducted was yet to take further steps to increase their targeting of tobacco within most of the Global South. Another key finding is that the changes in the associations with the individual and cluster-level variables over time show an increase in the likelihood of smoking among older people, males, those who are married, and those who are employed. Moreover, the likelihood of smoking decreases over time among those who have the most education, who are the richest, more children, and those who live in rural areas. Most of these associations are not surprising based on what was found in the wider literature. The age variable, however, was surprising as smoking prevalence was expected to decrease with age, which would align with the current theme found in the literature (ASH, 2019; West, 2017; Xi et al., 2016). Additionally, being married was also surprising as smoking prevalence was expected to decrease among married people, as the literature suggests (Magati et al., 2018; Marinho et al., 2008; Meyler et al., 2007). The increase in the likelihood of smoking among older and married people in this research highlights how the importance of some of the determinants of smoking varies over time. These research findings on country-level determinants have shown that an increase in MPOWER and HDI over time is associated with a reduction in smoking prevalence, and an increase in TP over time leads to a reduction in smoking prevalence, which supports the current literature on these associations.

This chapter has implications for policy stemming from its findings concerning country-level determinants. The significance of the within effects, rather than the between effects, highlights the enduring country effects, which provides insight into the extent to which the variables at this spatial level impact the estimates of the trajectory of smoking prevalence. As such, governments that adopt and implement MPOWER in full are likely to reduce smoking prevalence significantly over time. Additionally, reducing the amount of land being used to grow tobacco is also likely to see a further decline in smoking prevalence over time. The increase in MPOWER and the decline of TP are achievable goals for governments that they can commit to and monitor to decrease smoking prevalence in the future.

Future research to develop this chapter might involve replicating these results as further surveys conducted by the DHS will become available, enabling the inclusion of more countries and more time points. This will likely adjust the trajectories of smoking prevalences over time, providing a more robust understanding of the determinants of smoking and the extent to which these associations are changing. The significance of the MPOWER approach should also be investigated further by decomposing the index to evaluate the contribution of its components. There is also potential for in-country qualitative policy research, as well as re-calibrating the models using MCMC estimation. Lastly, while the focus in this chapter has primarily been on country-level effects over time, there is also a case (should data become available) for testing a regional decomposition of the country-level variables.

Chapter 6 Predicting small area geographies of cigarette smoking within the Global South: A geostatistical modelling approach

6.1 Abstract

The success of tobacco control depends on robust tobacco use monitoring. The global prevalence of tobacco use is growing within the Global South. Due to the limited datasets available from this region, indicators of tobacco use prevalence have been measured via national statistics that hide local-level spatial distributions. This restricts the ability to identify the variation in tobacco use prevalence and tailor interventions accordingly. With the inadequate resources for tobacco control available within the Global South, there is a need to identify a viable method to predict local-level prevalence accurately. Here, we explore the generation of high-resolution maps via geostatistical models to identify whether this approach could be promoted to improve tobacco use monitoring in the Global South.

Using Guatemala, Kenya, and Myanmar as case studies, cigarette smoking prevalence among men was explored using cluster-level DHS data. Prevalence was modelled via a Bayesian geostatistical model at a 1 x 1 km spatial resolution, with an aim to produce exceedance probability maps to indicate where new tobacco-control policies or better enforcement of existing policies are urgently needed. Prevalence was modelled with uncorrelated geospatial covariates that have statistically significant associations with cigarette smoking from the same time the DHS smoking prevalence data were recorded.

The models showed good fits for predicting the variation of smoking, with relatively high R^2 values. The high spatial resolution maps highlighted the heterogeneity of smoking prevalence. Prevalence is relatively high across Guatemala, while in Kenya, it is high in the centre of the country and to the South, and in Myanmar, it is high around the border regions. Exceedance probability maps identify regional administrative units that likely require additional resources to reduce smoking.

Geostatistical modelling highlights how statistical methods can combine geo-referenced surveys and small-area level geospatial data to produce high spatial resolution predictions and shows potential for use within other Global South countries. Additional geospatial covariates, however, should also be considered where available to improve the fit of models and explore the extent to which they are associated with tobacco use.

6.2 Background

Tobacco use has been associated with more than 8 million global deaths per year (WHO, 2023). The WHO (2023) states that tobacco use is currently an epidemic, with more than 1.3 billion tobacco users. The burden of this tobacco epidemic is unequally distributed, with 80% of tobacco users residing within low- and middle-income countries (WHO, 2023), referred to as the Global South in this chapter. Moreover, the rate of cigarette smoking across the Global South tripled between 1970 and 2000 (Guindon and Boisclair, 2003). This unequal distribution and growth in tobacco use has been exacerbated by the tobacco industry's strategy to target emerging Global South markets that lack financial resources to fight legal challenges and enforce tobacco control policies (Egbe et al., 2017). As the tobacco epidemic continues to grow within the Global South, this will increase the pool of long-term tobacco users who are more susceptible to premature ill health (Tang et al., 2018; Bonnie et al., 2015). This public health issue has increased pressure across Global South countries that lack sufficient healthcare funding, with limited resources and underdeveloped healthcare infrastructures (Tang et al., 2018).

In 2013, the WHO set a target to reduce global tobacco use by 30% across all countries by 2025 via the WHO's FCTC (Bilano et al., 2015). The WHO planned to achieve a 30% reduction using tobacco use prevalence estimations from 2010 as the baseline (Bilano et al., 2015). This target, however, is unlikely to be achieved by 2025, particularly in the Global South, where there is little evidence to suggest that the FCTC has been widely enforced (Reitsma et al., 2021). Consequently, there has been no significant decline in overall tobacco use within the Global South, but rather, there is evidence of an increasing smoking population, predominantly within African countries (Reitsma et al., 2021; Chung-Hall et al., 2019).

The successful implementation of tobacco control strategies depends on the effective surveillance of the tobacco epidemic (WHO, 2023). As a result, large quantities of regularly updated data are required to monitor the changing prevalence of tobacco use (Reitsma et al., 2021). Data on tobacco use within the Global South, however, is limited. The inadequate availability of comprehensive national censuses within the Global South and the irregularity in which they are conducted restrict tobacco use surveillance. Existing census data and most survey datasets on tobacco use only indicate generalised national- or regional-level prevalence rates rather than small-area level heterogeneities in prevalence rates. Broad inferences based on national tobacco use estimates are likely unreliable in informing tobacco control policies implemented at the subnational administration level. Therefore, small area datasets are potentially valuable, as they can help tailor these tobacco control policies to improve the accuracy of targeting anti-tobacco resources in the most impacted subnational areas. The need for a small-area level approach is further inspired by the UN General Assembly 2030 Agenda for Sustainable Development Implementation, which pledges that all goals should be achieved everywhere and that no one should be left behind (United Nations General Assembly, 2015). As such, methods that can capture and measure small area heterogeneities can fill this gap in the surveillance of tobacco use prevalence.

Small area estimation (SAE) methods have been used to further our understanding of spatial heterogeneities in health geographies by making local estimates from national surveys and other data. They have been widely applied to tobacco use in high-income countries (Zhang et al., 2015; Hermes and Poulsen, 2012; Smith, Pearce, and Harland, 2011; Twigg, Moon, and Jones, 2000) and to other health indicators in the Global South (Paige et al., 2022; Utazi et al., 2021; Dwyer-Lindgren et al., 2018; Soltani-Kermanshahi et al., 2017). There does not yet appear to have been any applications to tobacco use in the Global South.

There are several SAE methods for a researcher to choose from, which can be grouped as either spatial microsimulation approaches or geostatistical modelling approaches. These have also been referred to as design- and model-based approaches, respectively (Wakefield, Okonek, and Pedersen, 2020; Whitworth et al., 2013). Microsimulation approaches, adopted by Smith et al. (2011) and Hermes and Poulsen (2012), can generate synthetic artificial smoking populations with specific characteristics, including outcomes of interest. Geostatistical modelling approaches, such as the approach adopted by Twigg et al. (2000), essentially use different forms of a regression model to generate estimates of smoking. These different geostatistical forms originally stem from the random-effect Fay-Herriot model (Fay, Herriot, 1979). This was preferred over fixed-effect models if the small-area level representativeness of a dataset is an issue, as it is with tobacco use in the Global South. Recent extensions to the geostatistical model use Bayesian estimation approaches and spatial smoothing functions (Marhuenda, Molina, and Morales, 2013).

This chapter aims to address the lack of small-area estimates of smoking in the Global South by testing an SAE approach to generate robust estimates of smoking prevalence within a set of case study countries.

6.3 Methods

Spatial microsimulation data requirements, or the data requirements of statistical-based estimation methods as applied to more high-income countries, are not easily met in the Global South, mainly as comprehensive datasets on tobacco use or from national censuses are usually either unavailable or seldom collected at regular intervals. Both are required for small estimations using either of the two standard approaches. For these reasons, and in recognising its wide use in generating other SAE of other health indicators, it was decided to adopt a geostatistical modelling approach with a Bayesian framework. This approach has previously been utilised by the WorldPop Group at the University of Southampton to produce small area estimations of vaccination uptake, childhood malnutrition, and other health measures in the Global South (Utazi et al., 2021; Utazi et al., 2018). This chapter marks the first application of this method in relation to tobacco consumption.

In brief, this approach utilises geospatial covariates to characterise the spatial dependence of the outcome variable (Diggle, Tawn and Moyeed, 1998). It utilises existing survey datasets and borrows strength from prior knowledge of existing spatial covariate relationships to fill in gaps where survey data is missing to generate gridded predictions of a spatial variable and statistical distributions of the uncertainty around these predictions (Fuglstad, Li, Wakefield, 2021). A Stochastic Partial Differential Equation (SPDE) approach, a spatial smoothing technique, is used on a spatial mesh (Lindgren, Rue, Lindström, 2011). This approach accounts for the spatial autocorrelation associated with geographical modelling, as nearer clusters tend to be more closely related to each other than clusters further away (Duncan and Mengersen, 2020; Leasure et al., 2020). The SPDE is applied with an Integrated Nested Laplace Approximation (INLA) method (Rue, Martino, Chopin, 2009). INLA is an approximate Bayesian inference method that can estimate posterior distributions of tobacco use prevalence that accounts for priors on the mesh. This further limit the results' uncertainty and the probability of prevalence over a given gridded area. INLA is both accurate and a speedier alternative to MCMC, which has been used more in Bayesian frameworks (Utazi et al., 2019). By using the SPDE approach, supported by INLA, the range and the standard deviation priors on the spatial effect were set in the mesh by a penalised-complexity prior formulation, which prevented the model from overfitting (Simpson et al., 2017). Such techniques allow the model to generate more robust predictions and alleviate uncertainty around these estimates.

The modelling was run using R version 3.6.3 (R Core Team, 2020a), using the foreign (R Core Team, 2020b), dplyr (Hadley et al., 2020), haven (Wickham and Miller, 2020), raster (Hijmans, 2020), rgdal (Bivand, Keitt, Rowlingson, 2021), leaflet (Cheng, Karambelkar, Xie, 2021), Viridis (Garnier et al., 2021), INLA (Martins et al., 2013; Lindgren et al., 2011; Rue, Martino, Chopin, 2009), and sf packages (Pebesma, 2018). The maps were created using ArcMap version 10.8 (Esri, 2020).

The chapter uses data from three case study Global South countries chosen from three different continents: Guatemala, Kenya, and Myanmar. Figure 8 outlines the methodology using Kenya as an example. The subsequent sections provide details on the data and the method used.

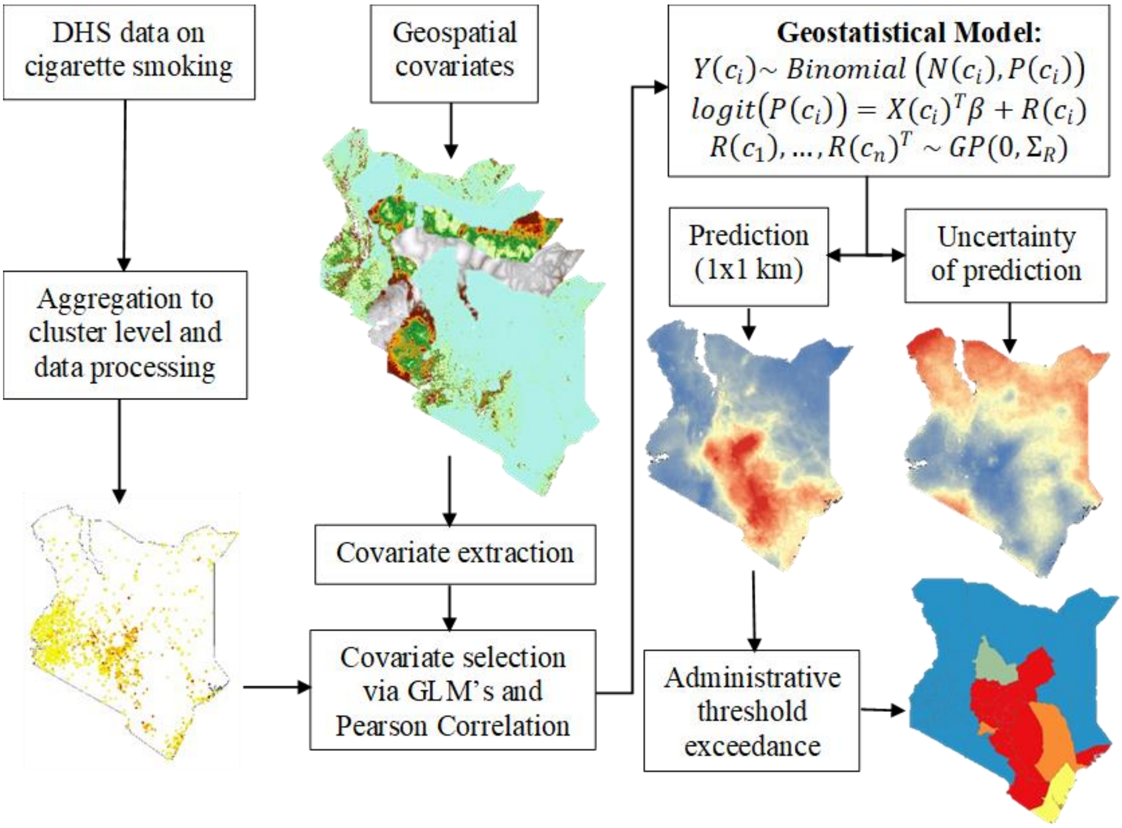

Figure 8. Methodology of the modelling approach to generate predictions of cigarette smoking.

6.3.1 Survey data

There are multiple tobacco-focused surveys, such as the ITC, the GATS, and the GYTS, that are collated into the GTSS (CDC, 2020). These surveys, however, only provide data at the national or sub-national administrative level. The DHS, on the other hand, are population and health surveys that include data on tobacco use at the sampling unit level, referred to as clusters (ICF, 2020). These clusters' geolocations are also provided, allowing DHS data to be used in a geostatistical model. The DHS is a standardised survey with a two-stage sample design conducted in Global South countries for people aged 15 to 59 (ICF, 2020). The DHS maintains the confidentiality of these respondents by randomly displacing the GPS for the sample clusters by a maximum of five km in rural areas and two km in urban areas (Burgert et al., 2013).

As cigarette smoking is the most common form of tobacco use (WHO, 2023), cigarette smoking DHS data is used for this research. This data is available as a binary variable that indicates if the respondent at the time smokes cigarettes or that they do not. This form of tobacco use refers only to the white manufactured cigarettes that are used across the globe to make more reliable comparisons between the predictions of smoking in different countries. As such, types of cigarettes such as bidis and kreteks that are more prominent in specific countries are not included.

This research selected a country from each continent within the Global South with the most recently completed standard DHS at the time of writing. As such, Guatemala's (2015) survey was chosen from the Americas, Kenya's (2014) survey was chosen from Africa, and Myanmar's (2015) survey was chosen from Asia. Only male cigarette smokers are used in this research as there were very few women who smoke cigarettes compared to men in the study countries, and this would have added uncertainty to the results.

6.3.2 Geospatial covariate selection

A geospatial covariate is a gridded variable across a country at a particular spatial resolution, which acts as a proxy for capturing demographic and socioeconomic variations that may directly or indirectly affect smoking behaviours. During geostatistical modelling, the spatial relationships between the geospatial covariates and smoking at each cluster are calculated by extracting the gridded covariate values that overlay the cluster point smoking prevalence values. Predictions of smoking prevalence at grid square scales are generated by leveraging the spatial relationships between clusters and the relationships between covariates.

The selection of the geospatial covariates to fit this model is crucial in optimising the accuracy of the smoking predictions within each country (Bosco et al., 2017). A correlation between a geospatial covariate and smoking must exist, while multicollinearity between multiple geospatial covariates must be considered. Moreover, a balance is needed between having too few covariates, which could reduce the model‘s predictive power, and too many covariates, which could create a model that overfits the data.

Specific geospatial covariates with plausible prior relationships with smoking were obtained from WorldPop (2018) and the DHS spatial data repository (DHS Spatial Data Repository, 2021). Population count, population density, night-time lights (nanoWatts/cm2/sr), distance to coast (km), distance to main roads (m), slope (°), and elevation from sea-level (m) were downloaded from the former to indicate rurality and so-called 'hard to reach' areas, that may affect the accessibility and availability to cigarettes which has been shown to correlate with poverty. A more urbanised area is likely to see greater accessibility and availability of tobacco, which has been linked to an increase in smoking prevalence (Guliani, Gamtessa, and Çule, 2019; Tun et al., 2017). Although remote areas in the Global South are known for having less access to health services (WHO, 2010), high levels of smoking prevalence could similarly be present in these areas and, therefore, would also depend on the success of any tobacco control policies of regions that include these areas (Guliani et al., 2019). Average male literacy rates were downloaded from the DHS spatial data repository due to clear evidence in the literature that education is associated with the likelihood of smoking (Sreeramareddy et al., 2021; Fernando et al., 2019; Rajabizadeh et al., 2011; Lin, 2010; Marinho et al., 2008; Siahpush et al., 2008). Moreover, a male poverty covariate was also downloaded via WorldPop for Kenya as a proxy indicator for income, which also has a clear association with smoking in the literature (Donfouet et al., 2021; Marinho et al., 2008; Meyler, Stimpson, and Peek, 2007; Rani et al., 2003), although no such covariate was available for Guatemala or Myanmar. The estimated total number of men per grid square in age groups 20 to 24 from Guatemala, 30 to 34 from Kenya, and 25 to 29 from Myanmar were also obtained from WorldPop (2018), as the respondents in these age groups make the largest proportion of smokers in each of these countries according to the DHS datasets. These covariates were aggregated or disaggregated to a one km gridded spatial resolution to standardise the grids and account for the computational power available. When extracting the chosen covariates for the model, buffers are used around all rural clusters by five km and urban clusters by two km to account for the displacement in the cluster locations.

Further information on the source of these covariates is given in Table S 8 of Appendix C. All covariates used are unconstrained, meaning that they are grid square estimations from across the entire surface of each country. Each covariate is representative of the year in which the DHS survey was conducted, except for distance to main roads, which was calculated in the year 2016, male poverty in Kenya, which was calculated for the year 2008, and slope and elevation from sea-level, which was calculated in the year 2000.

To improve the predictive power of the results, this research adopted a framework recommended by Giorgi et al. (2021) in covariate selection. Generalised linear modelling (GLM) was conducted to test the significance of each covariate at the cluster level. Covariates with a p-value > 0.1 were removed, indicating a significantly weak association with cigarette smoking. A control covariate for each model was chosen depending on the P-value of population count or population density. A Pearson's correlation was then used to further test the associations between each covariate. Any covariate with a coefficient of ±0.8 indicates a strong correlation with another covariate and was removed.

6.3.3 The model

The equation for this model can be expressed as:

$$
\begin{aligned}
&Y(c_i) \sim Binomial\left(N(c_i), P(c_i)\right) \\
&logit\left(P(c_i)\right) = X(c_i)^T \beta + R(c_i) \\
&R(c_1), \dots, R(c_n)^T \sim GP(0, \Sigma_R)
\end{aligned}
$$

Where c_i indicates a cluster location (i = 1, ..., n), $Y(c_i)$ is modelled as the predicted outcomes of smoking prevalence in each cluster where $N(c_i)$ is the number of men surveyed in each cluster, and $P(c_i)$ is the number of reported smokers in each cluster. The logit-transformed probability of smoking is related to $X(c_i)$, the matrix of selected covariates at location c_i. β is the estimated regression coefficient of each covariate. $R(c_i)$ is a spatial effect modelled with a zero-mean Gaussian process and a covariance matrix as Σ_R. This effect extends the linear model with a spatial smoothing for the spatial correlation in the data as well as to account for the effect of potentially missing covariates.

The generated coefficient estimates for each covariate from the model give insight into the effect and significance of each case study's regression model. R^2 values were given for each model to indicate the in-sample correlation between predicted and observed smoking prevalence values within the clusters within each country. With these results, 1,000 samples from the posterior distribution of the fitted model were applied to the observed covariates to generate predictions and statistical distributions of the uncertainty around these predictions of male smoking prevalence with a spatial resolution of the gridded surface at 1 km for each case study country.

Using a Bayesian framework, the posterior distribution of gridded predictions generated from the geostatistical model produced for each cell can be aggregated as different outputs, including uncertainty measures, such as setting a 95% confidence interval, which can serve as a measure of the reliability of the smoking prevalence predictions across each country. Measuring the extent of the uncertainty in smoking prevalence predictions within countries identifies the viability of using a geostatistical model to pursue consistent and robust smoking prevalence predictions to benefit tobacco control strategies. Another output of these gridded predictions are predictions that target thresholds have yet to be reached by aggregating the predictions to an administration level where policy decisions are made. The WHO target to reduce national tobacco use by 30% by 2025 from the rates of 2010 was used as the target threshold for each case study (Bilano et al., 2015), with the value set at 15.75% in Guatemala, 17.57% in Kenya, and 53.27% in Myanmar. These proportions were calculated by obtaining the baseline male smoking prevalence in 2010 for Kenya and Myanmar from the WHO Global Health Observatory Data Repository (The World Bank, 2021). Guatemala's 2010 male smoking rates were estimated by assuming a linear trend in prevalence between the 2003 World Health Survey (The World Bank, 2019) and the 2015 DHS dataset for Guatemala. The results are presented in exceedance probability maps, which are the probabilities that the target threshold for a specific country has been exceeded, and so illustrate areas in each country that have or have yet to meet the WHO target.

6.4 Results

Table 16 provides an overview of those who identified as a smoker and those who do not smoke among the male populations from the most recent DHS survey results of the three case study countries.

Table 16. Descriptive statistics of the DHS survey male respondent's cigarette smoking status for Guatemala, Kenya, and Myanmar.

Country	Smokes cigarettes		Total
	No (%)	Yes (%)	
Guatemala	8,753 (78.5)	2,383 (21.7)	11,136
Kenya	10,640 (83.0)	2,175 (17.0)	12,815
Myanmar	3,143 (66.4)	1,594 (33.6)	4,737

The weighted mean of cigarette smoking prevalence among men in the DHS datasets was 21.7% in 2014 for Guatemala, 17.0% in 2014 for Kenya, and 33.6% in 2015 for Myanmar. Therefore, at the national level, the prevalence estimates for Kenya and Myanmar are already lower than the WHO 2025 target threshold prevalence values of 17.57% and 53.27%, respectively. At the cluster level, however, there is considerable spatial variation in smoking prevalence among the respondents around the weighted prevalence mean values, presented in Figure 9, along with the total number of respondents in each cluster. The different scales for each map should be accounted for when comparisons are made. The number of clusters in each country varies, with 853 in Guatemala, 1578 in Kenya, and 440 in Myanmar. The observed smoking prevalence against the number of respondents in each cluster was plotted in Figure S 1, Figure S 2, and Figure S 3 of Appendix C to illustrate potential denominator bias.

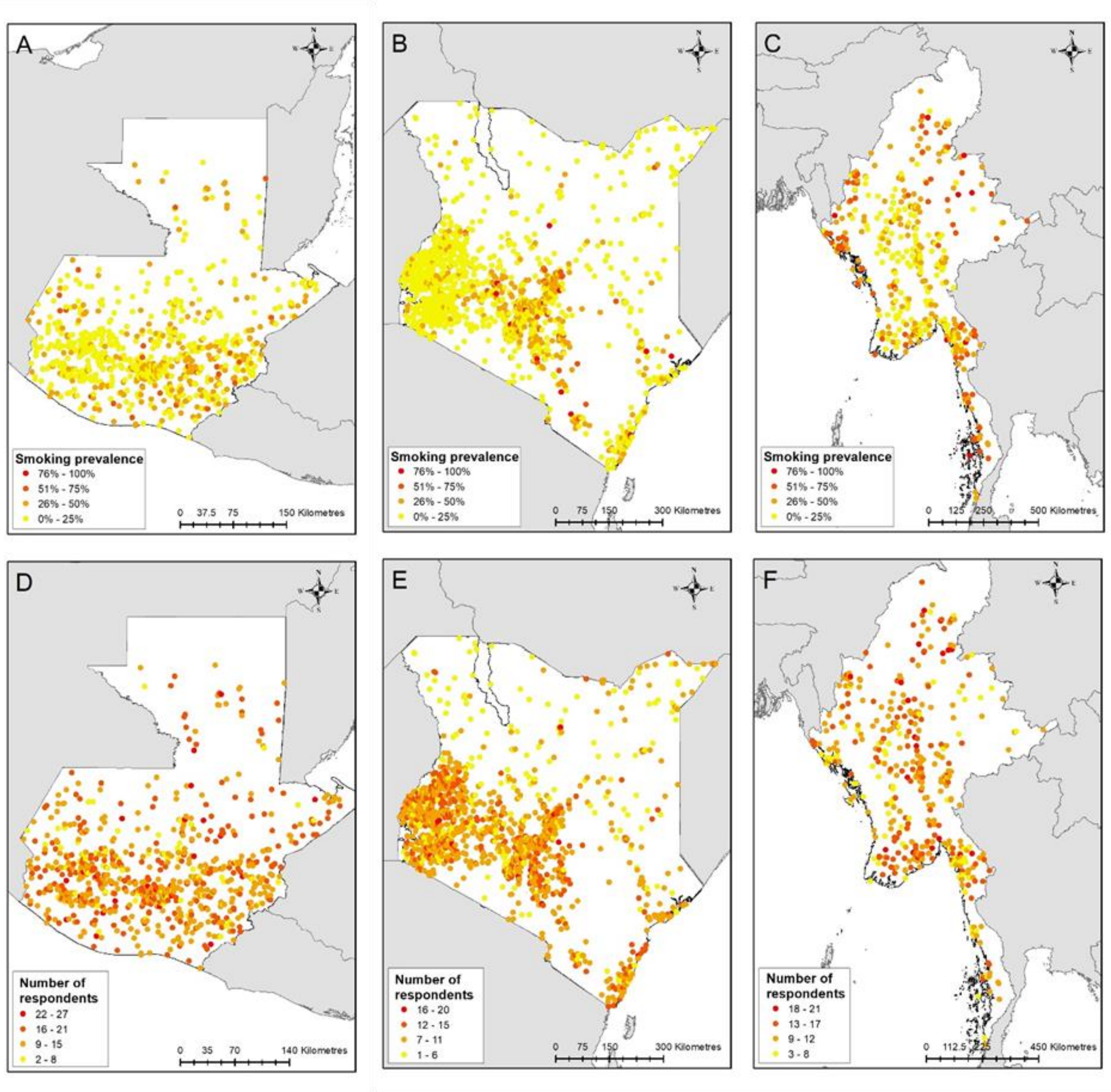

Figure 9. The spatial distribution of the DHS clusters with the calculated smoking prevalence as a percentage for (A) Guatemala with 853 clusters, (B) Kenya with 1578 clusters, and (C) Myanmar with 440 clusters in the First line. The total number of respondent s at each cluster is given in the last line of maps as (D), (E), and (F), respectively.

The results of the non-spatial GLMs for covariate selection for each case can be found in Table 17. Although population count and population density have p-values > 0.1, population density is removed, and population count remains a control covariate in all three case study models. Table 17 highlighted that night-time lights and age have p-values > 0.1 associated with cluster-level smoking prevalence for each country and were eliminated. The remaining covariates with p-values <0.1 were selected for the specific case study model. Pearson correlation tests, given in Table S 9, Table S 10, and Table S 11 of Appendix C, confirm the remaining covariates as having weak correlations between each covariate with a value <0.8.

Table 17. A summary of p-value results from the generalised linear models for each case study country.

Geospatial covariates	**P-values**		
	Guatemala	Kenya	Myanmar
Population count	0.197	0.144	0.639
Population density	0.201	0.276	0.650
Night-time lights	0.937	0.799	0.424
Age	0.352	0.416	0.634
Distance to main roads	0.400	0.301	0.001
Distance to coast	0.067	2.000E-16	0.061
Male literacy rates	0.004	2.040E-10	1.890E-13
Slope	0.755	0.0328	1.170E-6
Elevation from sea-level	1.180E-04	0.003	0.288
Poverty rates	N/A	2.700E-11	N/A

The predictions generated from the geostatistical model for each country are presented in Table 18. Although the GLMs indicate that the selected covariates are statistically associated with smoking prevalence, the covariates vary in their importance as a predictor of smoking prevalence in the models, which is indicated by the 95% credible interval. Covariates that have coefficients with 95% credible intervals that do not include zero are related to smoking prevalence. As such, only the male literacy rates for Guatemala and Kenya are significant predictors of smoking in the model. Therefore, when considering the posterior mean, the former shows that high smoking rates are associated with lower male literacy rates, whereas the latter shows that high smoking rates are associated with higher male literacy rates. Myanmar, on the other hand, had no significant coefficients for the covariates. The models may contain more statistically insignificant separate covariates; however, the collective effect of these covariates to control the spatial effect of smoking has still generated significant models, to varying extents, when accounting for the R^2 values. These R^2 values in Table 18 indicate the variance between the observed and predicted smoking prevalence at each cluster, with a higher percentage indicating a lower variance in the model. As such, the Myanmar model is better at predicting smoking prevalence with a value of 48.27% than Guatemala's model at 27.79% and Kenya's model at 29.07%. Figure S 3 of Appendix C highlights Myanmar's greater predictive power as more cluster-level predictions were closer to the observations in the data than Guatemala (Figure S 1) and Kenya (Figure S 2).

The range parameter refers to the spatial smoothing in the models. A larger range, such as Kenya's, indicates a smoother effect in the model, which generated more robust predictions and reduced the uncertainty associated with these estimates than Guatemala, which has a smaller range.

Table 18. Results of geostatistical models predicting cigarette smoking in three case studies. The coefficients of the model parameters and the posterior estimates of the spatial effect for cigarette smoking among men which includes the R2, posterior mean, Standard Deviation (SD), and the 2.5% and 97.5% quantiles.

Parameters	Mean	SD	2.5% quantile	97.5% quantile
Guatemala (R^2 27.79%)				
B_0	-1.221	0.086	-1.376	-1.033
Population count	-0.015	0.010	-0.034	0.004
Distance to coast	-0.129	0.082	-0.290	0.035
Male literacy rates	-0.110	0.047	-0.201	-0.018
Elevation from sea-level	0.024	0.062	-0.092	0.151
Range (SD)	0.513 (0.378)	0.238 (0.053)	0.237 (0.283)	1.130 (0.490)
Kenya (R^2 29.07%)				
B_0	-2.256	0.181	-2.637	-1.924
Population count	-0.009	0.005	-0.019	0.001
Distance to coast	-0.298	0.307	-0.896	0.364
Male literacy rates	0.267	0.111	0.050	0.487
Slope	-0.018	0.042	-0.101	0.065
Elevation from sea-level	0.162	0.087	-0.008	0.332
Poverty rates	-0.012	0.078	-0.166	0.142
Range (SD)	3.632 (0.699)	1.794 (0.162)	1.514 (0.449)	8.300 (1.080)
Myanmar (R^2 48.27%)				
B_0	-0.355	0.173	-0.676	0.011
Population count	0.002	0.006	-0.009	0.013
Distance to main roads	-0.029	0.089	-0.206	0.145
Distance to coast	0.002	0.175	-0.351	0.346
Male literacy rates	-0.219	0.118	-0.451	0.014
Slope	0.056	0.102	-0.146	0.255
Range (SD)	2.001 (0.601)	0.644 (0.086)	1.084 (0.447)	3.583 (0.787)

The mean of the 1000 posterior estimates sampled from the posterior distribution from the geostatistical models of smoking prevalence among men in each case study have been mapped at a 1 x 1 km resolution in Figure 10. Guatemala (A) shows the highest levels of prevalence occurring in the South/South-East, along part of the coast and around Guatemala City. Kenya (B) shows the highest levels of smoking prevalence in areas in the centre, above Nairobi, and the South of the country along the entire coastline. Myanmar (C), on the other hand, shows the highest smoking prevalence in the periphery of the country. The relative uncertainty associated with these predictions in Guatemala (D), Kenya (E), and Myanmar (F) of Figure 10 highlights areas in which the model is more certain relative to surrounding areas within each country. The relative uncertainty maps in Figure 10 (D) Guatemala, (E) Kenya, and (F) Myanmar were calculated by using the quantile function set at 0.95 in R on the posterior distribution samples. The maps show areas in each country where the predictions from the model are more uncertain. A higher value indicates predictions with a greater SD relative to the mean, indicating greater statistical uncertainty. In all three case studies, the highest level of uncertainty can be found where there are few clusters (Figure 10).

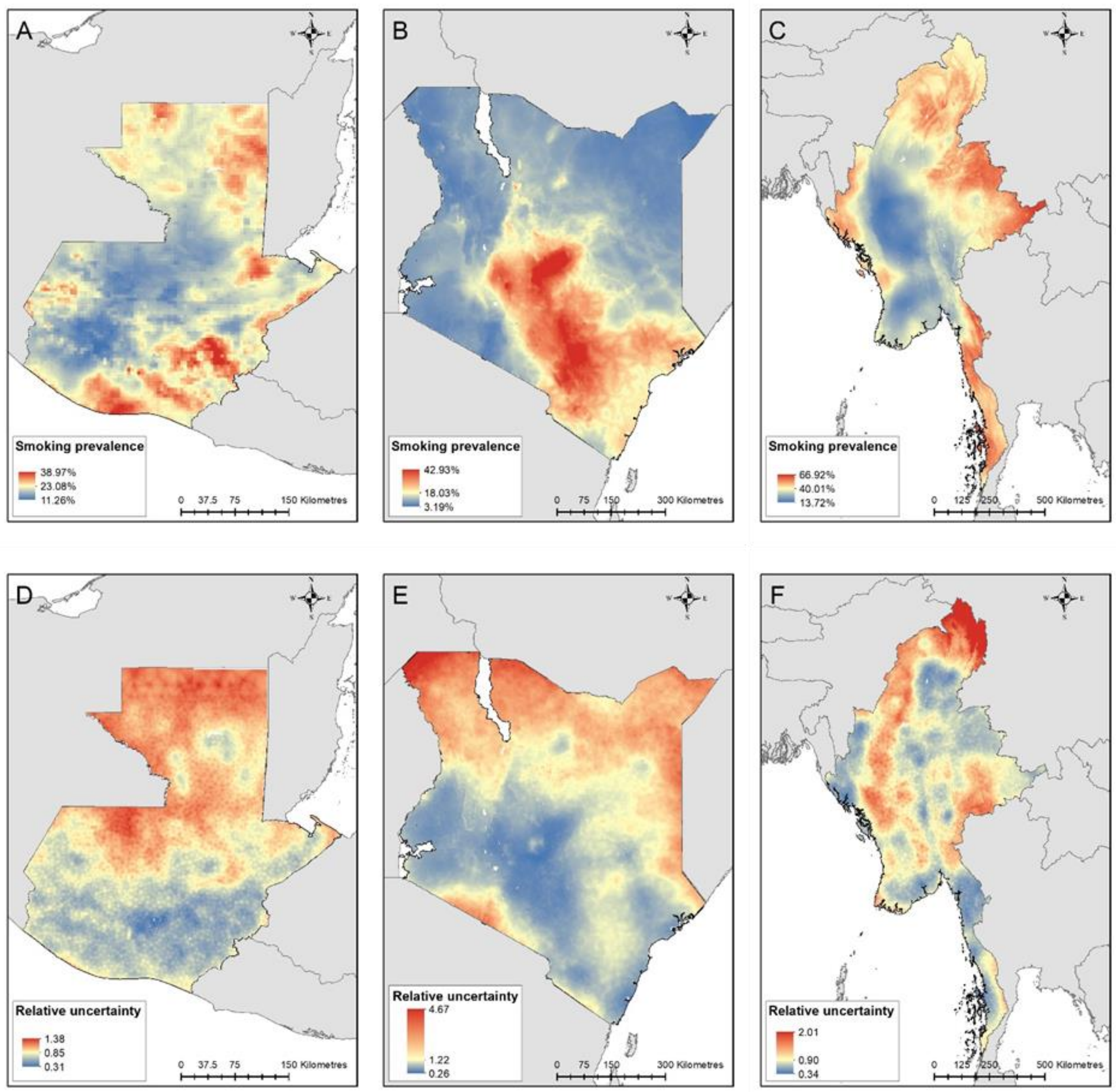

Figure 10. The first line of maps highlights the predicted cigarette smoking prevalence among men at 1 x 1 km for (A) Guatemala in 2015, (B) Kenya in 2014, and (C) Myanmar in 2016. The last line of maps are the accompanying relative uncertainty maps as (D), (E), and (F) which represent the difference in the 95% credible intervals of the predictions by the mean of the prediction of smoking.

Exceedance probability maps presented in Figure 11 indicate smoking prevalence in areas within (A) Guatemala, (B) Kenya, and (C) Myanmar that the model is confident is above the threshold set by the WHO for each country at 15.75%, 17.57%, and 53.27%, respectively. Areas with probabilities close to zero indicate where the model has no confidence that smoking prevalence is more than the threshold. In contrast, areas with a probability close to 100% indicate where the model is almost certain that smoking prevalence exceeds the set threshold. The model for Guatemala is confident that most of the country, except for the centre, exhibits a smoking prevalence higher than 15.75%. The model for Kenya is confident of exceeding the threshold in the centre and to the South of the country along the coast. The model for Myanmar is confident that smoking prevalence exceeds the threshold in the periphery of the country.

The exceedance probabilities were aggregated to these administration levels to relate these exceedance maps to districts within each country where policy decisions are typically made. These maps are presented in Figure 11 for (D) Guatemala, (E) Kenya, and (F) Myanmar. Red indicates areas with smoking prevalence predicted to exceed the national thresholds, whereas blue indicates the opposite.

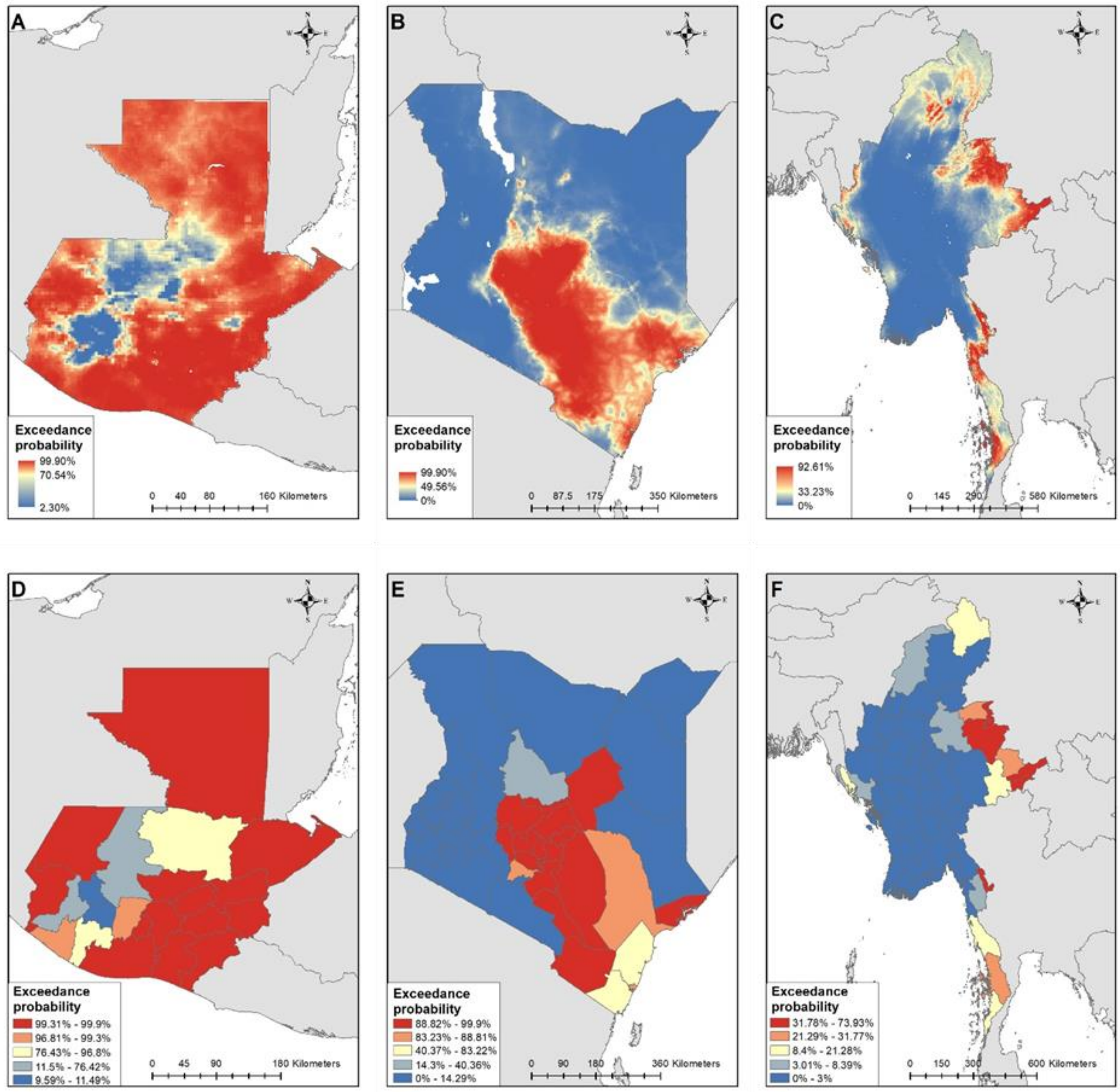

Figure 11. The first line of maps highlights the exceedance probabilities with the minimum smoking prevalence threshold set in (A) Guatemala at 15.75%, (B) Kenya at 17.57%, and (C) Myanmar at 53.27%. The last line of maps shows the exceedance probabilities aggregated into administration level 1 for (D) Guatemala, and administration level 2 for (E) Kenya and (F) Myanmar.

6.5 Discussion

In the Global South context, no SAEs have been generated to predict smoking prevalence at a high spatial resolution in past literature. Doing so in this chapter has highlighted that significant progress is still needed to mitigate the smoking prevalence in local administrative regions that have been predicted to be most affected by it. This presents a significant challenge when considering the limited resources and the lack of implementation of the FCTC within the Global South, making it hard to achieve a significant decline in tobacco use (Reitsma et al., 2021; Tang et al., 2018). The SDG agenda to leave no one behind, however, shifts the focus from top-down to bottom-up approaches to monitoring public health issues, such as the tobacco epidemic (UN, 2015). Monitoring is key to the success of a decline in prevalence; using a geostatistical model to predict prevalence at the small-area level where data is limited can be utilised by policymakers to improve resource prioritisation in areas with high smoking prevalence.

The observed national smoking prevalence in 2014 Kenya and 2015 Myanmar may have already met the WHO's target of 30% reduction by 2025; the exceedance probability maps in Figure 11, however, highlight high levels of heterogeneity of prevalence at the subnational level. The use of such predictions to inform the application of more locally targeted tobacco control policies could reduce the smoking prevalence disparities within countries at the subnational level, which would further build on the progress of the WHO's target in reducing the impact of the tobacco epidemic. The red areas in Figure 11 indicate where governments could prioritise tobacco control resources. Although blue areas may not be as urgent as red areas, the need for tobacco control resources in some areas should not be disregarded, as smoking prevalence, such as in blue areas in Myanmar (Figure 11), may still be considerably high relative to other countries. Unlike Myanmar and Kenya, Guatemala appears unlikely to reach the WHO's national target. The small-area level predictions for Guatemala indicate that smoking prevalence is high, relative to the target threshold, throughout the country. It should be noted that deaths from tobacco use are a growing problem within Guatemala; however, according to the Global Burden of Disease Study, tobacco use is ranked 10th in associated deaths (IHME, 2021). Although the results of this research may promote the mitigation of tobacco use, it would also be prudent to warrant additional attention on the other higher-ranked public health issues.

The predictions generated in Table 18 and the mapped predictions in Figure 10 illustrate both the spatial heterogeneities of smoking prevalence and the difficulty in finding geospatial covariates that are consistent in explaining the variation throughout the Global South. The lack of consistency, however, was expected. The contrasting relationship between male literacy and smoking in Kenya (Table 18) is supported by Kurgat et al. (2019), whose research identified that higher educational attainment is associated with a higher likelihood of cigarette smoking within Kenya. Using population count, distance to main roads, distance to coast, slope, and elevation from sea level as proxies for rurality has highlighted large urban areas with low relative uncertainty that have either low or high smoking prevalence within Kenya in Figure 10. For instance, Nairobi, near the centre of the country, has a higher predicted prevalence than Kisumu to the east of the country. This urban difference is noted in Achoki et al. (2019), whose research found that smoking was a larger risk factor in Nairobi than in Kisumu. Poverty rates could influence this, as according to Donfouet et al. (2021), higher rates of smoking were associated with poorer urban areas. By further dissecting the cluster-level data in Nairobi, of which a significant portion of its inhabitants were found to live in slums (Kyobutungi et al., 2008), there were a number of areas with either low or high smoking prevalence throughout Nairobi. Literature from Myanmar also corroborates the same association between lower literacy rates and smoking found in the Myanmar model in Table 18, with Sreeramareddy et al. (2021), who found higher smoking rates among those with no education. Sreeramareddy et al. (2021), however, found an inconsistent association with rural areas among men in contrast to the high prevalence levels in mostly rural areas in Figure 10 of this research. Tong et al. (2011), however, found that smoking prevalence in Guatemala was higher among men in urban areas than in rural areas, which agrees with the predictions of this research. Figure 10, however, shows high rates in the country's rural North, although high uncertainty levels are associated with these estimates.

At the time of writing, the DHS Spatial Data Repository (2021) supplied spatial interpolation surfaces using a geostatistical model, with its most recent datasets for men who do not smoke in Guatemala and Myanmar. These models, however, focused on men who specifically smoke cigarettes and indicated areas of high prevalence, so the results of which are different. Focusing on one method of tobacco use acknowledges the variation in the social and economic factors that vary nationally and sub-nationally that affect a person's choice of tobacco use. Doing so was an attempt to provide more meaningful associations between cigarette smoking and the covariates to improve the model's predictive power. Additionally, the covariates this research mainly used differed from those used to generate the DHS maps. This is because this research attempts to tailor a model for each country with covariates that indicate known determinants of smoking (literacy rates and poverty rates) and the possible accessibility and availability of cigarettes rather than a set of standardised covariates that cover a range of dependent variables like the surfaces modelled by the DHS (Gething et al., 2015). Though some areas within the North of these countries in the DHS modelled surfaces show relatively lower rates of non-smokers in areas of relatively high smoking prevalence shown in A and C in Figure 10, there are differences in these results throughout the rest of Guatemala and Myanmar.

Notwithstanding the supporting evidence for the modelled SAEs drawn from previous research, it must be acknowledged that this research has limitations. The method may be feasible to predict tobacco use with cluster-level data, but the input datasets have limitations. Firstly, the DHS surveys included only those aged between 15 and 59 in Guatemala, 15 and 54 in Kenya, and 15 and 49 in Myanmar. Therefore, the results represent those specific age groups rather than the entire adult population. Secondly, the R^2 results show that, as expected, the model did not predict smoking prevalence perfectly, relative to the observations, across each country. The sparsity of clusters in rural areas added greater relative uncertainty within low-populated regions, as did the clusters with a low number of respondents, particularly for Kenya, as seen in

Figure S 2 and Figure 9. Moreover, as discussed previously, urban areas have more significant variations in cluster-level smoking prevalence. As the models appear to predict homogenous levels in urban areas, these predictions may also add uncertainty to the model. A possible solution to this would be to model urban areas separately. Thirdly, the accuracy of the predictions is likely reduced due to the buffering of rural and urban clusters to account for the cluster displacement (Gething et al., 2015). This especially affects urban areas as a two km displacement is a considerable distance when considering the population densities and characteristics within highly urban areas. Fourthly, the model could have benefitted from additional geospatial covariates that could be used as proxies of other determinants of smoking, such as marital status and unemployment rates. Whilst such variables may be available through national census data, which other SAE methods could use, this research aimed to test an approach that could overcome the limitations of irregularly conducted national census data by testing the associations between geospatial covariates and smoking prevalence. Lastly, the predictions generated for Guatemala, Kenya, and Myanmar used the most recent datasets at the time of writing from 2014, 2014, and 2015, respectively, meaning that the results represent a snapshot in time and so may not be a reliable representation of the current smoking prevalence landscape. To overcome this in future research, previous data must also be modelled to indicate possible trends. Much like Reitsma et al. (2021), which used a space-time direct estimate model that incorporated continuous cigarette use variables centred around the mean and age to generate trends in smoking prevalence in most countries from 1990 to 2019.

6.6 Conclusion

This research has indicated an SAE approach in which local heterogeneities of tobacco use, in this case, cigarette smoking, can be predicted in three case studies. In Guatemala, the predictions found that male smoking prevalence is higher in rural areas, which is contradictory to what was found in Tong et al. (2011) research. Whereas in Kenya, urban areas, such as Nairobi, have higher predicted smoking prevalences than other urban areas, such as Kisumu. Predicted smoking prevalence in Myanmar, on the other hand, was found along the mountainous periphery of the country. Figure 11 shows that the predictions can be aggregated to a regional administration level. This highlights which local government administration needs more tobacco control support than others within the country to meet the WHO target.

Regarding policy implications, this chapter shows the importance of identifying where high smoking prevalence is in each country so that tobacco control resources can be more efficiently allocated, rather than just identifying which country has the highest national smoking prevalence. The governments of Guatemala, Kenya, and Myanmar must, therefore, supply more tobacco control resources in areas in greater need. Doing so would ensure that no area is left behind, which would otherwise likely feel the negative health impacts of smoking in the future more so than the rest of the country. International Organisations, such as the WHO, must account for local-level smoking prevalences, rather than just using national-level statistics, to observe if a country has achieved tobacco reduction goals. The methodology tested here provides interested parties an opportunity for such surveillance. Tailoring the model further for other countries may also generate robust predictions that can help guide the allocations of tobacco control resources and policies at the local administrative level.

In future research, inputting new cluster-level data when it becomes available could highlight trends in smoking prevalence over time within countries. Doing so would indicate the progress regions are making within countries to reduce cigarette smoking, which could also support the guidance of tobacco control resources to areas with high prevalence. This would result in robust tobacco use monitoring that could be key to the SDG agenda, specific for each country, which is essential for the success of tobacco control within the Global South. Future research should also focus on other forms of tobacco use, such as smokeless tobacco or local types of consumption more commonly found in specific regions, or on the impact of ENDS. These extensions would improve the monitoring of tobacco use in general.

Chapter 7 General discussion and conclusion

This thesis has sought to further knowledge of the spatial heterogeneity of smoking prevalence in the Global South. Chapter one established the importance of the research topic by highlighting the urgency of mitigating the tobacco epidemic and its unequal burden within countries of the Global South. Chapter two presented a scoping review of the current literature on tobacco use prevalence in the Global South and examined the extent to which the known social determinants of smoking apply in the Global South; it identified gaps in current knowledge concerning tobacco consumption in the Global South and formulated research questions to address these gaps. The research questions were:

1. How does the significance of the social determinants of tobacco use vary within the Global South?

2. How has tobacco use changed over time within the Global South?

3. How have the country-level determinants of tobacco use impacted changes in tobacco use prevalence over time in the Global South?

4. How does tobacco use vary within countries of the Global South?

Chapter three examined the available databases that hold robust, internationally comparable information on tobacco use and which can be used to address the chosen research questions. The chapter also details the measurement and management of key variables used in the subsequent empirical chapters.

Chapters four, five, and six form the empirical core of the thesis. Each of these empirical chapters has been written for journal submission. Chapter four addresses research question one. Chapter five jointly addresses research questions two and three. Chapter six, the third empirical chapter, examines the final research question, developing small area estimates of smoking prevalence for three case-study countries of the Global South and examining these local prevalences in relation to current international tobacco reduction goals.

This concluding chapter discusses the academic contribution made by the research in terms of its findings concerning the research questions posed in chapter two and the implications of the results for tobacco control policy. The chapter concludes with possible future research directions that build upon the results of this thesis before ending with a brief reflection on tobacco consumption in the Global South.

7.1 Addressing the Research Questions

This section summarises the approach taken to each research question, the findings for each research question and the limitations of the respective empirical study. Each section concludes with a summary of each research question's general academic contribution to knowledge.

7.1.1 Research Question 1: How does the significance of the social determinants of tobacco use vary within the Global South?

Current literature from the Global South has, in most cases, not extensively examined the extent to which social determinants of smoking vary in their impact on smoking prevalence across national populations. Chapter four addresses research question one by finding statistically significant patterns between key determinants identified in chapter two using the DHS datasets identified in chapter three.

Chapter four used binomial logistic multilevel models with IGLS as a novel approach to highlight how the models change by introducing each variable separately to identify the extent to which they influence the model for multiple countries. The variables indicated a respondent's household, cluster, and region to account for the multilevel cluster-random design of the DHS datasets for 37 countries. This also allowed for the analysis of these associations at different spatial scales. The models were unweighted as the variables, and the spatial levels controlled the non-uniform probability of selection in the DHS survey. The cluster-level residuals of the results were explored with global and local Moran's I statistics to identify the extent of spatial autocorrelation in the models and, more simply, where the models are over- or under-predicting smoking prevalence at the small-area level. Evidence of spatial autocorrelation would suggest there are other missing variables influencing the models.

The themes identified in the results for chapter four showed that, in general, being male, older, single, having fewer children, having less education, being employed, less wealthy, and living in urban areas confer more risk of smoking. There are exceptions, especially with the socioeconomic variables, some of which have insignificant or contradictory results, generally confirming prior literature. The lack of common patterns to the socioeconomic determinants of smoking across the Global South points to the heterogeneity underpinning smoking in the Global South and the need to examine additional determinants of smoking that are country-specific. The significant spatial autocorrelation found within the results for specific countries found groupings of cluster-level residuals that, in most cases, indicated that the models were under-predicting smoking. There was no discernible pattern between these countries that could identify the reasons behind this finding. This suggests that multi-country research should use a model with small-area level variables representing country-specific smoking determinants that can be applied to each country separately.

The analysis in this chapter was subject to the limitations of the datasets. The definitions of some variables could vary between countries. The type of place, whether urban or rural, is usually decided by the DHS surveyor, reflecting either the level of infrastructure visible at each data collection point or the size of the population. This means that this variable may have a degree of operator variation. There was also a limit on the age at which someone could be included in the survey results, with most DHS surveys limiting the respondents to people between the ages of 15 and 59. The generalisations generated from this research, therefore, do not include those outside this age range. Moreover, the generalisations may be more specific to Africa as most of the datasets used were from African countries. Additionally, cluster displacement affected the spatial autocorrelation, which protected the respondents' anonymity. This introduces uncertainty into the inverse distancing technique used to calculate Moran's statistics, meaning that clear conclusions could not be drawn about where smoking prevalence is being under or over-estimated. Finally, the interpretations of the results show only associations between selected determinants and smoking; they do not explain why people smoke due to this being a cross-sectional analysis.

Chapter four builds on our current understanding of smoking prevalence across the Global South by showing how selected social determinants vary between countries. Only Reistma et al. (2021) and Ng et al. (2014) have examined smoking prevalence in the Global South and its association with social determinants on a multi-national scale. Both highlighted the need for more monitoring of such variations. The results of this chapter highlight both straightforward and more complicated novel associations with the determinants of smoking across the Global South. In corroboration with the prior literature, the demographic determinants appear to have more consistent associations with smoking. In contrast, the literature on socioeconomic variables shows no consistent associations with smoking prevalence, which is apparent in this chapter's results. As such, this chapter, like Reistma et al. (2021) and Ng et al. (2014), confirms the need to avoid generalised and, therefore, oversimplified assumptions about the magnitude and direction of the association between smoking and socioeconomic determinants within the Global South.

7.1.2 Research question 2: How has tobacco use changed over time within the Global South? Research Question 3: How have country-level determinants of tobacco use impacted the change in tobacco use prevalence over time in the Global South?

The study of the SETM in chapter two noted how the association between gender and smoking was predicted to change over time. Chapter two highlighted the relative lack of research in the Global South into these changes and the associations between other determinants and smoking over time. This research gap extended to associations with national-level determinants of smoking. Chapter five addresses research questions two and three by identifying the extent to which national-level determinants influence the smoking rate over time, with individual and cluster-level determinants as a control.

Chapter five used binomial logistic multilevel regression models with IGLS as a novel approach to examine changes in smoking prevalence in 17 Global South countries that had multiple surveys over time. The individual and cluster-level variables in chapter four of the DHS were used to understand how these effects have changed over time. National-level determinants from international organisation databases were added to the model, and the additional effect of changes in these high-level determinants on smoking prevalence was considered. A within-between formulation was used to account separately for the longitudinal and cross-sectional effects associated with such models (Bell and Jones, 2015). As such, country-year and country-level variables were calculated for each national-level determinant. A sequential model-building strategy first identified the pattern in smoking prevalence over time between countries. A second model added gender, mean-centred year, and mean-centred age variables to separate age and period effects. The third model added the remaining individual, cluster, and national-level determinants to the analysis, with the analytical focus on the latter.

The results for chapter five indicated expected significant associations between sub-national explanatory variables and smoking across the datasets. For the 17 countries in the analysis, smoking prevalence remained constant or increased over time; Nepal was an exception, showing a decline in smoking prevalence. These results indicate that the 17 selected countries can be placed at different points on the SETM. The associations with individual- and cluster-level determinants of smoking found in chapter four and the literature were also found in this chapter; however, analysis over time showed that, in general, those who are younger, are female, have more education, more wealth, more children, those who are unmarried, who are unemployed, and who live in rural areas are becoming less likely to smoke. This indicates less entrenched tobacco societal norms, less tobacco-friendly environments, and greater access to tobacco control resources within these subpopulations. The within-country results show that increases in HDI and MPOWER are linked with a decreasing smoking rate over time. This supports the general literature and shows the importance of the MPOWER tool for tobacco control. Conversely, an increase in tobacco production is linked with an increasing rate of smoking over time.

Most of the respondents in the DHS datasets used in chapter four were women, so the analysis of change over time and the impact of national determinants applies largely to smoking by women. This is a clear limitation to the analysis as either issue may differ for male smokers. Another limitation is the simplification of variables; employment status, for example, was aggregated to be either unemployed or employed. Although this helped to avoid overcomplicating the model, excluding different types of jobs or partial/casual employment overlooks that some types of jobs may be more associated with smoking than others. Similarly to chapter four, there may also be other national-level variables that have yet to be distinguished in the literature that could be added to the model.

This chapter took a novel method approach to the analysis of determinants of smoking at different spatial levels over time within countries. The trajectories of the small-area and cluster-area level determinants indicate a growing inequality in smoking among men, who are poorer, married, employed, less educated, and have fewer children and a growing likelihood of smoking over time. This furthers our understanding of the extent to which smoking prevalence changes, thus providing trajectories that indicate future smoking prevalence in each country. This brings the future relationships between smoking prevalence and the determinants of smoking to attention when the literature mostly focuses on the current rates of smoking. The literature on the longitudinal variation of smoking prevalence in the Global South that does exist focuses on examining it in relation to national-level determinants, such as MPOWER (Ahsan et al., 2022; Islami et al., 2015; Husain et al., 2021), human development (Bogdanovica et al., 2011), and tobacco production (Martins-da-Silva et al., 2022). The research results strengthen this literature and highlight the importance of national-level determinants as predictors of smoking prevalence; these have not previously been explored as much as individual and small-area level determinants.

7.1.3 Research Question 4: How does tobacco use vary within the countries of the Global South?

There is a lack of representative small-area level data within the countries of the Global South. Small-area data are needed to show how smoking prevalence varies within a country and to enable the targeting of tobacco control initiatives to the places of greatest need. Understanding the geographically differentiated impact of the tobacco epidemic within countries that are most economically vulnerable will be key to future tobacco control and the mitigation of local, national and global economic and human costs. Chapter six answers research question four by generating SAEs for three selected Global South countries: Guatemala, Kenya and Myanmar. It thus examines the small-area level heterogeneity of smoking prevalence.

The method chosen for SAE used Bayesian geostatistical estimation with a spatial smoothing function to produce exceedance probability maps, visualising the probability of meeting the WHO's target for a 30% reduction of tobacco use of the 2010 prevalence rates by 2025. The exceedance probability predictions were aggregated to local administrative area levels to make the results more applicable to national and local governments. Using weighted mean prevalence, the WHO target for tobacco use reduction for these countries was calculated to be 15.75% in Guatemala, 17.57% in Kenya, and 53.27% in Myanmar prior to the model analysis. The choice of using three countries was based on a desire to cover different continents. Novel geospatial covariates were also used as spatial markers of smoking, impacting an individual's accessibility to tobacco. Given the low levels of smoking among women found in the results of chapters four and five, chapter six focussed only on the SAEs of male smoking.

The results of this chapter identified the heterogeneities of smoking prevalence among men across these countries. The associations between smoking prevalence and the covariates in the model indicate that male literacy rates for Guatemala and Kenya were statistically significant predictors of smoking, with no individual significance found in any associations in Myanmar. The chosen covariates did, however, generate collectively significant models. The spatial smoothing within the models indicated that the predictions for Kenya were more robust and had less associated uncertainty, with Guatemala's predictions being the least robust and having the most uncertainty. The lowest variance between the observed and predicted smoking prevalence indicated that the model was best overall at predicting smoking prevalence within Myanmar. The relative uncertainty generated in all three countries highlighted the sparsity of data collection points within rural areas; this impacted the reliability of the smoking prevalence predictions in these areas. The exceedance probability maps highlighted which subnational administrative governments hit the 30% tobacco use prevalence target during data collection. Most of the subnational administrative areas within Guatemala did not exceed this target compared with Kenya and Myanmar, where central and mostly northern regions, respectively, needed additional tobacco control measures to meet the target.

Chapter six had limitations similar to those found in chapters four and five. One limitation was that urban areas exhibit less variation in prevalence than rural areas; this could add uncertainty, and the predictions may have been more reliable if urban and rural areas had been modelled separately. The buffering technique used to control cluster displacement for anonymity was also a limitation: rural respondents' data are displaced over a larger area than the urban respondent's data. Lastly, the results represent predictions of smoking in Guatemala and Kenya in 2014 and Myanmar in 2015. As such, these predictions are not up-to-date and add uncertainty if used to inform where tobacco mitigation resources are most needed.

To date, SAEs of smoking prevalence have been mainly generated for Global North countries (Smith et al., 2011; Twigg et al., 2000, 2004). In addressing research question four, this thesis has provided a novel methodological and substantive extension to a Global South context that also contributes to our understanding of the extent to which these countries meet tobacco control targets set by the WHO. Though Kenya and Myanmar have already reached the WHO's tobacco reduction target at a national level at the time of data collection, the results of this chapter show there are subnational areas within these countries and Guatemala that have not. The areas that are likely to miss the target may indicate an unequal implementation of the FCTC within these countries and lend weight to the findings of Reitsma et al. (2021) and Tang et al. (2018), who observed a lack of resources and motivation for implementing the FCTC in the Global South compared to the Global North. The exceedance probability maps highlight an approach that can be used to monitor prevalence, which honours the SDG's agenda of leaving no one behind (UN, 2015).

7.2 Policy implications

The intended primary audiences targeted by this thesis are national government policymakers and international bodies, such as the UN and the WHO, which have decision-making power in the process of implementing and fine-tuning current and future tobacco control policies at national and local levels. The secondary target audiences are any interested researchers and research groups that can build upon this research in the future to further our understanding of the determinants of tobacco use, the trajectories of tobacco use over time, and generating predictions of tobacco use in areas with less reliable and poorly represented small-area level data.

While the main outputs of this thesis will be academic papers, it is acknowledged that influencing policy will likely require more targeted and succinct summaries of the research findings. It is hoped that these summaries can be tailored for specific policymakers, responding to relevant policy initiatives at both the national health planning level and internationally, such as those related to monitoring the FCTC.

With the intended audiences of this thesis in mind, the implications drawn from the findings in this thesis highlight areas in which policy must improve. Firstly, the three empirical chapters show specific subpopulations with the highest smoking prevalence. As such, policies must account for this by targeting tobacco control measures on people who are male, older, single, have fewer children, have less education, are employed, are less wealthy, and live in urban areas. Doing so would improve the utilisation of the limited resources at hand for those most at risk, thus mitigating the long-term health impacts for the individuals involved and the long-term impacts for the national economies that would bear the burden of an ill-health-induced diminishing workforce.

Secondly, the country-level determinant MPOWER was significantly associated with declining smoking prevalence. Collecting MPOWER data at a subnational level would enhance our understanding of smoking variation and improve our predicted prevalence trajectories. Doing so would better prepare public health professionals and government agencies for small-area level tobacco control within local administrative regions in the near future. Implementing MPOWER is clearly effective and should be encouraged.

Thirdly, country-level statistics and targets often mask small-area inequalities and provide a sense of success when issues such as the tobacco epidemic vary locally. Tobacco use reduction targets should, therefore, account for small-area level heterogeneities so that no one is left behind. This, of course, is the overall aim of the SDGs. Doing so would stop countries from using national-level prevalence rates as the benchmark when small areas and communities that are often overlooked are as important.

Fourthly, though the methods employed are effective, when limited data is available at the cluster level, more regular standardised data collection must be encouraged to generate more robust projections, especially in rural areas. This is to improve the monitoring of tobacco use by reducing uncertainty in predictions or risk assessment. This is key to the effectiveness of the FCTC when larger and less regular surveys and national censuses would be too expensive to conduct. Moreover, improving the monitoring with more data would help enhance understanding of the trajectories of smoking prevalence. This would benefit Global South countries by providing greater insight into the changing dynamics of smoking prevalence associations with determinants that can be subject to interventions. These predictions would help guide and tailor current and future tobacco control policies.

Lastly, the persistence of smoking prevalence in Global South countries highlights the need for a greater international response to curtail the growing health and economic impacts of the tobacco epidemic in countries that are least able to afford it. The FCTC must, therefore, be prioritised and implemented more than it currently is in the Global South, with strong support from neighbouring and Global North countries. Doing so would minimise the human and economic cost of smoking and bring about the beginning of the end of the tobacco epidemic. It is important to acknowledge that other communicable and non-communicable public health issues are also a cause of concern and must be mitigated; however, the impact of the tobacco epidemic is undeniable.

7.3 Future research

The methods adopted and the results generated in this thesis contribute to our wider understanding of smoking in the Global South. Other researchers or public health experts can use them to gain further insights and monitor tobacco use for the FCTC. Numerous future research possibilities arise from both the results presented here and the research methods applied.

Regarding methods, the modelling approaches in this thesis, with the exception of chapter six, have relied on IGLS estimation. Other approaches could also be used, most notably MCMC estimation (Browne, 2009). This could be used instead of IGLS, and comparisons between the approaches can be made to identify which are more effective models for measuring the associations between the determinants of smoking. Microsimulation approaches used by Smith et al. (2011) could also be explored to generate synthetic estimations of smoking when more small-area level datasets become available, which can be compared with the predictions generated with the geostatistical modelling approach.

Careful selective processes were used to find viable databases for analysis, as set out in chapter three. Nevertheless, other datasets are available, and replication, where possible, with these alternative sources would add strength to the research. Improvements to datasets over time and the emergence of replicated datasets or even cohorts would allow for significantly extended research possibilities. For example, the longitudinal effects on smoking prevalence and the association with national determinants should be analysed further to build upon the findings of this thesis. Additionally, more Global South countries must be investigated when data becomes available, as this thesis could not include all countries within this region.

Another area for future investigation is the other unknown influences of smoking prevalence that were not accounted for here, which could explain the varying effectiveness of the models for each country. Such work should examine local area variables specific to each Global South country to tailor the methods used here to better improve our understanding of the heterogeneity of smoking prevalence. Moreover, the feasibility of generating SAEs from DHS and auxiliary datasets must be regularly examined, as other sources of datasets may, in the future, be more of a viable choice.

Finally, this thesis focused specifically on cigarette smoking as this is the main form of tobacco use in the Global South. The choice also reflected the complex social and cultural norms that apply to other forms of tobacco use. Going beyond cigarette smoking would have overcomplicated the analysis. Similar investigations with other forms of tobacco use that are more region-specific would further improve the monitoring of tobacco use and be beneficial for tobacco control policies within these regions. The emergence of ENDS as a replacement for tobacco is also a critical area of concern, as this could lead to a new nicotine-related epidemic. Future research must investigate new and alternative prevalences and their long-term harms.

7.4 Concluding remarks

The vast scale of the tobacco epidemic and the impacts discussed in this thesis highlight the urgency of mitigating tobacco use sooner rather than later when the health and economic costs will be much greater in the Global South than they currently are. Compared with the Global North, the ‘endgame’ of tobacco use within this region is currently far from being achieved as it is not prioritised as highly as improving economic forecasts and the eradication of infectious diseases (Moon et al., 2018). Regardless, the aim of eradicating the tobacco epidemic must be achieved to diminish the inequality that tobacco use perpetuates. This requires monitoring. Care must be taken to identify and remove the risk of people trying or continually using tobacco in areas of the world that have tobacco use interwoven into cultural practices and societal norms. A lack of care could be misconstrued as an attack on local customs and beliefs, isolating local smokers further and inadvertently creating ‘smoking islands’ that are less likely to accept tobacco control measures (Barnett et al., 2016).

Appendix A Supplementary materials for chapter 4 "Investigating the determinants of cigarette smoking in the Global South: A multilevel analysis".

Table S 1. Table of the DHS data cleaning process, in which missing data is removed incrementally from the datasets in the order presented in this table.

Country	**Missing variable data**					**Total removed**	**Total remaining**
	Cigarette smoking	Employment status	Marital status	Number of children	Education level		
Angola	0	0	0	0	0	0	20,063
Benin	0	0	0	0	0	0	21,779
Burkina Faso	9	22	1	0	0	32	24,357
Burundi	1	7	0	0	0	8	13,661
Cambodia	2	8	0	0	0	10	22,758
Cameroon	7,987	30	0	0	0	8,017	14,600
Comoros	10	0	0	0	19	29	7,447
Cote d'Ivoire	17	42	0	0	0	59	15,136
DRC[21]	4	68	0	0	0	72	27,411
Eswatini	3	23	0	0	0	26	9,117
Ethiopia	15	28	0	0	0	43	30,582
Gabon	19	37	0	0	0	56	14,020
Ghana	4	7	0	0	0	11	13,773
Guatemala	25	8	0	0	0	33	37,026
Guyana	38	41	0	0	0	79	8,439
Haiti	8	15	0	0	0	23	23,757
Honduras	5	35	0	0	0	40	29,837

[21] DRC is an abbreviation of the Democratic Republic of the Congo.

Country	**Missing variable data**					**Total removed**	**Total remaining**
	Cigarette smoking	Employment status	Marital status	Number of children	Education level		
India	0	577,336	0	0	0	577,336	234,472
Kenya	16,348	30	0	0	0	16,378	27,520
Lesotho	0	0	0	0	0	0	9,552
Liberia	3	31	0	0	0	34	13,323
Madagascar	8,832	13	0	0	0	8,845	17,116
Malawi	22	46	0	0	0	68	30,127
Mali	0	0	0	0	0	0	14,823
Mozambique	0	0	0	0	0	0	17,780
Myanmar	0	5	0	0	2	7	17,615
Namibia	7	60	0	1,373	0	1,440	11,689
Nepal	0	0	0	0	0	0	16,794
Nigeria	150	287	0	0	0	437	55,870
Philippines	3	28	0	0	0	31	18,368
Rwanda	3	33	0	0	0	36	19,678
Senegal	2	0	0	0	0	2	20,615
Sierra Leone	24	0	0	0	0	24	23,853
Tanzania	5	36	0	0	0	41	12,625
Timor-Leste	1	8	0	0	0	9	17,204
Togo	3	12	0	0	0	15	13,941
Uganda	9	0	1	0	0	10	10,959
Zambia	4	81	0	0	20	105	31,079
Zimbabwe	0	0	0	0	0	0	16,651

Appendix B Supplementary materials for chapter 5 "investigating the trajectories and national determinants of cigarette smoking in the Global South: A multilevel model approach".

Table S 2. Table of the DHS data cleaning process, in which missing data is removed incrementally from the datasets in the order presented in this table.

Country	**Missing variable data**					**Total removed**	**Total remaining**
	Cigarette smoking	Number of children	Marital status	Employment status	Education level		
Cambodia	11	0	0	20	0	31	49,730
Ethiopia	23	0	0	40	0	63	50,665
Ghana	12	0	0	64	0	76	33,898
Indonesia	4,442	0	0	123	5	4,570	151,632
Kenya	16,361	0	0	79	0	16,440	51,140
Lesotho	10	0	2	9	0	21	30,364
Liberia	17	0	2	133	8	160	26,298
Malawi	69	0	0	55	0	124	45,030
Mozambique	7	0	0	24	0	31	33,067
Namibia	13	1,373	4	113	0	1,499	26,715
Nepal	0	0	0	0	1	1	31,984
Nigeria	222	0	4	583	0	809	114,335
Rwanda	20	0	0	80	0	100	55,755
Sierra Leone	65	0	0	106	0	171	34,403
Uganda	10	0	1	27	0	38	21,965
Zambia	14	0	0	109	20	143	44,687
Zimbabwe	7	0	0	51	0	58	32,675

Country	**Missing variable data**					**Total removed**	**Total remaining**
	Cigarette smoking	Number of children	Marital status	Employment status	Education level		
						Total dataset	834,343

Table S 3. Multicollinearity of the variables in the model.

		Collinearity Statistics	
		Tolerance	VIF
Individual and Household level	Age	.586	1.707
	Gender	.894	1.118
	Education	.634	1.576
	Wealth	.576	1.736
	Children	.593	1.685
	Married	.636	1.572
	Employed	.860	1.163
Cluster level	Place	.652	1.535
Country-year level (Within effects	CPI	.342	2.922
	PSI	.568	1.759
	MPOWER	.312	3.203
	UI	.121	8.297
	HDI	.094	10.601
	TP	.631	1.584
Country Level (Between effects	CPI	.487	2.055
	PSI	.470	2.126
	MPOWER	.226	4.427
	UI	.360	2.779
	HDI	.154	6.504
	TP	.573	1.746

Table S 4. Random part variance of each model, including the standard error values.

		Model 1	Model 2	Model 3
Random Part	Country level variance	0.262 (0.103)	0.569 (0.205)	0.294 (0.107)
	Country-year level variance	0.060 (0.024)	0.030 (0.017)	~0
	Region level variance	0.167 (0.013)	0.241 (0.019)	0.180 (0.016)
	Cluster level variance	0.209 (0.006)	0.320 (0.007)	0.245 (0.008)
	Household level variance	~0	~0	~0

Table S 5. Model 1 (null model) and model 2 results for age, gender, and year coefficients; including standard error values.

Variables			Model 1	Model 2
Constant			-2.424 (0.133)	-4.228 (0.188)
Individual and Household level	Age			0.042 (0.000)
	Gender	Male		2.981 (0.012)
Country-year level (within effect)	Year			-0.002 (0.011)

Table S 6. Part one of the results for a 5-level (respondent, household, cluster, region, and country-year) binomial logistic multilevel regression model for individual countries.

	Variables		Cambodia	Ethiopia	Ghana	Indonesia	Kenya	Lesotho	Liberia	Malawi	Mozambique
	Constant		-3.183 (0.120)	-4.902 (0.213)	-6.593 (0.309)	-2.752 (0.090)	-6.008 (0.174)	-6.284 (0.213)	-5.225 (0.170)	-4.814 (0.161)	-3.886 (0.172)
Individual and Household level	Age		0.055 (0.002)	0.032 (0.002)	0.060 (0.003)	0.007 (0.002)	0.052 (0.002)	0.014 (0.002)	0.087 (0.004)	0.062 (0.003)	0.040 (0.003)
	Gender	Male	3.515 (0.046)	3.200 (0.083)	4.625 (0.254)	4.558 (0.030)	3.726 (0.088)	5.348 (0.162)	3.536 (0.112)	4.045 (0.092)	2.533 (0.070)
	Education	Primary	-0.824 (0.056)	0.007 (0.051)	-0.364 (0.098)	-0.502 (0.064)	0.596 (0.090)	-0.063 (0.075)	-0.235 (0.080)	-0.350 (0.081)	0.029 (0.078)
		Secondary	-1.344 (0.066)	-0.068 (0.082)	-0.946 (0.090)	-0.672 (0.066)	0.222 (0.097)	-0.260 (0.090)	-0.799 (0.081)	-0.650 (0.105)	-0.547 (0.121)
		Higher	-2.425 (0.140)	-0.290 (0.106)	-1.164 (0.184)	-1.327 (0.075)	0.008 (0.112)	-0.801 (0.148)	-1.239 (0.193)	-1.241 (0.264)	-0.390 (0.247)
	Wealth	Poorer	-0.310 (0.056)	-0.116 (0.067)	-0.279 (0.095)	-0.143 (0.037)	0.008 (0.064)	0.044 (0.079)	-0.063 (0.081)	-0.335 (0.080)	-0.037 (0.100)
		Middle	-0.548 (0.061)	-0.232 (0.071)	-0.437 (0.113)	-0.290 (0.041)	-0.161 (0.066)	0.021 (0.083)	-0.226 (0.094)	-0.465 (0.081)	-0.135 (0.103)
		Richer	-0.815 (0.066)	-0.293 (0.073)	-0.868 (0.145)	-0.398 (0.044)	-0.340 (0.069)	-0.006 (0.091)	-0.493 (0.121)	-0.784 (0.087)	-0.348 (0.115)
		Richest	-1.156 (0.081)	-0.533 (0.101)	-1.280 (0.173)	-0.660 (0.049)	-0.641 (0.082)	-0.219 (0.106)	-0.695 (0.148)	-1.069 (0.109)	-0.713 (0.143)

	Variables		Cambodia	Ethiopia	Ghana	Indonesia	Kenya	Lesotho	Liberia	Malawi	Mozambique
	Children		0.066 (0.015)	-0.023 (0.012)	-0.038 (0.018)	0.002 (0.010)	-0.085 (0.012)	-0.059 (0.022)	-0.064 (0.018)	-0.058 (0.016)	-0.070 (0.016)
	Married		0.291 (0.053)	0.258 (0.056)	-0.205 (0.090)	-2.09 (0.046)	-0.144 (0.051)	0.205 (0.063)	-0.071 (0.069)	0.076 (0.067)	-0.002 (0.077)
	Employed		0.406 (0.059)	0.121 (0.056)	0.670 (0.149)	0.320 (0.037)	1.074 (0.072)	0.477 (0.052)	0.444 (0.100)	0.226 (0.070)	0.504 (0.077)
Cluster level	Place	Rural	-0.098 (0.068)	-0.117 (0.108)	-0.360 (0.107)	-0.162 (0.034)	-0.327 (0.053)	-0.205 (0.074)	0.038 (0.095)	-0.193 (0.102)	-0.565 (0.098)
	Year		-0.040 (0.035)	-0.007 (0.055)	-0.071 (0.011)	0.008 (0.010)	-0.061 (0.022)	0.127 (0.021)	-0.073 (0.021)	0.004 (0.016)	0.040 (0.026)
Random Part	Country-year level variance		~0	~0	~0	~0	~0	0.015 (0.019)	~0	~0	~0
	Region level variance		0.162 (0.043)	0.569 (0.178)	0.030 (0.018)	0.154 (0.025)	0.226 (0.070)	0.055 (0.021)	0.025 (0.018)	0.006 (0.007)	0.205 (0.071)
	Cluster level variance		0.307 (0.030)	0.405 (0.036)	0.236 (0.060)	0.409 (0.022)	0.121 (0.027)	0.090 (0.033)	0.253 (0.045)	0.274 (0.047)	0.519 (0.064)
	Household level variance		0.133 (0.052)	~0	0.050 (0.131)	~0	~0	0.106 (0.070)	0.077 (0.098)	0.023 (0.091)	0.030 (0.104)

Table S 7. Part two of the results for a 5-level (respondent, household, cluster, region, and country-year) binomial logistic multilevel regression model for individual countries.

	Variables		Namibia	Nepal	Nigeria	Rwanda	Sierra Leone	Uganda	Zambia	Zimbabwe
	Constant		-2.542 (0.182)	-1.632 (0.116)	-6.421 (0.151)	-4.988 (0.154)	-3.394 (0.114)	-4.000 (0.279)	-4.133 (0.144)	-5.147 (0.223)
Individual and Household level	Age		0.037 (0.003)	0.057 (0.002)	0.036 (0.002)	0.051 (0.003)	0.043 (0.002)	0.070 (0.004)	0.052 (0.002)	0.059 (0.003)
	Gender	Male	1.593 (0.044)	1.621 (0.043)	3.449 (0.078)	3.639 (0.090)	2.141 (0.041)	3.308 (0.105)	3.811 (0.090)	4.610 (0.147)
	Education	Primary	-0.083 (0.077)	-0.671 (0.050)	0.250 (0.061)	-0.219 (0.063)	-0.071 (0.058)	-0.082 (0.123)	-0.390 (0.076)	-0.424 (0.149)
		Secondary	-0.107 (0.078)	-1.226 (0.057)	-0.063 (0.066)	-0.742 (0.100)	-0.608 (0.056)	-0.454 (0.157)	-0.693 (0.081)	-0.554 (0.151)
		Higher	-0.607 (0.125)	-1.535 (0.097)	-0.411 (0.088)	-1.390 (0.225)	-1.165 (0.125)	-0.857 (0.242)	-1.266 (0.120)	-1.253 (0.186)
	Wealth	Poorer	-0.074 (0.074)	-0.290 (0.054)	-0.015 (0.067)	-0.315 (0.078)	-0.050 (0.060)	-0.224 (0.113)	-0.387 (0.055)	-0.274 (0.071)
		Middle	-0.252 (0.080)	-0.442 (0.059)	-0.029 (0.075)	-0.232 (0.076)	-0.130 (0.062)	-0.667 (0.132)	-0.762 (0.060)	-0.258 (0.074)
		Richer	-0.239 (0.091)	-0.768 (0.065)	-0.127 (0.084)	-0.462 (0.078)	-0.186 (0.070)	-0.985 (0.141)	-1.069 (0.074)	-0.578 (0.086)

	Variables		Namibia	Nepal	Nigeria	Rwanda	Sierra Leone	Uganda	Zambia	Zimbabwe
		Richest	-0.140 (0.108)	-0.975 (0.081)	-0.314 (0.099)	-0.517 (0.090)	-0.650 (0.096)	-1.862 (0.193)	-1.576 (0.093)	-0.945 (0.106)
	Children		0.020 (0.018)	0.041 (0.013)	-0.087 (0.011)	-0.017 (0.016)	-0.067 (0.012)	-0.056 (0.020)	-0.079 (0.011)	-0.117 (0.016)
	Married		-0.312 (0.062)	0.033 (0.054)	-0.039 (0.055)	-0.495 (0.062)	0257 (0.051)	-0.018 (0.096)	0.136 (0.051)	0.121 (0.058)
	Employed		0.039 (0.047)	0.485 (0.051)	0.879 (0.073)	0.386 (0.072)	0.721 (0.065)	0.454 (0.177)	0.625 (0.055)	0.395 (0.051)
Cluster level	Place	Rural	0.043 (0.075)	-0.145 (0.069)	-0.065 (0.064)	-0.418 (0.081)	0.032 (0.070)	-0.710 (0.160)	-0.479 (0.059)	-0.143 (0.091)
	Year		-0.023 (0.042)	-0.028 (0.029)	-0.022 (0.020)	-0.052 (0.019)	-0.074 (0.021)	-0.068 (0.048)	-0.045 (0.020)	-0.011 (0.020)
Random Part	Country-year level variance		~0	~0	~0	~0	~0	~0	~0	~0
	Region level variance		0.529 (0.153)	0.043 (0.023)	0.094 (0.037)	0.060 (0.026)	0.017 (0.011)	0.215 (0.084)	0.055 (0.021)	0.037 (0.016)
	Cluster level variance		0.453 (0.040)	0.263 (0.026)	0.553 (0.041)	0.191 (0.038)	0.185 (0.024)	0.331 (0.071)	0.116 (0.020)	0.128 (0.026)
	Household level variance		0.012 (0.058)	0.125 (0.043)	~0	0.194 (0.088)	0.187 (0.052)	~0	0.121 (0.053)	0.259 (0.067)

Appendix C Supplementary materials for chapter 6 “Predicting small area geographies of cigarette smoking within the Global South: A geostatistical modelling approach”.

Table S 8. The Geospatial covariates obtained for the selection process.

Covariates	Source
Literacy rates	Spatial Data Repository, The Demographic and Health Surveys Program. Modeled Surfaces. ICF International. Funded by the United States Agency for International Development (USAID). Available from spatialdata.dhsprogram.com.
Slope angle, Elevation from sea level, Night-time lights, Distance to OSM major roads, Distance to coastline, Age group, Population count, and Population density	WorldPop (www.worldpop.org - School of Geography and Environmental Science, University of Southampton; Department of Geography and Geosciences, University of Louisville; Departement de Geographie, Universite de Namur) and Center for International Earth Science Information Network (CIESIN), Columbia University (2018). Global High Resolution Population Denominators Project - Funded by The Bill and Melinda Gates Foundation (OPP1134076). https://dx.doi.org/10.5258/SOTON/WP00644
Poverty rates	Tatem AJ, Gething PW, Bhatt S, Weiss D and Pezzulo C (2013) Pilot high resolution poverty maps, University of Southampton/Oxford DOI: 10.5258/SOTON/WP00127

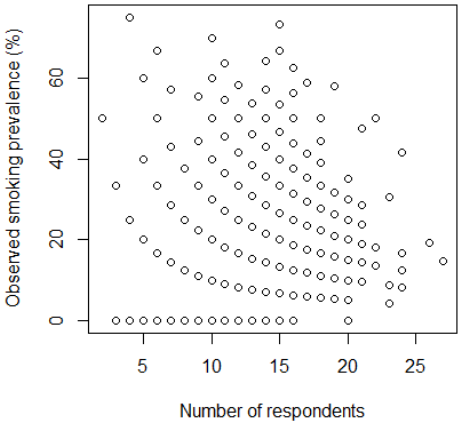

Figure S 1. Cluster plot of observed smoking against the number of respondents in Guatemala.

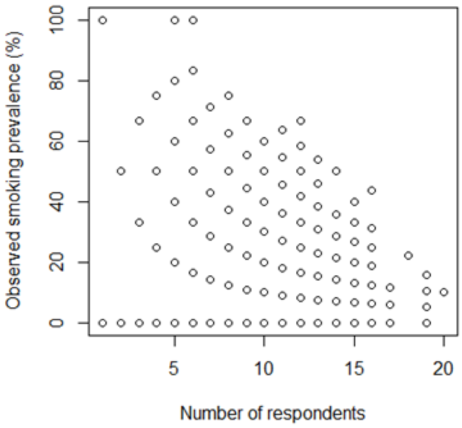

Figure S 2. Cluster plot of observed smoking against the number of respondents in Kenya.

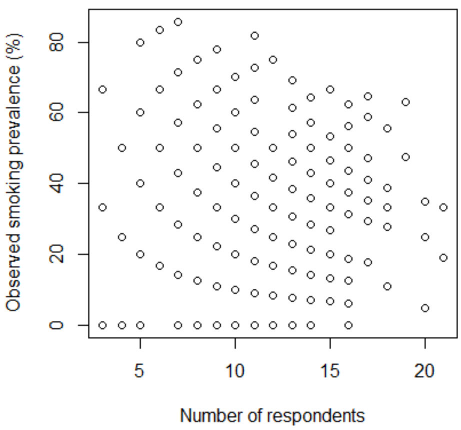

Figure S 3. Cluster plot of observed smoking against the number of respondents in Myanmar.

Table S 9. Pearson correlation coefficients between each covariate for Guatemala.

	Elevation from sea-level	Male literacy rates	Distance to coast	Population count
Population count	0.16	0.50	-0.09	1
Distance to coast	0.24	-0.40	1	-0.09
Male literacy rates	0.04	1	-0.40	0.50
Elevation from sea level	1	0.04	0.24	0.16

Table S 10. Pearson correlation coefficients between each covariate for Kenya.

	Poverty rates	Elevation from sea level	Slope	Male literacy rates	Distance to coast	Population count
Population count	-0.47	1E-3	-0.17	0.21	-0.13	1
Distance to coast	0.22	0.61	0.21	-0.08	1	-0.13
Male literacy rates	-0.74	0.38	0.16	1	-0.08	0.21
Slope	-0.04	0.48	1	0.16	0.21	-0.17
Elevation from sea level	-0.37	1	0.48	0.38	0.61	1E-3
Poverty rates	1	-0.37	-0.04	-0.74	0.22	-0.47

Table S 11. Pearson correlation coefficients between each covariate for Myanmar.

	Slope	**Male literacy rates**	**Distance to coast**	**Distance to main Roads**	**Population count**
Population count	-0.17	0.17	-0.13	-0.19	1
Distance to main roads	0.26	-0.25	-0.02	1	-0.19
Distance to coast	0.13	-0.13	1	-0.02	-0.13
Male literacy rates	-0.34	1	-0.13	-0.25	0.17
Slope	1	-0.34	0.13	0.26	-0.17

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