Cities, Immigrant Diversity, and Complex Problem Solving

Abigail Cooke*[a] and Thomas Kemeny[b]

[a]University at Buffalo-SUNY
[b]University of Southampton

Accepted version. The Version of Record of this manuscript is forthcoming at *Research Policy* (accepted May 8, 2017) DOI:10.1016/j.respol.2017.05.003

Abstract

Recent evidence suggests that greater immigrant diversity in cities and workplaces makes workers more productive. However, even the most careful extant empirical work remains at some remove from the main mechanisms that theory says underlie this relationship: interpersonal interaction in the service of complex problem solving. This paper aims to 'stress-test' these theoretical foundations, by observing how the relationship between diversity and productivity varies across workers differently engaged in complex problem solving and interaction. Using a uniquely comprehensive matched employer-employee dataset for the United States starting as early as 1991 and continuing to 2008, this paper shows that growing immigrant diversity in cities and workplaces is related to higher wages for workers intensively engaged in various forms of complex problem solving, including tasks involving high levels of innovation, creativity, and STEM. Mixed evidence is found for the theory that benefits are concentrated among those whose work require problem solving as well as high levels of interpersonal interaction.

Keywords: immigration, diversity, complex problem solving, spillovers, productivity, human capital

JEL: J15, J24, R11, R23, O4

Disclaimer: This work was produced while the authors were Special Sworn Status researchers at the U.S. Census Bureau's Center for Economic Studies. Any opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed.

*Corresponding author: Department of Geography; 122 Wilkeson Quad, Buffalo, NY 14621, USA; E-mail: amcooke@buffalo.edu

1 Introduction

Are diverse populations better at problem solving than those that are homogeneous? Researchers in a wide range of disciplines contend that people with different demographic characteristics carry with them different perspectives, and that the combination of these perspectives can confer either economic advantages or drawbacks. Advantages are said to arise because diverse populations are collectively able to map out a wider range of approaches and solutions to complex problems. Drawbacks are caused by the difficulties that individuals from different backgrounds experience in establishing trust and common ground. To the extent that such mechanisms operate in the economy, we can think of diversity as a public good, generating costs or benefits that are not fully captured by individuals. Scholars have explored these ideas for at least half a century (e.g. Hoffman and Maier 1961, Dawson 2012), mostly studying gender, education, and other forms of demographic heterogeneity manifested within work teams and organizations.

Over the past decade, social scientists have begun exploring a distinct type of diversity at a different scale: immigrant (or birthplace) diversity in metropolitan areas. Several factors can explain interest in this topic. One is that global flows of migrants have doubled since 1960 (Özden et al. 2011), with populations in prime receiving countries like the U.S. becoming dramatically more heterogeneous.[1] This heterogeneity is not spread evenly across receiving economies; it is concentrated in metropolitan areas (Wilson and Svajlenka 2014). Meanwhile, researchers studying the economics of immigration increasingly contend that immigrants and natives are best understood as complements in the labor market (e.g. Peri and Yasenov 2015); an immigrant-derived plurality of heuristics represents one channel for such complementarity. Cities are also sensible containers for such externalities, since we recognize that many of the most important factors explaining economic performance are external to firms but internal to regional economies (Moretti 2012, Storper 2013).

Most empirical studies find a positive correlation between urban immigrant diversity and productivity, suggestive of the idea that the benefits of immigrant diversity outweigh the costs (Ottaviano and Peri 2006, Nathan 2011, Kemeny 2012, Bellini et al. 2013,

[1] In the US, this sea change has been enabled by the 1965 Hart Celler Act: a piece of legislation that eliminated quotas that privileged Western European migrants.

Suedekum et al. 2014, Trax et al. 2015, Kemeny and Cooke 2015, 2017a, Elias and Paradies 2016). However, these studies lie at some remove from the behavioral foundations that underlie the hypothesized mechanisms. One can observe a robust association between urban immigrant diversity and various measures of productivity, but one cannot observe actual interactions among members of a diverse populace, at least not at scale. This paper aims to more closely connect available evidence to these foundations. It extends knowledge by exploring the idea that the productivity benefits from urban and workplace-specific immigrant diversity will vary according to the kind of activities in which workers are engaged.

Theory offers two potential axes of differentiation. First, according to Hong and Page (2001), Weber and Fujita (2004), and others, benefits from diversity ought to be amplified in activities that are challenging, knowledge-intensive, innovation-oriented, and lacking in pre-established routines, activities that we will henceforth describe using the shorthand 'complex problem solving.' Second, given that spillovers are generated through interpersonal interaction, workers in activities that require high levels of both complex problem solving and social engagement should benefit more strongly from the diversity that surrounds them. To take an extreme example, contrast a sculptor's job, which requires a great deal of a certain kind of complex problem solving – creativity – but does not necessarily require a great deal of interpersonal interaction, with that of a director of a Hollywood film, whose success depends on both. If the mechanisms shaping diversity's relationship to productivity are in fact rooted in the interaction of heuristics and the concomitant benefits to problem solving, then diversity effects ought to matter more for the movie director than the sculptor.

Data on U.S. workers, employers, industries, and occupations are used to test these ideas. Our primary data source is the U.S. Census Bureau's confidential Longitudinal Employer-Household Dynamics (LEHD). LEHD provides uniquely comprehensive matched employer-employee data describing workers and their work establishments, available between 1991 and 2008. LEHD describes workers' place of birth, and permits description of their productivity as measured by their earnings. Using these data we are able to measure diversity in one's city as well as one's establishment, allowing clearer identification of the specific contexts where any productivity-enhancing or -inhibiting effects may reside. We capture variation in complex problem solving and interaction by combining occupation-specific task characteristics from the U.S. Department of Labor's O*NET database with detailed information on the occupational structure of industries from the Bureau of Labor Statistics' Occupational Employment Statistics (OES).

Grouping workers according to the task characteristics of their industry, we predict how their wages respond to changes in the diversity found in their city and workplace. Models are estimated over multi-year job 'spells', within which workers remain in a single establishment and city, permitting the inclusion of *worker x workplace x city* fixed effects. The primary strength of this strategy is that it accounts for bias from unobserved but pertinent durable features of individuals, their workplaces, and their metropolitan areas. We additionally implement the generalized method of moments (GMM) instrumental variables estimator in order to help address potential bias from unobserved shocks. Though our approach cannot fully eliminate the potential effects of such bias, it represents a strong empirical strategy that ought to build confidence about the nature of the relationships between diversity and productivity.

Our findings largely offer support for the theory underlying this growing body of scholarship. We observe a robustly positive, statistically significant and substantial relationship between urban immigrant diversity and wages among workers in industries that intensively demand complex problem solving. The wages of a typical worker in an industry requiring high levels of complex problem solving rise by an average of nearly 7 percent in response to a one standard deviation increase in urban immigrant diversity. By contrast, for workers where complex problem solving is unimportant, we find no significant association between city diversity and wages. Estimates of the links between wages and diversity in the workplace are also differentiated. As workplace diversity rises by one standard deviation, the wages of workers in industries featuring high levels of complex problem solving rise by approximately 2%, as compared with only 0.7% for workers in activities where complex problem solving is unimportant. Considering the intersection of problem solving and social interaction, we find mixed evidence. While at the establishment scale we find evidence that the benefits of diversity are concentrated among workers engaged in high levels of both complex problem solving and social interaction, at the urban scale we do not detect such a differentiated relationship.

2 Literature

The idea that a population containing a diverse group of immigrants might outperform one in which individuals are more homogeneous finds its chief motivation at the intersection of two bodies of work: one exploring the consequences of heterogeneity in organizations; the other examining subnational regions as sites of external economies.

From the longstanding scholarship on the impacts of heterogeneity in organizations comes the main theoretical logic for an economic impact of immigrant diversity. The initial premise is that observable demographic characteristics are related to underlying cognitive regularities (Nisbett et al. 1980, Clearwater et al. 1991, Thomas and Ely 1996, Hong and Page 2001). Hong and Page (2004), for example consider that individuals with 'identity diversity,' defined as those with particular demographic, geographic, ethnic, or cultural backgrounds, are also likely to be distinctive in terms of their 'functional diversity,' meaning the ways they perceive and solve problems. Some hold that this functional diversity can improve economic performance, while others contend it ought to reduce it. On the positive side, it is argued that more functionally-diverse organizations ought to be more productive for two reasons. First, when faced with a problem or challenge, they will be able to access a larger range of potential solutions, and should thereby be able to select the one that will be most effective. Second, they ought to be able to cross-pollinate to generate new solutions that cannot be reduced to any one perspective (Aiken and Hage 1971). Computational models of this idea provide support, by showing that groups composed of diverse problem solvers can outperform teams made up of agents with superior but more homogeneous abilities (Huberman 1990, Hong and Page 2004).

Arguments suggesting that diversity will negatively impact performance flow from psychology's 'social identity theory.' According to this view, diverse organizations will tend toward internal fragmentation, with rent-seeking behavior and raised costs of cooperation across the fragments (Tajfel 1974, Turner et al. 1987, Van Knippenberg and Schippers 2007, Harrison and Klein 2007). It is worth noting that, while these streams of organizational research make different predictions, they posit fundamentally compatible visions of the mechanisms by which diversity influences economic outcomes. Whether diversity helps or hurts, its economic effects flow from interpersonal interactions among individuals who are demographically, and therefore cognitively different. One side emphasizes the costs associated with such interactions when problem solving is needed, while the other side stresses the benefits.

Urban-focused researchers have built upon this foundation, suggesting that the public-good (or bad) qualities ascribed to diversity in the workplace may operate at higher spatial scales. The logic for this emerges from a larger body of theory and empirics making the point that regional economies are an important site of positive externalities – economic benefits that are a function of scale but that cannot be fully captured by individual agents (Moretti 2012, Fujita and Thisse 2013, Storper 2013). Chief among these are gains to worker productivity that flow from concentrations of workers with high levels of human capital. Workers are made more productive when their fellow city residents are better-educated (Rauch 1993, Moretti 2004a,b). Such localized externalities have also been modeled in relation to research and development activity: inputs into innovation relate more closely to outputs at the metropolitan rather than organizational scale (Audretsch and Feldman 2004).

The present paper is motivated by an analogous logic. Just as spillovers arise from local concentrations of educated workers and R&D, concentrations of birthplace-diverse workers in cities may augment worker productivity. A growing body of empirical work has sought to determine whether these spillovers exist. The seminal reference is Ottaviano and Peri (2006), who find that birthplace diversity is positively and robustly correlated with both wages and rents in U.S. cities, indicating that diversity raises worker productivity. Similar studies in other advanced economies confirm this positive relationship (Nathan 2011, Kemeny 2012, Trax et al. 2015, Bellini et al. 2013, Bakens et al. 2013, Longhi 2013, Ager and Brückner 2013, Suedekum et al. 2014, Elias and Paradies 2016).[2] Recent work has gone deeper by addressing lingering concerns arising from unmeasured sorting behavior and reverse causality; researchers have also begun to consider whether any diversity effects operate at the workplace or metropolitan scale (Trax et al. 2015, Kemeny and Cooke 2015, Nathan 2015, Østergaard and Timmermans 2015). Studies addressing some or all of these issues continue to find a positive association between diversity and productivity at both

[2] For a detailed review of the empirical literature on the productivity implications of urban immigrant diversity, see Kemeny (2017).

metropolitan and workplace scales.

Despite stronger econometrics, existing work remains at some remove from the behavioral foundations that are said to underlie the relationship of interest. Based on their microeconomic model of problem solving, Hong and Page (2001, p.124) argue that diverse populations are more likely to produce "optimal solutions to difficult problems, despite the fact that each individual agent may not be able to locate a good solution if acting alone." Weber and Fujita (2004) make a similar point, rooting the success of hubs of knowledge-intensive activity like Silicon Valley in part in the interpersonal interactions among individuals from diverse backgrounds. Yet existing studies do not directly observe complex problem solving, nor do they capture the interpersonal interaction upon which it depends. As a result, studies investigating the links between immigrant diversity and productivity tend to merely assume that outcomes observed over undifferentiated samples of workers are driven by these latent phenomena.

This paper responds to this gap. Our aim is to 'stress-test' the motivating theory by considering the following hypotheses:

1. The positive effects of city and workplace diversity on productivity will be stronger for workers in industries that intensively require *complex problem solving*.

2. The positive effects of city and workplace diversity on productivity will be especially strong for workers in industries that require high levels of both *interaction* and *complex problem solving*.

3 Empirical Approach

The approach taken in this paper is adapted from several studies of educational spillovers, notably Moretti (2004a). Out of the set of all available workers, we estimate the relationship between immigrant diversity and productivity only on job spells of 'stayers' – individuals that remain in their work establishment (and thus metropolitan area) for at least two consecutive calendar years.[3] As these workers are fixed in place, one important

[3]Except for perhaps a small segment of the working population that is so mobile as to never hold a single job for two years, our focus on 'stayers' does not exclude people who move at some point over our study period or beyond it. We simply observe workers during a spell of staying, rather than actively excluding people who move jobs or cities.

source of variation comes from the panel structure of the data, and more specifically from the shifts around these workers in the birthplace composition of the cities in which they live, and the establishments in which they work. In short, by observing the same individual in a single firm and city across time, we control for stationary unobserved heterogeneity among individuals, establishments, and cities.

While some recent studies exploit data on workplace-specific total factor productivity (Trax et al. 2015, Mőhlmann and Bakens 2015), we follow the majority of the extant literature (e.g., Ottaviano and Peri 2006, Bakens et al. 2013) in proxying for productivity using individual-level information on wages. This decision is motivated mainly on practical grounds – data limitations prevent us from directly measuring productivity in work establishments. In arguing for the suitability of wages, we rely on that fact that, while imperfect, they are the best available and most commonly used indicator of worker productivity (Feldstein 2008). Considering the utility of this proxy in a specifically urban context, research also indicates that rising productivity is likely to be expressed in higher wages (Combes et al. 2005). Further, in estimates of agglomeration economies, establishment level productivity and wages exhibit similar elasticities with respect to city size (Combes et al. 2011).

Our general estimation approach is represented in the following equation:

$$ln(w)_{ipjt} = d_{jt}\beta + +d_{pjt}\gamma + X'_{ipjt}\delta + E'_{pjt}\theta + C'_{jt} + \mu_{ipj} + \eta_t + \nu_{ipjt} \quad (1)$$

where, $ln(w)$ represents the log annual wages of an individual worker i in establishment p located in metropolitan area j at time t; d_{jt}, a key independent variable of interest, measures city-specific immigrant diversity, while d_{pjt} measures diversity at the level of the establishment; X' represents time-varying worker characteristics; E' describes a vector of dynamic employer characteristics; and C' indicates time-varying city-specific characteristics. Of particular importance is μ_{ipj}, our individual-establishment-city fixed effect, which simultaneously accounts for bias arising due to variation in permanent but potentially unobserved characteristics of individual workers, the establishments where they work, and the regional economies in which they live. At the individual level, such pertinent stationary unobserved heterogeneity could arise due to differences in such characteristics as innate ability, intelligence, or motivation. Among establishments, it could be driven by differences in such features as capital intensiveness or product quality. And at the level of metropolitan regions, differences in specialization, agglomeration, and other factors could be relevant, if hard to observe. Of the remainder of equation (1), η_t represents unobserved time-specific shocks that exert uniform impacts across all individuals, such as the business cycle; ν_{ipjt} is the standard error term.

Applying the fixed effects estimator, equation (1) explores how an individual's productivity responds to changes in the level of immigrant diversity present in her metropolitan area, while it accounts for the major sources of spurious correlation that might bias estimates of the impact of diversity on wages produced using the standard approach. As in Acemoglu and Angrist (2001) and Moretti (2004a), we argue that identification does not require a complementary equation predicting rents, since for regions that contain producers selling tradable goods, wages unadjusted for cost-of-living difference will reflect underlying productivity, as such firms face national, not local prices. The main identifying assumption to be satisfied is that the return on unobserved worker ability in their establishment and city is stationary over time, or at least that changes are uncorrelated with changes in city-specific diversity. As in Moretti (2004a), this return need not be general across higher-order categories, in this case establishments and cities.

Sketching out our analytical approach in more detail, we address our two hypotheses in turn. We first estimate equation (1) separately for workers who we classify as being involved in high and low levels of complex problem solving. Hypothesis (1) suggests that coefficients on our measures of diversity ought to be larger among the group of workers engaged in complex problem solving. Next, among those workers with high levels of complex problem solving, we estimate equation (1) separately for those with low and high levels of interaction – our sculptors and movie directors, respectively. Hypothesis (2) suggests that coefficients for diversity will be comparatively higher among workers in activities that demand high levels of both complex problem solving and interaction.

4 Data

4.1 Building Diversity Measures and the Main Analytical Sample

Our primary source of information is quarterly data from the U.S. Census Bureau's confidential Longitudinal Employer-Household Dynamics (LEHD) Infrastructure files. The LEHD program integrates administrative records from state-specific unemployment insurance (UI) programs with Census Bureau economic and demographic data, providing a nearly universal picture of jobs in the United States (McKinney and Vilhuber 2011). LEHD provides a range of information about individual workers, such as their place of birth, sex, birth year, race, and quarterly wages earned. Data specific to each establishment are relatively limited, but include their precise location, monthly employment, and a six-digit NAICS industry code. The version of the data available for this study covers 29 states starting as early as 1991 and continuing through 2008.[4] Within those states, our sample is limited to jobs occurring in the set of 163 Metropolitan Core-Based Statistical Areas (CBSAs) which do not cross state borders with a state unavailable in the raw data, ensuring that we observe all workers throughout each analyzed CBSA.

Assembling the core analytical sample involves two major steps. The first is to estimate annual immigrant diversity for the sample of CBSAs, as well as for the work establishments operating within them. The second key task is to assemble the sample of workers from which to estimate our relationships of interest.

To create city-specific measures of diversity, we observe each working-age individual's job spell with each employer, and by implication, each employee's city of work in a given quarter. We use this information, in combination with LEHD's record of each worker's country of birth, to estimate a CBSA-specific measure of immigrant diversity based on the set of all workers in the city during a given calendar year. To do so, we follow standard practice by estimating a fractionalization index:

$$Fractionalization_{jt} = 1 - \sum_{r=1}^{R} s_{jtr}^2 \quad (2)$$

where s is the proportion of residents in city j and time t who were born in country r; and

[4] States used in our project: AR, CA, CO, FL, GA, HI, IA, ID, IL, IN, LA, MD, ME, MT, NC, NJ, NM, NV, OK, OR, SC, TN, TX, UT, VA, VT, WA, WI, WV. States vary in their earliest year of data.

R is the number of different countries represented among residents of that city. The index nears zero as diversity decreases and its maximum value approaches one as heterogeneity increases; it is commonly described as measuring the probability that two randomly-drawn individuals in a location were born in different countries. The pervasiveness of this measure in diversity research is no doubt related to the simple and intuitive manner by which it captures the breadth of countries from which individuals originate, as well as the sizes of these different country groups in a given city.[5]

Birthplace fractionalization is constructed analogously for workplaces, based on the set of coworkers in each establishment and year. One difference between the city and establishment measures is that instead of weighting each person's contribution to birthplace diversity evenly (as we do in the city measures), we weight each person's contribution depending on how many quarters they work in a particular establishment. If they worked half the year in one establishment and half the year in another, then they count as half a person in the diversity measures of each establishment for that year. The resulting annual diversity measures at the CBSA and workplace levels provide key independent variables of interest in our models.

To build our analytical sample of 'stayers', we start from the same initial sample of workers in establishments and cities. From this initial pool, we then identify and keep each worker's longest continuous job spell, so they appear in only one establishment and one city in the panel, even if they have multiple job spells over their observed career that meet the two-year minimum. We further limit the analytical sample in various ways. We exclude workers with extremely low wages – those below the 5th percentile of the wage distribution – on the basis that LEHD's inclusion of all workers earning at least one dollar in a quarter captures some very low earners operating under irregular employment situations. Although this decision involves a tradeoff in terms of generalizability, we believe that the inclusion of these extremely low earners might reduce the signal to noise ratio in the relationship of interest. We also drop workers who are simultaneously employed

[5] Fractionalization indices of this kind have been used to capture a wide variety of categorical forms of diversity, including language, birthplace, race and ethnicity (see, for example, Taylor and Hudson 1972, Easterly and Levine 1997, Knack and Keefer 1997, Ottaviano and Peri 2006, Sparber 2010). Other ways of measuring diversity have been proposed (Ozgen et al. 2013, Kemeny 2017), and explored empirically in relation to wages (see Kemeny and Cooke 2015), with results that did not materially depart from those gained using the fractionalization index.

in multiple jobs, so that we can clearly identify the source of any establishment-specific diversity effects. Finally, to ensure that our measure of workplace diversity is sensible, we restrict the sample to jobs at establishments with at least ten employees. Though the resulting sample is very large, it is necessarily limited in what it can tell us about the relationship to diversity for workers with extremely tenuous labor market attachment, very low wages, and those working in very small establishments. Given the focus on cities, it also has no purchase on the shape of this relationship in small rural towns and municipalities.

4.2 Measuring Complex Problem Solving and Interaction in Work Activities

Our empirical strategy relies on differentiating individuals based on the kinds of work activities in which they are engaged. LEHD does not classify workers on the basis of their occupation, but it does offer detailed information about the industry in which their establishment is involved. We use this information to capture variation in complex problem solving and interaction.

To do so, we start from the Department of Labor's O*NET database, which provides rich information on the work characteristics that distinguish different occupations. From the dozens of characteristics described for each occupation, we select the following that triangulate on the latent concept of complex problem solving: (1) creativity, (2) innovation, (3) complex problem solving, (4) educational requirements (schooling). Because they are often considered to feature complex problem solving, we also examine the following STEM characteristics (Hyde et al. 2008): (5) science, (6) engineering & technology, and (7) mathematical reasoning. As a proxy for interpersonal interaction, we use a measure of the 'social orientation' of workers in occupations. Each of these variables provides an occupation-specific score indicating the intensiveness with which the characteristic is present in a particular kind of job.

In order to arrive at industry-specific measures of complex problem solving and interaction, we combine these data with occupation-by-industry employment estimates from the Bureau of Labor Statistics' Occupational Employment Statistics (OES). Specifically, for each work characteristic, we calculate the weighted sum of all occupations' scores, where the weight is the proportion of total 4-digit NAICS industry employment a particular occupation represents. This results in a series of industry-specific measures, each capturing some aspect of the underlying concepts of complex problem solving and interaction. Finally, for each measure, each of nearly 300 industries is assigned to a tercile. Equation (1) is then estimated on workers in industries in the highest, and separately, the lowest terciles.[6] We focus on these extremes because, in the absence of clear theoretical or empirical guidance on thresholds that distinguish sufficient intensities of our work characteristics, we can be more confident that those in the highest tercile will systematically differ from their counterparts in the lowest. A naive assessment of the resulting groups suggests the usefulness of this approach, with industries conforming to general intuition. For example, leading the high tercile of problem solving are 'Computer Systems Design and Related Services' and 'Software Publishers'; and near the bottom of the low tercile are 'Consumer Goods Rental' and 'Health and Personal Care Stores'.[7]

Table 1 describes relationships between the various indicators of the deeper latent concept of complex problem solving. It demonstrates that, while there is considerable overlap among these measures, they remain distinct. Pearson correlation coefficients span a wide range, from 0.89 between innovation and creativity, to 0.09 between math and science, with an average coefficient of 0.56. We believe that the shape of these relationships supports our approach. Specifically, should we produce consistent results across each of these measures, we can be more confident in relating these results to the underlying latent concept.

4.3 Sample characteristics and control variables

Table 2 provides summary statistics for the analytical sample. It includes nearly 29 million individuals working in over one million establishments. Average annual earnings in the analytical sample are just over $35,000. Because they are time-invariant, other available individual-level variables, such as gender or race, drop out in estimation; these are included in Table 2 to better describe the sample. The average age of the workers is just over 40

[6]We use the 2008 OES data to capture employment by occupation and industry. While there are likely some changes in the occupational structure of certain industries between 1991 and 2008, our analytical strategy of comparing the extremes (highest versus lowest tercile of each measure) makes any restructuring unlikely to matter substantially.

[7]A full list of industries is available upon request.

Table 1: Pearson Correlation Coefficients for Measures of Complex Problem Solving

	Creativity	Innovation	Problem Solving	School Requirements	Science	Engineering & Technology	Mathematical Reasoning
Creativity	1.0000						
Innovation	0.8994	1.0000					
Problem Solving	0.6397	0.6267	1.0000				
School Req.	0.7327	0.7113	0.7419	1.0000			
Science	0.3824	0.3791	0.7194	0.4071	1.0000		
Eng. & Tech	0.6986	0.6525	0.6508	0.7859	0.2963	1.0000	
Math Reason.	0.4444	0.4207	0.3641	0.4651	0.0933	0.7322	1.0000

years old and the average job spell is just under five years. At the establishment level, besides birthplace diversity, we also include annual workplace employment in the models, since workforce size can influence productivity. The average establishment in the sample has 64 employees. At the city level, birthplace diversity is the chief variable of interest, however we also include controls for other localized externalities. CBSA employment (average 472,000 workers), sourced from the Bureau of Economic Analysis, is included to capture the effect of agglomeration economies. To account for shocks to the human capital available in each city, we include the annual share of each CBSA's workforce holding at least a 4-year college degree, using 5% public-use IPUMS extracts from the 1990 and 2000 Decennial Censuses, as well as 1% samples for each year of the 2001–2008 American Community Survey (Ruggles et al. 2010).[8] In the average city in our sample, about 26% of the labor force has a college education.

Table 2: Summary Statistics

Variable	Mean	Standard Deviation
Individual Characteristics		
Log Annual Earnings	10.47	0.65
Age	40.23	11.72
Spell Duration	4.92	3.27
Establishment Characteristics		
Birthplace Fractionalization	0.219	0.205
Foreign-Born	0.058	0.143
Employment	64.01	284.33
City Characteristics		
Birthplace Fractionalization	0.180	0.129
College Share, All Workers	0.257	0.074
Employment (10,000s)	47.20	88.34
Share Foreign-Born	0.102	0.084
Individuals	28,950,000	
Establishments	1,026,000	
CBSAs	163	

Note: Observation counts are rounded to ensure confidentiality.

[8] We use available data to interpolate across absent years (1991–1999) as in Moretti (2004b). Our measure of education is sourced in this way despite having annual, individual-level imputed values of schooling attainment available in LEHD, since we found that the latter, when aggregated to the CBSA level, are only moderately correlated (<0.4) with the more reliable values drawn from the Decennial and ACS.

5 Results

This section presents results from models estimating equation (1), describing the relationship between the wages of individual workers and the immigrant diversity that surrounds them. The chief aim is to identify potential contrasts in this relationship between workers engaged in different kinds of activities. Specifically, we explore how diversity may differently impact workers engaged in high and low levels of complex problem solving. Within the subset of workers solving complex problems, we additionally explore differential impacts on the basis of the intensity of interpersonal interaction.

As discussed in the previous section, we are able to capture changes in diversity at both the city and the workplace scale. We expect that interactions in a workplace ought to reflect the kinds of characteristics found in the industry in which it operates. For instance, an industry like computer programming that intensively requires complex problem solving will mechanically feature firms, and by extension establishments, in which complex problem solving features prominently. The theory we explore in this article suggests that diversity ought to be especially important in establishments in such industries, as compared to establishments in industries where complex problem solving is relatively peripheral.

The interpretation of potential task-specific city effects is more complex. One possibility is that such effects represent interactions that are directly about work, but of an extra-establishment nature. These could be interactions that occur across establishments within a multi-unit firm; between a firm and external buyers and suppliers or partners; or merely workplaces linked through other more informal interactions. Alternately (or additionally), observed city-level relationships could represent a looser kind of interaction, where people from different backgrounds act as complements in creating vibrant urban environments; fertile ground for the 'sidewalk ballet' in which new and economically-significant ideas are produced and disseminated (Jacobs 1961). In such a case, we need to believe either that one's industry shapes orientation to one's environment, such that a worker in industry X will derive different productivity benefits from a worker in industry Y, or that the encounters with others that occur in diverse cities disproportionately augment the productivity of workers engaged particular types of tasks. Whichever route, we expect changes in city diversity to differentially influence worker productivity on the basis of that worker's industry. Given the absence of well-specified theoretical priors regarding the relative importance of these channels, we leave all options open.

5.1 Main Estimates

Table 3 presents the main panel estimates of the relationship between birthplace diversity and wages as moderated by levels of complex problem solving. For each of our seven indicators of complex problem solving, we estimate equation (1) twice - once over workers in industries that fall into the lowest tercile for that indicator, and a second time for workers that fall into the highest tercile. For concision, for each model Table 3 presents coefficients and standard errors only for the key independent variables of interest – metropolitan and establishment immigrant diversity. The top two rows present coefficients for diversity among workers in the lowest tercile of each indicator of complex problem solving, the bottom two rows show diversity coefficients for workers in the highest. Note, however, that each model includes the full battery of control variables discussed in section 4.3. These controls offer consistent predictions across the various models, and are in line with expectations. Specifically, the measure of the proportion of workers holding at least a college degree is positive and significant only for workers engaged in high levels of problem solving, suggesting that spillovers from education accrue to those engaged in more complex activities. For workers in all groups, the size of the overall metropolitan labor force is positively and significantly related to wages. Establishment employment levels are positively related to wages for all groups, though it is not always significant for workers more intensively engaged in complex problem solving.[9]

Throughout the results section, we compare regression coefficients across terciles on the assumption that error variances may not be constant. Consequently, we formally test for differences by calculating z-scores according to the approach described for large samples in Clogg et al. (1995):

$$z = \frac{(\hat{\beta}_{m1} - \hat{\beta}_{m2})}{\sqrt{s^2_{m1}(\hat{\beta}_{m1}) + s^2_{m2}(\hat{\beta}_{m2})}} \tag{3}$$

[9] Full tables of results are available upon request.

where $\hat{\beta}$ represents an estimated regression coefficient, m_n indexes the regression models being compared, and s indicates the standard error. The null hypothesis being tested is that there are no differences between coefficients for immigrant diversity in low and high terciles of a particular operationalization of complex problem solving. Our alternative hypothesis is that the coefficient for diversity in the highest tercile of complex problem solving is larger than for those in the lowest, indicating a one-tailed test. We conduct such tests across pairs of terciles for a given measure of complex problem solving shown in Table 3, in each case testing separately for city-specific and establishment-specific manifestations of immigrant diversity.

The first column of Table 3 explores whether and how the association between diversity and wages is moderated by our first proxy for complex problem solving: creativity. Among workers in the least creative industries, urban immigrant diversity is not significantly related to wages. Meanwhile, we observe a positive and significant relationship between wages and establishment immigrant diversity. Among workers in the highest tercile of creativity, both city and establishment immigrant diversity are positively and significantly related to wages. These results suggest a relationship between diversity and wages that depends on the degree to which creativity is an important feature of the activities in which a worker is engaged. Workers in low-creativity industries receive no spillovers from the immigrant diversity found in their city, and only a modest benefit from the diversity in their workplace. Meanwhile, the average worker in an industry in the top tercile of creativity experiences a 6.4% rise in wages for a one standard deviation increase in urban immigrant diversity, and a 2.2% rise in wages in response to a one standard deviation increase in establishment immigrant diversity, the latter being twice as large as the coefficient estimated for workers in the lowest tercile. Based on z scores calculated as per equation (3), for comparisons at both scales we reject the null at a 1 percent threshold, supporting the idea that estimates for the highest tercile for creativity are larger than for the lowest.

The remainder of Table 3 considers additional proxies for complex problem solving: innovation (Column 2); problem solving (Column 3); schooling requirements (Column 4); science (Column 5); engineering & technology (Column 6); and mathematical reasoning (Column 7). Reading across the rows, we observe a consistent pattern. With the exception of engineering & technology, all of the coefficients on city immigrant diversity in the

Table 3: Summary Results for Fixed Effects Estimates of Relationship between Change in Immigrant Diversity and Change in Log Annual Wages by Task Types: Low- and High Complex Problem Solving

	Dependent Variable: Log of Annual Earnings						
	Creativity (1)	Innovation (2)	Problem Solving (3)	School Reqs. (4)	Science (5)	Tech & Eng. (6)	Math (7)
Lowest Tercile							
City Diversity	0.081	0.144	0.036	0.055	0.039	0.191**	0.014
	(0.073)	(0.095)	(0.066)	(0.072)	(0.071)	(0.082)	(0.092)
Workplace Diversity	0.050***	0.028***	0.038***	0.043***	0.047***	0.023***	0.025***
	(0.006)	(0.007)	(0.005)	(0.006)	(0.005)	(0.006)	(0.007)
Highest Tercile							
City Diversity	0.404***	0.408***	0.438***	0.335***	0.515***	0.363***	0.505***
	(0.106)	(0.104)	(0.111)	(0.109)	(0.146)	(0.103)	(0.123)
Workplace Diversity	0.101***	0.082***	0.097***	0.090***	0.125***	0.097***	0.091***
	(0.018)	(0.016)	(0.018)	(0.019)	(0.026)	(0.017)	(0.015)
Lowest Tercile							
Observations (millions)	38.14	35.12	41.4	34.79	49.23	28.88	24.61
Individuals (millions)	8.73	7.96	9.47	7.75	11.27	6.63	5.62
Highest Tercile							
Observations (millions)	77.41	73.76	76.45	74.54	51.99	80.59	71.78
Individuals (millions)	15.28	14.98	15.05	14.78	9.77	15.99	14.68

Note: Standard errors in parentheses, corrected for clustering by establishment. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Estimated equation is (1). Full set of control variables (E' = establishment employment size; C' = metro labor force size and college share of labor force), as well as individual-establishment-city and year effects included in each model. In every model in this table, the R^2 is greater than or equal to 0.94. Counts are rounded to the nearest 10,000 to ensure confidentiality. Full range of coefficients available upon request.

lowest tercile are unrelated to wages. By contrast, among workers in the highest tercile of each indicator of complex problem solving, we observe a positive and significant association between city diversity and wages. The relationship across levels of engineering & technology operates somewhat differently: city diversity and wages are positively and significantly related in both high and low terciles, but estimated coefficients for workers in the highest tercile are nearly twice that of those in the lowest. Summarizing the city effect, as compared with no significant association among workers in the lowest tercile of complex problem solving, the wages of workers in the highest terciles respond to a one standard deviation increase in city diversity by rising between 5.1% and 8.7%. For each model we reject the null hypothesis of no difference between terciles at a 1 percent threshold.

The association between wages and immigrant diversity in establishments are also consistently differentiated. Considering results for the various measures of complex problem solving shown in Table 3, establishment diversity is positively and significantly related to wages in both high and low terciles, with coefficient sizes increasing systematically with the intensity of complex problem solving, roughly doubling in size from the lowest to the highest tercile. More concretely, a one standard deviation increase in establishment diversity for workers in low complex problem solving activities is associated with an average increase in wages of 0.7%; among workers in the highest terciles of the various measures of complex problem solving, the figure rises to 2.1%. Though city- and establishment-level results are not identical, at each scale we find evidence offering broad support for Hypothesis 1.

5.2 Robustness Checks

Equation (1) aims to address issues of worker selectivity into plants and metropolitan areas. More generally, a chief strength of the econometric approach taken is its ability to account for a wide range of sources of unobserved heterogeneity.[10] Still, bias arising from idiosyncratic shocks occurring at the level of the city, industry, firm, or establishment

[10] Diversity could take time to influence productivity, rather than assuming, as we do in our analysis, that wages respond to changes in diversity that occur during the same year. We explored lagged measures of diversity in seeking candidate instruments, as described in the next section, and found that shallow lags consistently emerged as positively and significantly related to wages. Absent theoretical guidance on how time might factor into this relationship, we take the sign and significance of these shallow lags as some confirmation of the robustness of our approach, though more work exploring the time dimension would be useful.

could be driving the overall relationship, as a reverse causal sequence running from wages to immigrant diversity. The paper now turns to addressing potential bias of this sort by instrumenting for key explanatory variables: city and establishment diversity.

Finding suitable instruments for these variables is challenging, and especially so at the establishment level, as LEHD offers a very limited range of workplace characteristics. Candidate instruments were subjected to the usual battery of tests for exclusion, instrument strength, and (joint) orthogonality. We settled on deep lags of immigrant diversity in cities (generally three- and four-year lags) and workplaces (typically two-year lags), as well as a widely used shift-share instrument, following Card (2001).[11] A wide range of 'internal' lagged instruments were explored until suitable combinations were found. Because these are lags of potentially endogenous regressors, we were especially concerned that they could directly influence the dependent variable, instead of influencing wages exclusively through current-year diversity levels. Indeed, this emerged as a problem for shallower lags, and for a few proxies for complex problem solving, in deeper lags as well. All the instruments used in the presented models passed exclusion tests. However, we were not able to find satisfactory sets of instruments for every measure of complex problem solving.

Table 4 presents results for the subset of problem solving indicators for which suitable instruments were discovered, and represents IV-estimate corollaries for results presented in Table 3. Results were produced using the two-step cluster-robust generalized method of moments (GMM) fixed effects estimator. Given the nesting of individual workers within establishments in our data, this approach ought to produce estimates that are more efficient than those produced using standard two stage least squares (Baum et al. 2003). As the table shows, for the presented groups, the Kleibergen-Paap underidentification and the Hansen J test statistics indicate, respectively, that our instruments are not weak, and that jointly they are distributed independently of the error process. As in Table 3, we report coefficients only for our city and workplace measures of birthplace diversity. Results for control variables do not depart materially from those produced in the non-instrumented

[11] The Card-style shift-share indicator is built in three steps. The first step is to estimate national-level annual growth rates, denoted as g for specific immigrant groups s, between $t-1$ and t. Second, we apply these growth rates to each city, generating the 'predicted' population share of a given immigrant group $(\widehat{s_j/s_j})$ in metropolitan area j as follows: $(\widehat{s_j/S_j})_t = (s_j/S_j)_{t-1}[1+(g_s)_{t-1-t}]$. Finally, we substitute these for actual shares of each group in fractionalization indices, thereby creating plausible exogenous indicators of city-level immigrant diversity.

models.

Although the estimates presented in Table 4 differ somewhat from non-instrumented results, they lend further support to Hypothesis 1. Across the lowest terciles of each measure of complex problem solving, coefficients on metropolitan immigrant diversity are negative. For creativity (Column 1) and science (Column 2), the coefficient is significant at only a ten percent level; coefficients for technology & engineering (Column 3) and math (Column 4) are significant at a five percent level. Results for workers in the highest terciles hew closer to uninstrumented estimates. Here the coefficients for city-level diversity are uniformly positive and significant, most at a one percent level. The main difference of note is that the coefficients are larger than those presented in Table 3. Calculation of z-scores indicates rejection of the null hypothesis at a 1 percent level, confirming that the relationship between city diversity and wages is larger among workers in the highest terciles of each measure of complex problem solving. The establishment level results are more idiosyncratic. Only three of the eight groups have a significant coefficient at the establishment level, and these represent a heterogeneous group: the highest tercile of creativity, the lowest tercile of science, and highest tercile of technology & engineering. For each measure of complex problem solving, we fail to reject the null hypothesis of no differences between establishment estimates at high and low terciles.

There are reasons to interpret Table 4 with some caution. Aside from the fact that IV generates less efficient estimates in general, although samples still number in the millions, the use of deep lags mean that many observations are lost. The result ought to be reduced precision, especially since the job spells over which the relationships of interest is measured are shortened. Moreover, given the challenges of finding suitable instruments, we are unable to present the full range of measures capturing complex problem solving.

Those caveats notwithstanding, the IV results support a clear contrast in the relationship between wages and urban manifestations of immigrant diversity among workers engaged in activities that differently feature complex problem solving. This variation conforms to both theoretical priors and uninstrumented results. Workers most intensively engaged in complex problem solving receive benefits from rising city diversity, unlike workers in the lowest terciles of complex problem solving. Though it would be possible to see the significant negative effect for workers in the lowest terciles as evidence of the more

Table 4: Summary Results for 2-Step GMM FE IV Estimates of Relationship between Change in Immigrant Diversity and Change in Log Annual Wages by Task Types: Low- and High Complex Problem Solving

	Dependent Variable: Log of Annual Earnings			
	Creativity (1)	Science (2)	Eng. & Tech (3)	Math (4)
Lowest Tercile				
City Diversity	-0.261*	-0.259*	-0.425**	-0.320**
	(0.150)	(0.142)	(0.200)	(0.152)
Workplace Diversity	0.022	0.049***	-0.007	0.017
	(0.019)	(0.018)	(0.105)	(0.040)
Highest Tercile				
City Diversity	0.576***	0.729***	0.556***	0.838**
	(0.158)	(0.224)	(0.154)	(0.380)
Workplace Diversity	0.097**	0.030	0.095**	-0.028
	(0.043)	(0.049)	(0.043)	(0.069)
Lowest Tercile				
Observations (millions)	13.60	17.48	2.90	6.68
Individuals (millions)	2.96	3.85	0.69	1.48
Kleibergen-Paap LM (Under-ID)	4372	7701	146	842
Kleibergen-Paap LM p-value	0.000	0.000	0.000	0.000
Kleibergen-Paap Wald F (weak ID)	2175	3616	64	594
Hansen J (overidentification)	0.024	0.852	0.28	0.02
Hansen J p-value	0.88	0.36	0.60	0.90
Highest Tercile				
Observations (millions)	25.68	18.52	26.40	16.89
Individuals (millions)	5.22	3.67	5.39	3.58
Kleibergen-Paap LM (Under-ID)	1731	1444	1710	1724
Kleibergen-Paap LM p-value	0.000	0.000	0.000	0.000
Kleibergen-Paap Wald F (weak ID)	1269	1169	1222	1191
Hansen J (overidentification)	1.01	2.67	0.28	1.55
Hansen J p-value	0.32	0.10	0.59	0.21

Note: Standard errors in parentheses, corrected for clustering by establishment. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Estimated equation is (1). Full set of control variables (E' = establishment employment size; C' = metro labor force size and college share of labor force), as well as individual-establishment-city and year effects included in each model. Centered R^2 range from 0.16 to 0.33 across the models in this table. Counts are rounded to the nearest 10,000 to ensure confidentiality. Full range of coefficients available upon request.

negative theoretical effects of diversity, we remain hesitant to push this very far given issues of precision as well as lower levels of significance. We prefer to focus on the enduring contrast between the low and high groups as the more important story from these results. The GMM results offer less clear support for the interpretation of the links between diversity at the establishment level and wages. However, since a considerable amount of prior work (i.e. Kemeny and Cooke 2015, Trax et al. 2015, Ottaviano and Peri 2006) provides broad support for this relationship across all workers in a similar IV context, it is plausible that the IV results have been biased by the aforementioned constraints placed upon the sample.

5.3 Complex Problem Solving and Interaction

In Table 5 we turn to the exploration of our second hypothesis: that positive spillovers from diversity will be especially strong for workers engaged in high levels of both complex problem solving and interaction. To differentiate low-and high interaction industries, we deploy the O*NET-derived measure capturing the importance of 'social orientation.' The estimation approach directly follows from equation (1), and can be interpreted in a manner consistent with results shown in Table 3. The key difference lies in how the contrasting groups of workers are identified. All of the workers analyzed to test this hypothesis fall into the highest tercile of the relevant proxy for complex problem solving. Hence, in Table 5, the designated lowest tercile represents workers in industries that intensively demand complex problem solving but require little interpersonal interaction. Workers of this kind are employed in establishments that NAICS classifies into categories like Independent Artists and Writers, but also, curiously, a variety of retail industries. The highest tercile represents those for whom both complex problem solving and interaction are important – the film directors of our hypothesis. In practice, this group covers workers in such industries as Science Research and Design Services as well as Computer Systems Design.

Table 5 offers relatively consistent patterns across the different measures of complex problem solving, considering both city-specific and workplace-specific manifestations of diversity. Starting with diversity measured at the city scale, naive estimates contrast sharply among workers in the highest and lowest terciles of social interaction (each of whom are in the highest tercile of creativity, innovation, hard problem solving, school

Table 5: Summary Results for Fixed Effects Estimates of Relationship between Change in Immigrant Diversity and Change in Log Annual Wages by Task Types and Social Orientation: High Complex Problem Solving, Low- and High Social Orientation

	Dependent Variable: Log of Annual Earnings						
	Creativity (1)	Innovation (2)	Problem Solving (3)	School Reqs. (4)	Science (5)	Eng. & Tech (6)	Math (7)
High Complexity & Low Interaction							
City Diversity	0.011	0.222	0.089	0.169	0.981***	0.278**	0.092
	(0.385)	(0.136)	(0.287)	(0.200)	(0.185)	(0.130)	(0.088)
Workplace Diversity	0.013	0.020***	0.078***	0.019	-0.007	0.043***	0.061***
	(0.013)	(0.006)	(0.025)	(0.014)	(0.021)	(0.010)	(0.007)
High Complexity & High Interaction							
City Diversity	0.425***	0.419***	0.426***	0.366***	0.481***	0.387***	0.611***
	(0.120)	(0.124)	(0.116)	(0.123)	(0.159)	(0.125)	(0.180)
Workplace Diversity	0.113***	0.109***	0.113***	0.103***	0.154***	0.114***	0.119***
	(0.027)	(0.029)	(0.026)	(0.028)	(0.033)	(0.029)	(0.029)
High Complexity & Low Interaction							
Observations (millions)	2.80	8.03	1.21	1.27	0.55	10.14	16.50
Individuals (millions)	0.69	1.92	0.23	0.31	0.14	2.35	3.75
High Complexity & High Interaction							
Observations (millions)	62.28	54.09	61.81	60.09	45.60	58.41	42.57
Individuals (millions)	11.87	10.53	11.95	11.60	8.45	11.15	8.38

Note: Standard errors in parentheses, corrected for clustering by establishment. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Estimated equation is (1). Full set of control variables (E' = establishment employment size; C' = metro labor force size and college share of labor force), as well as individual-establishment-city and year effects included in each model. In every model in this table, the R^2 is greater than or equal to 0.93. Counts are rounded to the nearest 10,000 to ensure confidentiality. Full range of coefficients available upon request.

requirements and mathematical reasoning. Specifically, for workers engaged in activities that are rich in complexity but are not socially-demanding, coefficients on city diversity are relatively small compared to prior estimates, and they not statistically significant. Meanwhile, for workers in activities that intensively demand both problem solving and a strong social orientation, coefficients are positive, larger, and uniformly significant at a 1 percent level. However, z-scores indicate a failure to reject the null hypothesis of no differences among these estimates. The relationship differs for workers in engineering- & technology-intensive sectors, whereby city diversity coefficients for both high and low terciles of social interaction are positive and significant. Results for workers in science-intensive industries (Column 5) are highly idiosyncratic. For these workers, coefficients on city immigrant diversity at either end of the spectrum of social interaction are positive and significant. Curiously, the city coefficient for workers in low-interaction activities is quite large and nearly twice the size as the estimate for those that are more socially oriented - a difference we confirm to be significant.

Results are more clearly differentiated when considering diversity at the establishment scale. For workers engaged in high levels of complexity and low levels of social interaction, coefficients are mostly positive and occasionally significant. Coefficients on workplace diversity among workers in high complexity and high interaction categories are uniformly positive and significant at a one percent level, and they are considerably larger than their counterparts for whom social orientation is low. Significance tests confirm these differences.

Hence, we find mixed evidence in support of Hypothesis 2. Considering the operation of immigrant diversity at the level of cities, we find little unambiguous support for the idea that diversity ought to matter most for workers deeply involved in complex problem solving and interpersonal interaction. We do find evidence supporting this kind of differentiation in our estimates of immigrant diversity at the establishment scale.

6 Discussion

This paper set out to 'stress test' the theory underlying a raft of recent papers exploring the relationship between immigrant diversity and productivity. This growing body of work, connected to deeper traditions in management, organizational sociology and regional science considers that interpersonal interactions among a diverse populace may influence worker productivity by improving collective problem solving. Yet existing studies explore diversity impacts without distinguishing workers based on the extent to which complex problem solving and interpersonal intreraction are important, leaving theory at some remove from empirical evidence.

This paper takes steps toward bringing them closer together. Two hypotheses are tested. The first considers that diversity impacts ought to be stronger among workers that are intensively involved in complex problem solving. The second suggests that, among such workers, those who are additionally oriented toward social interaction ought to be particularly enriched by the diversity in their midst.

In addition to the novelty of the hypotheses, we add value to the literature in a few ways. First, we adopt an empirical strategy that accounts for a wide array of selectivity issues, absorbing bias from any pertinent, durable, but unobserved factors that could differentiate workers, workplaces, and cities. Second, we differentiate between the influence of diversity in the cities in which individuals live and the establishments in which they work. Third, our dataset covers a large proportion of the population of workers and workplaces in a large number of American metropolitan areas. Fourth, we triangulate across a wide range of proxies for complex problem solving, letting us observe consistency as well as variation between different dimensions of this latent variable.

Results reported in this paper strongly support the first hypothesis, and offer mixed evidence in favor of the second. Workers involved in activities that intensively feature creativity, innovation, problem solving, schooling, science, engineering and technology, and mathematical reasoning are all rewarded from rising immigrant diversity in both their cities and their places of work. Those employed in sectors featuring the lowest levels of such characteristics are either unaffected by changes in diversity or they receive much smaller diversity benefits. Results aiming to address remaining sources of bias from endogeneity broadly support these findings, most clearly in regards to diversity impacts flowing from the urban context. In relation to our second hypothesis, we find that spillovers from immigrant diversity at the establishment scale are clearest for those workers intensively engaged in highly interactive acts of complex problem solving. At the city scale, we do not find evidence of differentiation on the basis of social interaction.

Though the estimation approach in the paper accounts for a wide array of sources of potential bias, there remain many opportunities for future work. The measurement of latent characteristics remains a concern, in particular for interpersonal interaction for which we have used only a single, imperfect measure: 'social orientation.' This measure diverges from the ideal in at least two ways. First, it captures workers' preferences for working with others. These preferences may not be fully reflected in actual work tasks, given that workers likely make occupational choices that optimize on bundles of characteristics, rather than maximizing each individual preference. More practically, we find that industries that require high levels of various forms of complex problem solving generally involve workers who also prefer high levels of social orientation. This is reflected in the comparatively small analytical samples for estimates of high-complexity/low-interaction. This renders these estimates much more vulnerable to being driven by idiosyncratic unobserved features of workers in these industries. These issues might lead one to search for better measures of social interaction, but if interaction and complexity truly move in lockstep in the contemporary economy, it might be more appropriate to reject Hypothesis 2 as a valid avenue for future study.

Perhaps the largest lingering challenge to our ability to speak confidently about a causal relationship flowing from diversity to productivity is the possibility that unmeasured shocks, whether city- or workplace-specific, are in fact driving the observed associations. The relationships between diversity and wages at each scale could conceivably be driven by other factors that happen to be correlated with changes in diversity (or perhaps even shape both diversity and productivity). The GMM estimates presented in Table 4 help to alleviate such concerns, but cannot fully eliminate them. Potential bias from omitted variables looms over many if not most empirical studies, but it is worth considering whether there are specific factors whose absence in this context is likely to materially bias estimates of the relationship of interest.

One such concern comes from our inability to directly capture individual-level human capital in its various forms. Human capital is a latent variable that resists precise measurement, and educational length is at best an imperfect proxy (Delgado et al. 2014). Still, it would be desirable to include workplace-specific measures of the stock of available educational experiences, to help ensure that results are not being driven by a shock to observable workplace human capital. Workplace human capital could co-move with birthplace diversity to the extent that immigrants are more likely to take jobs for which they are overqualified. Based on evidence for the UK Dustmann et al. (2013), however, problems of overqualification decline with length of residence in the receiving country. To the extent that this also holds for the U.S., measures of immigrant diversity that include a substantial number of immigrants who arrived years or even decades ago (as the measures used in this research do) ought not to be vulnerable from bias from this source. Still, to the extent that such shocks are present but unmeasured, it is conceivable that they, rather than diversity, explain changes in wages. These are less plausible explanations at the city level, since we include indicators of the share of college educated workers in each model.

Relatedly, unobserved human capital might be a confounder through a kind of 'matching' channel, in which that people from particular national backgrounds could have specific skills sought by employers, which could also be manifested in occupational diversity. However, for this to be a issue at the establishment scale, birthplace diversity would need to move in lock-step with increases in learned skills or occupational diversity, particularly in the high complex problem solving industries. Related work based on German data does not find occupational diversity to be statistically significant or alter the association between immigrant diversity and productivity (Trax et al. 2015, p.22). It is worth noting that, unlike immigration policies in many other advanced economies, in the specific context of the U.S. the majority of immigration flows are not skill-biased. If most U.S. visas were premised on preferential treatment for workers with specific skills in short supply in the domestic labor market, like the H-1B program, then this would be somewhat more of a concern for our results. However, as an example, in 2015 the share of highly-skilled workers among all new foreign arrivals eligible for work was approximately 18 percent.[12] This example focuses on a single, recent year, whereas the set of foreign born workers in the LEHD data include many individuals who are not newly arrived in the U.S. Given the

[12] Authors' calculations based on figures reported in the U.S. Department of State's 2015 Report of the Visa Office (https://travel.state.gov/content/dam/visas/Statistics/AnnualReports/FY2015AnnualReport/FY15AnnualReport-TableXVIB.pdf) and in the Department of Homeland Security's 2015 Yearbook of Immigration Statistics (https://www.dhs.gov/immigration-statistics/yearbook/2015). Skilled workers – the numerator – are defined conservatively here as those admitted under employment-based preferences, including E3, E3R, H1-B, H-1B1, H-1C, L1, O1, O2, P1-3, Q1, R1, and TN. The denominator is defined as the sum of legal permanent residence applications granted and work-eligible nonimmigrant visas. Estimates are relatively consistent across recent years for which data is available.

relatively loose connection between national-level changes in foreign-born workers and the availability of skills, we see little reason to expect that changes in workplace immigrant diversity ought to be systematically positively correlated with changes in workplace human capital.

Another potential concern grows out of research demonstrating that immigrants' entry into labor markets spurs occupational upgrading by natives (Peri and Sparber 2009, 2011, D'Amuri and Peri 2011). This represents a distinct mechanism linking immigration and higher wages, one likely to be present in the workplaces and cities we observe. Among our 'stayers,' this could mean that some of the wage growth we ascribe to diversity flows instead comes from intra-establishment occupational upgrading. Still there are several reasons why this is unlikely to fully explain our findings. First, Peri and Sparber (2009) and D'Amuri and Peri (2011) find this upgrading effect among both workers across the educational spectrum, and this is hard to reconcile with the highly task-differentiated results documented in this article. Additionally, occupational upgrading generates expectations that natives ought to receive relatively larger benefits than foreign born workers, which is precisely the opposite of patterns documented in related research (Kemeny and Cooke 2017b,a). One material point is that, by focusing on stayers, this study may miss additional immigration-derived wage increases that arise when natives switch occupations by moving across establishments or firms.

Future work might also explore the possibility that increased competition from immigrants puts pressure on jobholders, prompting them to work longer hours and raising their wages through more time on the clock, or perhaps through greater effort thereby raising their productivity. In this case, the positive wage effect we observe would be due to more hours worked or more personal effort, rather than productivity gains associated with better problem solving from working and living in diverse environs. Neither effort nor hours worked are reported in LEHD data, thus, we cannot address this possibility directly. However, there may be reasons to be skeptical of this alternative. First, it is unclear why immigrant *diversity* should be correlated with increased competition in the labor market. Second, the avenue of more hours worked would only affect those earning hourly wages, who we would expect to see more heavily represented in the low complex problem solving industries. Thus, we would not expect to see a differential relationship between the low- and high complex problem solving industries. Finally, the recent Executive Order on salaried worker overtime[13] suggests that, absent regulation, employers are perfectly happy extracting as many hours and as much effort from their employees as possible without increasing their compensation. It is not implausible that competition-induced increases in effort or work hours could apply downward rather than upward pressure on wages.

These avenues of further exploration aside, this paper has produced the clearest evidence available in support of the idea that the robust association between immigrant diversity and wages reflects the role of heuristic heterogeneity in augmenting productivity. It also highlights the fact that diversity relates to productivity consistently at both the level of cities and workplaces. These results offer value in thinking about the economic implications of immigration at both scales, suggesting that birthplace heterogeneity offers concrete economic benefits, augmenting organizational competitiveness as well as regional vibrancy.

Acknowledgments

Thanks to Olmo Silva, Max Nathan, and seminar participants at Oxford, Stanford, Toronto and Stavanger, as well as conference participants at the North American Regional Science Council, GEOINNOV, and the AAG, for helpful discussions and suggestions. We are grateful for the thoughtful critiques by the four anonymous reviewers of this journal and patient guidance of John Walsh, which considerably improved the paper. Thanks also to Bert Grider at the Triangle RDC for help with disclosure avoidance review of the results. This work was supported by the U.S. National Science Foundation [grant BCS-1359768]. The research uses data from the Census Bureau's Longitudinal Employer Household Dynamics Program, which was partially supported by the following National Science Foundation grants [SES-9978093, SES-0339191, ITR-0427889]; the National Institute on Aging [grant AG018854]; and grants from the Alfred P. Sloan Foundation.

[13] United States Department of Labor, "Final Rule: Overtime": https://www.dol.gov/whd/overtime/final2016/index.htm.

References

Acemoglu, D. and Angrist, J.: 2001, How large are human-capital externalities? evidence from compulsory-schooling laws, *NBER Macroeconomics Annual 2000, Volume 15*, MIT Press, pp. 9–74.

Ager, P. and Brückner, M.: 2013, Cultural diversity and economic growth: Evidence from the US during the age of mass migration, *European Economic Review* **64**, 76–97.

Aiken, M. and Hage, J.: 1971, The organic organization and innovation, *Sociology* **5**(1), 63–82.

Audretsch, D. B. and Feldman, M. P.: 2004, Knowledge spillovers and the geography of innovation, *in* J. Henderson and J. F. Thisse (eds), *Handbook of Urban and Regional Economics*, Vol. 4: Cities and Geography, Elsevier, pp. 2713–2739.

Bakens, J., Mulder, P. and Nijkamp, P.: 2013, Economic impacts of cultural diversity in the Netherlands: Productivity, utility and sorting, *Journal of Regional Science* **53**(1), 8–36.

Baum, C. F., Schaffer, M. E., Stillman, S. et al.: 2003, Instrumental variables and gmm: Estimation and testing, *Stata journal* **3**(1), 1–31.

Bellini, E., Ottaviano, G., Pinelli, D. and Prarolo, G.: 2013, Cultural diversity and economic performance: Evidence from European regions, *in* R. Crescenzi and M. Percoco (eds), *Geography, institutions and regional economic performance*, Springer-Verlag, pp. 121–142.

Card, D.: 2001, Immigrant inflows, native outflows, and the local labor market impacts of higher immigration, *Journal of Labor Economics* **19**(1), 22–64.

Clearwater, S., Huberman, B. and Hogg, T.: 1991, Cooperative solution of constraint satisfaction problems, *Science* **254**(5035), 1181–1183.

Clogg, C. C., Petkova, E. and Haritou, A.: 1995, Statistical methods for comparing regression coefficients between models, *American Journal of Sociology* **100**(5), 1261–1293.

Combes, P., Duranton, G. and Overman, H.: 2005, Agglomeration and the adjustment of the spatial economy, *Papers in Regional Science* **84**(3), 311–349.

Combes, P.-P., Duranton, G. and Gobillon, L.: 2011, The identification of agglomeration economies, *Journal of Economic Geography* **11**(2), 253–266.

D'Amuri, F. and Peri, G.: 2011, Immigration, jobs and employment protection: Evidence from europe. National Bureau of Economic Research.

Dawson, J.: 2012, Measurement of work group diversity. Unpublished PhD Dissertation, Aston University.

Delgado, M. S., Henderson, D. J. and Parmeter, C. F.: 2014, Does education matter for economic growth?, *Oxford Bulletin of Economics and Statistics* **76**(3), 334–359.

Dustmann, C., Frattini, T. and Preston, I. P.: 2013, The effect of immigration along the distribution of wages, *The Review of Economic Studies* **80**(1), 145–173.

Easterly, W. and Levine, R.: 1997, Africa's growth tragedy: Policies and ethnic divisions, *Quarterly Journal of Economics* **112**(4), 1203–1250.

Elias, A. and Paradies, Y.: 2016, The regional impact of cultural diversity on wages: evidence from australia, *IZA Journal of Migration* **5**(1), 1–24.

Feldstein, M.: 2008, Did wages reflect growth in productivity?, *Journal of Policy Modeling* **30**(4), 591–594.

Fujita, M. and Thisse, J.-F.: 2013, *Economics of agglomeration: cities, industrial location, and globalization*, Cambridge university press.

Harrison, D. A. and Klein, K. J.: 2007, What's the difference? diversity constructs as separation, variety, or disparity in organizations., *Academy of Management Review* **32**(4), 1199–1228.

Hoffman, L. and Maier, N.: 1961, Quality and acceptance of problem solutions by members of homogeneous and heterogeneous groups, *Journal of Abnormal and Social Psychology* **62**(2), 401–407.

Hong, L. and Page, S.: 2001, Problem solving by heterogeneous agents, *Journal of Economic Theory* **97**(1), 123–163.

Hong, L. and Page, S.: 2004, Groups of diverse problem solvers can outperform groups of high-ability problem solvers, *Proceedings of the National Academy of Sciences of the United States of America* **101**(46), 16385–16389.

Huberman, B.: 1990, The performance of cooperative processes, *Physica D: Nonlinear Phenomena* **42**(1), 38–47.

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B. and Williams, C. C.: 2008, Gender similarities characterize math performance, *Science* **321**(5888), 494–495.

Jacobs, J.: 1961, *The death and life of great American cities*, Vintage.

Kemeny, T.: 2012, Cultural diversity, institutions, and urban economic performance, *Environment and Planning A* **44**(9), 2134–2152.

Kemeny, T.: 2017, Immigrant diversity and economic performance in cities, *International Regional Science Review* **40**(2), 164–208.

Kemeny, T. and Cooke, A.: 2015, Spillovers from immigrant diversity in cities. LSE Spatial Economics Research Centre Discussion Paper no.175.

Kemeny, T. and Cooke, A.: 2017a, The economic geography of immigrant diversity: Disparate impacts and new directions. Mimeo.

Kemeny, T. and Cooke, A.: 2017b, Urban immigrant diversity and inclusive institutions, *Economic Geography* **93**(3), 267–291.

Knack, S. and Keefer, P.: 1997, Does Social Capital Have An Economic Payoff? A Cross-Country Investigation, *Quarterly Journal of Economics* **112**(4), 1251–1288.

Longhi, S.: 2013, Impact of cultural diversity on wages, evidence from panel data, *Regional Science and Urban Economics* **43**(5), 797–807.

McKinney, K. and Vilhuber, L.: 2011, LEHD data documentation LEHD-OVERVIEW-S2008-rev1. U.S. Census Bureau Center for Economic Studies Working Paper 11-43.

Mőhlmann, J. and Bakens, J.: 2015, Ethnic diversity and firm productivity in the Netherlands, *in* P. Nijkamp, J. Poot and J. Bakens (eds), *The Economics of Cultural Diversity*, Edward Elgar Publishing, Cheltenham.

Moretti, E.: 2004a, Estimating the social return to higher education: evidence from longitudinal and repeated cross-sectional data, *Journal of Econometrics* **121**(1-2), 175–212.

Moretti, E.: 2004b, Human capital externalities in cities, *Handbook of regional and urban economics* **4**, 2243–2291.

Moretti, E.: 2012, *The New Geography of Jobs*, Houghton Mifflin Harcourt.

Nathan, M.: 2011, The long term impacts of migration in British cities: Diversity, wages, employment and prices. LSE Spatial Economics Research Centre (SERC) Discussion Paper 67.

Nathan, M.: 2015, Ethnic diversity and business performance and location: Which firms? which cities? Mimeo.

Nisbett, R., Ross, L. et al.: 1980, *Human inference: Strategies and shortcomings of social judgment*, Prentice-Hall Englewood Cliffs, NJ.

Østergaard, C. and Timmermans, B.: 2015, Diversity and innovation: The link between regional labor market characteristics, firm's employee diversity, and their innovative capabilities. Mimeo.

Ottaviano, G. and Peri, G.: 2006, The economic value of cultural diversity: Evidence from US cities, *Journal of Economic Geography* **6**(1), 9.

Özden, Ç., Parsons, C. R., Schiff, M. and Walmsley, T. L.: 2011, Where on earth is everybody? the evolution of global bilateral migration 1960–2000, *The World Bank Economic Review* **25**(1), 12–56.

Ozgen, C., Nijkamp, P. and Poot, J.: 2013, Measuring cultural diversity and its impact on innovation: Longitudinal evidence from dutch firms, *Technical report*, Discussion Paper Series, Forschungsinstitut zur Zukunft der Arbeit.

Peri, G. and Sparber, C.: 2009, Task specialization, immigration, and wages, *American Economic Journal: Applied Economics* **1**(3), 135–169.

Peri, G. and Sparber, C.: 2011, Highly educated immigrants and native occupational choice, *Industrial Relations: a journal of economy and society* **50**(3), 385–411.

Peri, G. and Yasenov, V.: 2015, The labor market effects of a refugee wave: Applying the synthetic control method to the mariel boatlift. National Bureau of Economic Research.

Rauch, J.: 1993, Productivity gains from geographic concentration of human capital: Evidence from the cities, *Journal of Urban Economics* **34**(3), 380–400.

Ruggles, S., Alexander, J., Genadek, K., Goeken, R., Schroeder, M. and M., S.: 2010, Integrated public use microdata series: Version 5.0, *Technical report*, Minneapolis, MN: Minnesota Population Center.

Sparber, C.: 2010, Racial diversity and aggregate productivity in US industries: 1980-2000, *Southern Economic Journal* **75**(3), 829.

Storper, M.: 2013, *Keys to the City: How Economics, Institutions, Social Interaction, and Politics Shape Development*, Princeton University Press.

Suedekum, J., Wolf, K. and Blien, U.: 2014, Cultural diversity and local labour markets, *Regional Studies* **48**(1), 173–191.

Tajfel, H.: 1974, Social identity and intergroup behaviour, *Social Science Information* **13**(2), 65–93.

Taylor, C. and Hudson, M.: 1972, *World Handbook of Political and Social Indicators*, Yale University Press.

Thomas, D. and Ely, R.: 1996, Making differences matter, *Harvard Business Review* **74**(5), 79–90.

Trax, M., Brunow, S. and Suedekum, J.: 2015, Cultural diversity and plant-level productivity, *Regional Science and Urban Economics* **53**, 85–96.

Turner, J. C., Hogg, M. A., Oakes, P. J., Reicher, S. D. and Wetherell, M. S.: 1987, *Rediscovering the social group: A self-categorization theory.*, Basil Blackwell.

Van Knippenberg, D. and Schippers, M. C.: 2007, Work group diversity, *Annual Review of Psychology* **58**, 515–541.

Weber, S. and Fujita, M.: 2004, Strategic immigration policies and welfare in heterogeneous countries. Fondazione Eni Enrico Mattei Research Paper 2-04.

Wilson, J. H. and Svajlenka, N. P.: 2014, Immigrants continue to disperse, with fastest growth in the suburbs. Brookings Immigration Facts Series, No. 18.