The Attenuation of the Agglomeration Economies:
A Manhattan Skyline Approach

Stuart S. Rosenthal
Department of Economics
Syracuse University
Syracuse, NY 13244-1020
USA
Phone: (315) 443-3809
ssrosent@maxwell.syr.edu
www-cpr.maxwell.syr.edu/faculty/rosenthal/

and

William C. Strange
RioCan Real Estate Investment Trust
Professor of Real Estate and Urban Economics
Rotman School of Management
University of Toronto
105 St. George Street
Toronto, ON M5S 3E6
Canada
Phone: (416) 978-1949
wstrange@rotman.utoronto.ca
www.rotman.utoronto.ca/~wstrange/

PRELIMINARY: COMMENTS WELCOME

February 21, 2005

*We gratefully acknowledge the financial support of the Kaufman Foundation, the Center for Policy Research at Syracuse University and the Social Sciences and Humanities Research Council of Canada. We are also grateful to Dan Black for helpful comments. Excellent research assistance has been provided by Yong Chen and Michael Eriksen.

Abstract

This paper estimates the effect of agglomeration on wages using a geographical approach (based on how much activity is close) rather than a political one (based on how much activity takes place in a given city). The estimates are carried out by developing “Manhattan Skyline” instruments, geological variables that predict the scale of urban development but are exogenous to a wage equation. These instruments are unique in their ability to predict differences in development within cities.

Using 2000 Census data, four key results are obtained. First, there exists a wage premium associated with local employment density. Specifically, wages increase roughly 3.5 percent for every additional 100,000 full-time workers present within five miles. Second, proximity to educated workers has a larger effect, an instance of human capital externalities. Keeping the number of workers within five miles constant and endowing 10,000 less-educated workers with college education raises wages by roughly 3 percent. Third, and most importantly, both the urbanization and the human capital effects attenuate with distance, with the effect of additional activity within five to twenty-five miles half to one-quarter as large as the effect of activity within five miles. However, in some models, agglomeration effects persist out to 100 miles, so there are agglomeration economies at work at both the city and the regional level. Fourth, the benefit received from agglomeration depends on a worker’s education. Usually, the benefit is greater for less educated workers. This is not always the case. Scientists and lawyers, for example, benefit substantially from proximity to college educated workers. For scientists, wages increase roughly 6 percent for every additional 10,000 college educated workers within five miles.

I. Introduction

Understanding the economy is not possible without understanding cities. The macroeconomy is an aggregate of individual agents, and these agents – both firms and households – are disproportionately urban. Productivity and growth depend on innovation, and innovation is also disproportionately urban. Trade takes place not between national aggregates but between individual economic agents located in particular places, mostly cities.[1] The importance of cities in growth, innovation, and trade has been widely noted, including, for instance, Marshall (1890) and Krugman (1991).

One fact that testifies particularly forthrightly to the importance of cities is the urban wage premium. Glaeser and Mare (2001) show that there is an urban wage premium of 33% between the largest metropolitan areas (with population 500,000 or more) and non-urban locations. Putting selection issues aside – we will take this problem seriously below – this premium suggests that urban labor is more productive, an instance of agglomeration economies. Other evidence of agglomeration economies has come from estimates of production functions (Henderson (2003)) and growth (Glaeser et al (1992) and Henderson et al (1995)).

In all of these cases and in nearly all of the rest of the literature, cities are taken as the fundamental geographic units. In the case of U.S. data, an economic city is a Metropolitan Statistical Area (MSA). These are aggregations of counties that are in some sense urban. Counties are, of course, both large and varied. The New York Primary MSA (PMSA) contains eight counties. The New York-Northern New Jersey-Long Island Consolidated MSA (CMSA) contains many more. Under either definition, there is considerable activity that takes place in New York that one would not normally think of as urban. For instance, in Putnam County (one of the eight PMSA counties), there were eight farms in 2001 (NAICS 111, data.bls.gov). This is

---

[1] See, for example Bairoch (1998) for a historical treatment of the role of cities in the economy.

clearly not an activity that one would typically classify as urban. Similarly, if we look just across a county line, we are likely to find activity that does seem to be urban. For example, there were 1327 financial and insurance establishments (NAICS 52) in Bergen County, New Jersey, in 2001, part of the New York CMSA but not the PMSA. One would not expect that moving an employee from a built-up part of Bergen Country to a less developed part of Putnam Country would result in a significant increase in the worker's productivity, wage, or tendency to innovate.

There is a compelling case, therefore, for considering cities as geographic units rather than as aggregates of political units like counties. This paper does this by estimating the effects of geographic agglomeration on wage. Our approach is to use geographic information software with 2000 Census data to characterize a worker's environment. We do this by creating concentric ring variables that characterize a worker's local environment for various distances, allowing us to estimate the degree to which immediate proximity matters for agglomeration. This allows us to ask whether it is cities that really matter at all, or whether the effect arises instead from a worker's immediate local environment or, in contrast, from regional agglomeration. In addition to controlling for local environment in this way, our models control also for a range of other characteristics that can impact a worker's wage, including education, marital status, and other typical wage equation variables.

In considering the local environment, we will be concerned with three things. The first is urbanization, the local scale of all activities. The second is local human capital, the proximity to more educated workers. The third is the rate at which these effects attenuate with distance. Of course, we must confront a significant econometric challenge in carrying out this estimation. Even with our range of controls for worker characteristics, it is possible that any observed wage premium is related to unobserved characteristics that are correlated with a worker's environment.

For instance, if highly motivated and productive workers are drawn to cities by bright lights, then a wage premium will arise because of selection. The importance of the selection issue is not unique to our work. Glaeser and Mare address the issue in several ways, including using as instruments the characteristics of a worker's parents' place of residence. They conclude that roughly half of the raw urban wage premium can be attributed to selection and that the rest is associated with agglomeration. In our case, we address this issue in two ways. First, because the estimation is carried out below the MSA level of aggregation and because of the size of the Census dataset, we are able to include a MSA-occupation fixed effects. With roughly 330 MSAs and 281 occupations, this adds over 92,000 fixed effects that should control for much of the unobserved heterogeneity across workers. Second, we estimate a two-stage least squares model in which the concentric ring employment variables are treated as endogenous. This controls for the possibility that even after including fixed effects, and so controlling for much of the unobserved heterogeneity across workers, individuals within individual city-occupation pairs may still sort across workplaces on the basis of unobserved skills in a manner that is correlated with local agglomerations of different types of employment. This is challenging, however, as the instruments used to identify the model in the two-stage least squares approach must vary with the geography of the concentric employment rings (e.g. 0 to 5 miles, 5 to 25 miles, etc.).

Our approach to instrumenting is motivated by the Manhattan Skyline. It is well-known among architects that the observed pattern of big buildings downtown and midtown, with smaller buildings in between reflects at least in part underlying geology. The tallest buildings are located where bedrock is relatively accessible. We therefore employ as instruments several geological variables that vary at a micro level of geography. For instance, for each urbanization ring, we use data from the U.S. Geological Survey to compute the amount of the ring covered by water, the fraction of the ring with sedimentary rock underground, the fraction of land designated as seismic hazard, and the fraction designated as landslide hazard. These variables are exogenous to a wage equation and are good predictors of micro variations in both the scale of all activity (urbanization) and the presence of highly educated workers (human capital). We believe, therefore, that they are valid instruments for these models.

The key results are as follows. First, there exists a wage premium associated with local employment density. Specifically, wages increase roughly 3.5 percent for every additional 100,000 full-time workers present within five miles. Second, proximity to educated workers has a larger effect, an instance of human capital externalities. Keeping the number of workers within five miles constant and endowing 10,000 less-educated workers with college education raises wages by roughly 3 percent. Third, and most importantly, both the urbanization and the human capital effects attenuate with distance, with the effect of additional activity within five to twenty-five miles half to one-quarter as large as the effect of activity within five miles. However, in some models, agglomeration effects persist out to 100 miles, so there are agglomeration economies at work at both the city and the regional level. Fourth, the benefit received from agglomeration depends on a worker's education. Usually, the benefit is greater for less educated workers. This is not always the case. Scientists and lawyers, for example, benefit substantially from proximity to college educated workers. For scientists, wages increase roughly 6 percent for every additional 10,000 college educated workers within five miles.

There are a number of papers that have considered agglomeration other than those mentioned above. The literature goes back to Marshall (1890), who proposes three sources of the productivity advantage of agglomeration: input sharing, labor market pooling, and knowledge spillovers. The theory literature on the microfoundations of agglomeration is surveyed by Duranton and Puga (2004). In the empirical literature, Wheaton and Lewis (2002) consider the impact of agglomeration on wages. They consider the impact of the specialization of a location in a worker's industry and the concentration of the worker's industry in that location on a worker's wage. They find a significant effect. They do not consider attenuation or the impact of urbanization on wage. Diamond and Simon (1990) also show that wages are higher in more specialized locations, a finding that they attribute to the compensation of workers for bearing industry specific risk. Adamson et al (2004) consider the relationship of the returns to education to agglomeration. They find that agglomeration reduces the education premium. Di Addario and del Blasio (2004) reach a similar conclusion using Italian data. They also show the returns to experience to be independent of agglomeration. Combes et al (2003), using French data, show that the primary effect of agglomeration on wages is through aggregate population rather than through the concentration of a worker's industry. See Rosenthal and Strange (2004) for a survey of the empirical literature.

Papers that consider the attenuation of agglomeration economies are much rarer. Rosenthal and Strange (2003) consider births. The key result is that the effects of the local environment on births and on new firm employment both attenuate by roughly half after five miles. Anderson et al (2004) consider the local impacts of a shift in the organization of higher education in Sweden. The policy change – a significant decentralization – is a kind of natural experiment. They key finding is that the effects are highly localized. Arzaghi and Henderson (2004) show that external economies in advertising are also highly localized.[2]

The rest of the paper is organized as follows. Section II describes some conceptual issues related to measurement of agglomeration economies and their impact on wages. Section III

---

[2] Ciccone and Hall (1996) look at density, but follow the rest of the literature in taking MSAs as primitive geographic units.

reviews the data. Section IV presents our results, highlighting the influence of urbanization and local human capital on wages. In each case, estimates of not only the level of effects but also the rate at which external economies attenuate over space are central to the discussion. Section V concludes.

II. Agglomeration, productivity, and wages

Our empirical approach to understanding the relationship of agglomeration to wages is to estimate a log wage equation containing agglomeration variables and the usual set of worker socio-demographic characteristics. This approach is standard. We also control for unobserved attributes by including fixed effects for the worker's MSA/occupation. To measure the influence of agglomeration, we include the concentric ring employment variables discussed in the introduction. They measure the spatial distribution of economic activity in the worker's local environment. All of our models are estimated twice, first by ordinary least squares (OLS) and then again by two-stage least squares (2SLS). In the latter case, we control for the possible endogenous choice of workplace location by instrumenting for the concentric ring employment variables. For instruments, we use the geological variables described in the Introduction. This section outlines the theoretical foundation for our empirical analysis. The central question is: under what conditions can the estimated impact of agglomeration on wages can be used as a measure of the benefits from agglomeration economies?

The theoretical basis for a relationship between agglomeration and wages is well-known (i.e., Roback (1982)). On the labor supply side, real wages must adjust so that mobile workers are indifferent between locations. On the labor demand side, nominal wages must equal the value of workers' marginal products. It is this equality that allows one to use nominal wages to look for evidence of agglomeration economies (see Moretti (2004), for example). However, although the competitive labor markets ensure that a worker will be paid the value of his or her marginal product, it is not necessarily the case that the influence of agglomeration on wages exactly reflects the benefits of agglomeration.

To clarify, we modify the open city approach from Gyourko and Tracy (1991) to characterize equilibrium wages and rents when both firms and workers are mobile. Figure 1 contains two curves. The first is combinations of rent and wage that give firms zero profit. It is labeled $\pi(A_a)= 0$. For any given increase in wage rates, land rents must fall if profits are to remain at zero, holding constant the attributes A_a of the local economic environment. The other curve ensures that workers enjoy equal utility in all locations. This locus, labeled $U(A_a) = U^*$, sets utility equal to a system-wide level, U*. It is upward sloping. If wage increases, land rent must also be higher if individuals are to maintain equal utility, holding constant the set of local attributes. Of course, firms are concerned with land rents in the commercial sector, while workers are directly concerned with residential land rents. However, these will be positively related in locational equilibrium, so we will for simplicity consider only one land rent variable. Under these conditions, the equilibrium wage and land rent at location a are given by w_a^* and r_a^* where the zero-profit and equal-utility curves intersect.

Each of these curves is shifted by the attributes specific to a workplace. Suppose that agglomeration increases productivity, reflected in an increase in attributes to A_b. In this case, the zero profit curve shifts out to $\pi(A_b)= 0$. If rents were not to change, then wages would rise by the full amount of the horizontal shift in the zero-profit locus. This is shown by $w_b^* - w_a^{**}$ in the figure. But, with the equal-utility curve upward sloping, land rents will also rise, and that difference reduces the change in wage that would otherwise occur. Under these conditions, estimates of the impact of agglomeration on wage rates provide a lower bound of the productivity gains from agglomeration.

In fact, the situation is even more complicated. Suppose that worker amenities depend on agglomeration. The sign of this effect in equilibrium is not clear. It may be that at the margin, worker utility falls with an increase in local population, a congestion effect. Or it may be that at the margin, worker utility rises with an increase in local population, a bright lights effect. Where the congestion effect is dominant, the equal-utility curve shifts to the right as the degree of local agglomeration rises. In this case, the wage will definitely be greater in a larger city. Even though urban disamenities exist, however, any increase in wages must be related to productivity. Otherwise, firms would not pay the urban wage premium. If the bright lights effect is dominant, then the equal utility curve shifts to the left. In this case, the amenity effect reduces the increase in wages that would have occurred had the equal utility curve not shifted. This suggests a second reason that the observed wage premium may understate the effect of agglomeration on productivity: urban amenities can encourage workers to agglomerate even if they receive a low wage. It should be noted, however, that our preferred specification will employ MSA/occupation fixed effects. These will control for at least some of the local amenity effect. Regarding whether the bright lights or congestion effect dominates, recent evidence on consumption and cities (Glaeser et al (2001)) favors the latter. In sum, a wage premium in dense areas is evidence of the existence of agglomeration economies. It is not a precise estimate of their magnitude.

In keeping with all this, our basic estimating equation will be:

$$\ln w_{i,z} = X_i\beta + A_z\gamma + Y_{i,z}\,\eta + \rho_{occ,z} + \varepsilon_{i,z}. \tag{1}$$

where $w_{i,z}$ is the wage of worker i in location z. X_i is a vector of worker i's observable characteristics (e.g. education). A_z is a vector of location-specific characteristics that affect productivity, for example, the total number of workers in the location. $Y_{i,z}$ is a vector of characteristics that are joint to the worker and location. An example here would be an MSA/occupation fixed effect. Unobserved effects are of two types. First, there are factors that are common to a worker's occupation and metropolitan area, $\rho_{i,z}$, and second, a purely random component denoted by $\varepsilon_{i,z}$. As noted above, in the estimation to follow, we effectively use fixed effects to control for $\rho_{i,z}$ by differencing out the MSA/occupation means from the data.

Our ability to obtain consistent estimates of the contributions of the agglomeration variables to wage, γ, then depends on the degree to which the remaining error component, $\varepsilon_{i,z}$, is orthogonal to the agglomeration variables. It is tempting to assume that the MSA-occupation fixed effects control for enough of the unobserved worker heterogeneity to render $\varepsilon_{i,z}$ independent of A_z . Indeed, evidence to be presented later suggests that for some of the models this is approximately true. However, it is also not difficult to construct scenarios where workers might still systematically sort on the basis of $\varepsilon_{i,z}$. For that reason, we estimate a set of two-stage least squares models to further control for unobserved heterogeneity of this kind.[3] For these models, we use geological variables that exogenously shift the cost of erecting tall buildings to instrument for the level of agglomeration. These and other data are described in the following section.

---

[3] Suppose, for example, that wages are higher in agglomerated areas, all else equal. Then unusually talented workers within a given MSA and occupation may be disproportionately drawn to such locations to the extent that skilled individuals benefit more from agglomeration economies than less skilled workers.

III. Data.

The primary data for the paper are drawn from the year 2000 5% Integrated Public Use Microdata Series (IPUMS).[4] Hourly wage rates are calculated by dividing annual wage earnings by the usual number of hours worked per week and the number of weeks worked in the last year. In our wage regressions, we make further use of the IPUMs data to control for a standard set of demographic attributes. These include the worker's level of education, the presence of children, marital status, age, race, and years of residency in the United States.[5] In addition, in various models we control for MSA/occupation fixed effects in order to capture unobserved MSA-wide effects that are specific to individual occupations that might affect individual wage rates. When the MSA fixed effects are interacted with the occupation fixed effects this results in over 92,000 fixed effects for models estimated over the entire United States. Ultimately, it is the large sample sizes in the IPUMs that make possible the inclusion of so many fixed effects.

The primary focus of the paper is the geographic reach of agglomeration economies. In order to achieve this focus, several data tasks are required. First, it is necessary for us to describe a worker's local environment in geographic terms. In the publicly available version of the Census, as accessed through the IPUMs, the location of the individual's workplace is identified down to the place-of-work PUMA level (PWPUMA). In most cases, work PUMAs correspond to regions identified by the first three digits of the 5-digit residential PUMA code. However, in some instances, work PUMAs correspond to a more idiosyncratic group of residential PUMAs. A correspondence file that enables one to identify the constituent residential PUMAs that make

---

[4] See www.ipums.org.

[5] We have also estimated all of our models controlling for the log of commute times, a variable reported in the IPUMs that one might expect would be related to wages. Results for the agglomeration variables are qualitatively unchanged when commute times is added to the model. However, because commute times is itself a function of the spatial distribution of employment in the metropolitan area, we omit commute times from the models presented in the paper in order to better identify the "full" effect of agglomeration.

up any given work PUMA is available at the IPUMs website. Also available at the IPUMs website and the U.S. Census are electronic maps of the residential PUMA boundaries. Those maps were used in conjunction with the PUMA/PWPUMA correspondence file and mapping software (MapInfo) to create an electronic map of the work PUMAs for the entire United States. That map is portrayed in Figures 2a and 2b. Figure 2a displays the map for the entire U.S., while Figure 2b displays expanded portions of the map for the eastern and western halves of the country. In addition, work PUMA boundaries for six large cities in the U.S. are portrayed in Figure 2c. As is apparent, large metropolitan areas have numerous work PUMAs, but in rural areas a single work PUMA can cover a large geographic area.

In measuring the spatial distribution of employment, we added up the number of individuals aged 30 to 65 employed full time in a given work PUMA including both men and women. In performing these calculations, the person weights from the IPUMSs were used to ensure that our employment counts correct for the non-random nature of the year 2000 Census. In addition, throughout the paper, we define full time workers as individuals who report that their usual number of hours worked per week in the last year was 35 hours or more.

For each work PUMA, we then created a set of concentric ring variables to describe the local environment. These variables are calculated as follows. First, employment in a given work PUMA is treated as being uniformly distributed throughout the work PUMA. Then, using mapping software, circles of radius r_i, i = 5, 25, 50, and 100 miles, are drawn around the Work PUMA's geographic centroid. The level of employment contained in a given circle is then calculated by constructing a proportional (weighted) sum of employment for those portions of the work PUMAs intersected by the circle. For example, if a circle includes all of work PUMA 1 and 10 percent of the area of work PUMA 2, then employment in the circle is set equal to the employment in work PUMA 1 plus 10 percent of the employment in work PUMA 2.[6] Differencing employment levels for adjacent circles yields estimates of the level of employment within a given concentric ring. Thus, the 25-mile ring reflects employment between the 5 and 25-mile circles. This procedure is carried out for every work PUMA in the United States, including Alaska and Hawaii.[7]

In sparsely developed areas where work PUMAs cover large geographic areas, all of the concentric employment rings may be contained within one work PUMA. Given the assumption of uniformly distributed workers throughout a work PUMA, this means that for these work PUMAs, all of the variation between employment rings is driven by the geographic area of the rings themselves, 25πd, 600πd, and so on, where d is employment density. While this does not bias our results, it does raise concerns about multicollinearity and our ability to identify the independent influence of the individual rings. For this reason, in all of the estimation to follow, we will estimate our models twice; first for the entire sample of workers across the United States, and then again for a sample of large cities. In the latter case, we use the 25 largest cities. As will become apparent, in most instances, results are largely robust across the two samples. For that reason, most of the results from the 25-MSA regressions are found only in the Appendix.

The paper will also make use of geological data from the United States Geological Survey (USGS.). These data were obtained over the web as boundary files that describe the spatial variation in seismic hazard, landslide hazard, and bedrock for the entire United States (including Alaska and Hawaii). Portions of these maps are illustrated in Figures 3a, 3b, and 3c,

---

[6] Various MapInfo software products were used to geocode the data and create the concentric ring variables.

[7] We initially calculated additional rings at 1 mile and 10 miles. However, it became apparent that the geographic scope of work PUMAs made it difficult to identify differences between 0 and 1 and 1 and 5 mile rings. Where a work PUMA is larger than 5 miles in size, the two inner rings are proportional to each other, resulting in a collinearity problem that made identifcation difficult. A similar problem operated between the 5 and 10 mile rings. Accordingly, we opted for our set of rings. Findings were largely consistent between the two specifications in that the 5-mile ring tends display the dominant effect.

respectively. As is clear from Figure 3a showing the bedrock underlying the New York metropolitan area, many different types of bedrock are identified in the USGS boundary file. We coded all regions in the bedrock map to equal one if they were associated with sedimentary rock, and zero otherwise. Overlaying the bedrock map on top of the work PUMA map from Figure 2, we then calculated the proportional average area of each work PUMA underlain by sedimentary rock. Similarly, seismic hazard varies on a scale from zero to 100 in the USGS file, as shown for San Francisco in Figure 3b. We calculated the average seismic hazard for each work PUMA by also overlaying the seismic map on top of the work PUMA map, allowing the relative contribution from each seismic region to a given work PUMA. Landslide hazard is coded into several different categories by the USGS, low, medium, and high, as shown for Los Angeles in Figure 3c. We attached numerical values to each of these categories, 1, 2, and 3, respectively, and then calculated the proportional average landslide hazard for each work PUMA following the same procedure as for the other geological variables. Finally, the percentage of each census tract covered by water was obtained from the year 2000 files of the Geolytics Neighborhood Change files. Together, these four variables (bedrock, seismic hazard, landslide hazard, and area covered by water) comprise our geological instruments. As discussed earlier, each of these variables is likely to affect the cost of erecting tall buildings and, in that regard, serves to predict agglomeration.

IV. Results

This section presents geographically motivated estimates of agglomeration economies. As discussed in Section II, the basic approach will be to estimate a wage equation containing the usual controls for worker characteristics and geographically constructed measures of the worker's local environment. We control for the endogeneity of the local environment using the geological "Manhattan Skyline" variables discussed in the Introduction.

A. Urbanization economies

We begin by analyzing the impact of urbanization on log wages where urbanization is measured by the total number of full-time (35 hours or more per week) male and female workers aged 30 to 65 currently employed within a given distance of the individual worker's workplace. All of the models both here and throughout the paper also include controls for a standard set of socio-demographic variables available in the IPUMS data. Coefficients on these additional variables are consistent with the labor literature and are not presented here to conserve space.[8] In addition, all of the models were estimated both for the entire United States and then again for a set of 25 large MSAs.[9] As will become apparent, in most instances results are robust between the two samples. For this reason, we will emphasize estimates for the entire country. All of the observations in the two samples are restricted to male workers between the ages of 30 and 65 who report that their usual hours worked per week in the previous year is equal to or greater than 35 hours.

Table 1 presents estimates of the urbanization/wage effects for several different specifications of the model. These specifications differ by the sort of fixed effects that are included (none, MSA, or MSA/occupation). Occupations are measured at the 3-digit level and

---

[8] These variables include dummy variables for the worker's education (less than a High School degree, High School degree, College degree, Masters degree, and more than a Masters). Also included are controls are also included for whether a child is present in the household, whether the worker is married, age and age squared of the worker, race of the worker (white, African American, Hispanic, Asian, and other), and the number of years the worker has been in the United States (less than 6 years, 6 to 10 years, 11 to 15 years, 16 to 20 years, 20 years or native citizen).

[9] These are
Akron, Atlanta, Baltimore, Boston, Chicago, Cleveland, Dallas, Denver, Detroit, Houston, Los Angeles, Miami, Milwuakee, New Orleans, New York, Philadelphia, Portland Oregon, Phoenix, Riverside, Sacramento, SanDiego, San Francisco, San Jose, Seattle, Washington DC.

include 281 categories. The MSA fixed effect models include 331 fixed effects while the MSA/occupation fixed effect models include over 92,000 fixed effects. The models also differ by estimation, either ordinary least squares (OLS) or two-stage least squares (2SLS). When estimating by 2SLS, we first differenced off the variable means for the fixed effects from both the dependent and independent variables.[10]

It is immediately apparent that the coefficients in Table 1 are very precisely estimated and typically highly significantly different from zero. The high degree of precision of the estimates is in part a consequence of the huge sample sizes available in the IPUMS data, in most instances well over 100,000 and in some cases over 1 million. Most of the models in later tables display a similar level of precision. For this reason, we will tend to focus on the point estimates in most of the discussion below and say little more about significance.

Figure 4a plots the urbanization coefficients for the 2SLS models for the entire US with MSA fixed effects, with MSA/occupation fixed effects, and with no fixed effects. The two fixed effects specifications are very similar, while the model without fixed effects gives quite different results. Given our strong priors that there are important characteristics of MSAs that might impact wages, we believe that some sorts of fixed effects should be included. In the various additional specifications to be discussed shortly, the similarity between the MSA and MSA/occupation fixed effect models persists in most cases, but not in all. For that reason, from here forward, we emphasize the MSA/occupation fixed effect model results since those estimates are more robust, bearing in mind that in most instances, results are quite similar to those obtained from the MSA fixed effect models.

---

[10] Because our focus is on identifying the influence of agglomeration on within fixed effect group variation in behavior we did not adjust the standard errors for the number of fixed effects.

Consider next the OLS and 2SLS estimates from the MSA/occupation fixed effects models. These estimates are plotted in Figure 4b. The pattern is that OLS tends to underestimate the nearby productivity effects of agglomeration, although estimates between the OLS and 2SLS models are quite similar out beyond 5 miles. We should caution, however, that in other specifications – both with and without a college degree – estimates from the OLS and 2SLS models sometimes differ. For that reason, we emphasize the 2SLS models in the remainder of the discussion.

Having settled on our preferred specification with regard to fixed effects and 2SLS, a general pattern is apparent from Figures 4a and 4b that will continue to hold in the models to follow: agglomeration economies attenuate with distance. This is evident from the downward slopping pattern of the plotted coefficients in the figures. The magnitudes of the effects are also of interest. In Table 1 (Figure 4b), for every 100,000 additional full-time workers within 5 miles, wages increase by roughly 3.3 percent.

B. Who benefits from agglomeration?

The previous discussion treats all workers as identical. There is reason to believe that this is not the case. In particular, there is reason to believe that human capital matters. Understanding of the relationship between agglomeration and human capital goes back quite far. Marshall (1890) wrote of the "secrets of the trade" being passed from worker to worker in an industry cluster. Jacobs (1967) wrote of "new work" being created in diverse cities. In both cases, cities foster knowledge spillovers. It is not at all clear, however, which workers one should expect to benefit the most from knowledge spillovers. It may be that the most learned will benefit the most because they have the greatest capacity to learn. This relates to the concept of absorptive capacity introduced by Cohen and Levinthal (1990), where firms that conducted research and development enjoyed greater spillovers from other firms' research. It may instead be that the least schooled will benefit the most because they have the most to learn. These issues aside, it is also not clear for whom the marginal benefit of a little extra learning is greatest. Diminishing marginal utility argues for the marginal benefit being greater for the unschooled, but the returns to being a superstar argues for the marginal benefit being greater for the learned. In sum, the contribution of knowledge spillovers to wage is theoretically ambiguous.

Although it is tempting to think primarily of knowledge spillovers when thinking about the effects of agglomeration on wages, there are other ways that agglomeration can impact wage. Returning to Marshall (1890), in addition to fostering knowledge spillovers, agglomeration also encourages labor market pooling and input sharing. Both of these should impact wages. In the case of labor market pooling, a better match adds to worker productivity, and so increases wage. In the case of input sharing, the presence of complementary inputs also raises productivity and wages. An instance of this sort of complementarity that has attracted interest among labor economists is the complementarity between workers with different education and experience. As above, the effect of these economies on productivity and wages for educated and uneducated workers is ambiguous. It depends on the strength of complementarities, broadly conceived.

This entire discussion makes it clear that although we argue in the pages to follow that we can identify and measure the extent of agglomeration economies, we are not able to say much about the forces that underlie the increasing returns. This failure of identification – called "Marshallian equivalence" by Duranton and Puga (2004) – is regrettably common in empirical work on agglomeration, as noted in Rosenthal and Strange (2004).

With this in mind, we now turn to the empirical analysis of who benefits from agglomeration economies. Table 2 presents estimates of the urbanization effects with the sample stratified into two groups: workers with a college degree or more and workers with less than a college degree. With regard to the various fixed effect specifications, Table 2 repeats the pattern from Table 1 (see also Figure 5a): estimates from the MSA and MSA/occupation fixed effect models are quite similar. Consider next the OLS and 2SLS estimates from the MSA/occupation fixed effects models. These estimates plotted in Figure 5b. As in Table 1, OLS tends to underestimate the effect of agglomeration within 5 miles. As Figure 5b shows, those differences are most pronounced for individuals with less than a college degree, while the differences between OLS and 2SLS are nearly absent for workers with a college degree or more. These results are interesting and suggest that less skilled workers may well be endogenously drawn to select workplaces on the basis of unobserved skills to a greater degree than more highly trained individuals.

As with the all education models of Table 1, Table 2 and Figures 5a and 5b show that agglomeration economies attenuate. Furthermore, they also show that the effect of agglomeration on productivity differs with the education of the individual workers. Specifically, workers with less than a college degree appear to benefit more from agglomeration than do college educated workers. This latter result will prove sensitive to further refinements of the model. Regarding magnitudes, in Table 2 and Figure 5b, the effect of 100,000 additional full-time workers is 3.9 percent for workers without a college degree and 2.4 percent for college educated workers. Moreover, for both of these groups it is clear that the effects attenuate, dropping to roughly 1 percent between 25 and 50 miles.

C. Human capital spillovers

We have dealt thus far with the reception of agglomeration economies, with a key result being that workers benefit differentially from agglomeration depending on their own levels of education. At this point, we turn to the parallel issue of how workers of different levels of education contribute to agglomeration economies. This issue involves the consideration of human capital spillovers: is it the case that an increase in the local level of education increases an individual worker's productivity and, therefore, wage?

Rauch (1993) considers human capital spillovers by looking at the impact of the average level of education on both wages and rents. His primary conclusion is that wages and rents rise significantly with average education. The magnitudes are nontrivial, with a one year increase in average schooling leading to an increase of 3% in wages and 13% in rents. One potential difficulty with this result is that schooling, whether at the average or individual level, is endogenous. Acemoglu and Angrist (2000) use compulsory schooling laws as an instrument for the local level of education. They then estimate the effects of local education, finding a positive effect, but one that is small and insignificantly different from zero. Building on Rauch, Moretti (2000) considers the impact of the presence of college graduates on a city's wages. He finds a positive effect of this kind of human capital. Together with Rauch and Acemoglu-Angrist, this might suggest that the human capital externalities depend on highly educated workers. See Moretti (2004) for a more complete survey of this literature.

There is again theoretical ambiguity on which workers will benefit the most from the presence of educated neighbors. As above, the less educated have more to learn but the more educated have evidenced a greater capacity to learn. And the contribution to marginal product from education is also ambiguous

To address these issues, we repeat the analysis in Tables 1 and 2 with the modification that our agglomeration variables are now disaggregated into two subcategories, the number of full-time workers aged 30 to 65 with less than a college degree, and the number with a college degree or more. Disaggregating in this manner makes it possible to assess the importance of proximity to human capital. As noted in Moretti (2004), despite a large literature that identifies the private returns to education, estimates of the spillover effects of education are remarkably scant. Those effects likely are of three types as described by Moretti (2004): (i) educated people commit fewer crimes, (ii) educated people make more informed decisions when voting, and (iii) proximity to educated workers may enhance productivity. It is the latter effect that we measure here.

In Figure 6a, we portray the estimates for the entire US for all education groups together (including education dummy variables in the regression models as before). Observe that proximity to educated workers increases wages, while proximity to workers with less than a college degree does the reverse. For every 10,000 educated workers within 5 miles, wages increase 2.5 percent. The effect attenuates monotonically, and is only half as large at 50 to 100 miles. The effect of proximity to workers with less than a college degree also attenuates, although here most of the attenuation appears to have occurred by roughly 5 miles. In addition, the external effects of nearby unskilled workers is less, roughly 1 percent lower wages for each 10,000 workers within 5 miles.

Figures 6b, 6c, and 6d plot results from specifications where we stratify the samples by education status, less than college degree and college or more. In Figure 6d, which summarizes the key patterns, for college educated workers, productivity effects associated with proximity to other workers attenuates monotonically, both with regard to proximity to college and less-than-college educated workers. For workers with less than a college degree, proximity to college degree workers also enhances wages but the effect appears to peak at roughly 5 to 25 miles, after which the pattern attenuates.

As before, our estimates also indicate that proximity to educated workers increases wages while proximity to workers with less than a college degree has the reverse effect. In addition, agglomeration within 5 miles affects productivity among college educated workers to a much greater degree relative to the productivity and wages of workers with less than a college degree. This holds both with respect to proximity to college degree workers and workers with less than a college degree. For completeness, it should be noted that in the 5 to 25 mile region, this pattern is reversed, with the wage effects of agglomeration more pronounced for the less educated workers.

The magnitudes evident in Table 3b and Figure 6d are also important. Focusing on the influence of nearby employment – within 5 miles – wage rates among college educated workers increase roughly 3 percent for every 10,000 college educated workers, while wages among workers with less than a college degree increase roughly 1 percent.

Finally, it is revealing to consider the external effect of taking a nearby worker without a college degree and replacing him/her with a college educated worker. This corresponds to the sort of calculations carried out by Rauch (1993) when measuring the effects of local human capital. In our model, this is captured by the difference in impact from proximity to college educated workes relative to less-than-college educated workers. These measures are displayed in Figure 6e for all workers combined, as well as for samples stratified into college and less-than-college educated workers. As is clear in the figure, for workers with less than a college degree, the influence of human capital peaks in the 5 to 25 mile range and attenuates thereafter, consistent with the patterns in Figure 6b. For college educated workers and also for all workers combined, the influence of proximity to human capital is largest in the 5 mile ring and attenuates monotonically thereafter.

D. Agglomeration economies by occupation

The discussion above makes clear that the influence of agglomeration differs across worker types, both with regard to reception of productivity effects and the generation of productivity spillovers. This section further explores these issues by repeating the analysis in Table 3b and Figure 6d with the sample stratified further by individual occupation. This allows for the possibility that workers belonging to individual occupations may respond differently to the presence of college educated and less-than-college educated workers.

Table 4 presents separate MSA fixed effect regressions for 25 large MSAs for five different occupations: Scientists, Lawyers, Engineers, Mechanics, and Service workers. In order to clearly distinguish between occupations, for the first three categories, we further required that individuals in the sample have a college degree or more, while for the latter two categories individuals had to have less than a college degree.[11] This distinguishes between workers classified in the same occupation, but who perform substantially different work (i.e., lawyers and paralegals). As before, estimates are presented for both the OLS and 2SLS regressions, but we focus on the 2SLS results. In addition, all of the regressions are specified as for the human capital models, with the agglomeration variables disaggregated into the number of workers with less than a college degree and the number with a college degree or more. The 2SLS coefficients

---

[11] Using the 1950 occupation definitions provided in the IPUMs, the 3-digit occupation codes that were used to define these occupations are as follows. For Mechanics, code 544. For Service workers, codes from 730 to 790. For Scientists, code 7 and all codes from 61 to 69. For Engineers, codes from 41 to 49. For Lawyers, code 55.

for the concentric ring variables are plotted in Figures 7a and 7b: Figure 7a plots the coefficients on the less-than-college degree rings, while Figure 7b plots the coefficients on the college-or-more rings.

Reviewing the two figures, several patterns discussed already are further reinforced. First, for each of these five occupations, proximity to workers with less than a college degree reduces wages, but those effects largely disappear after 5 miles. The one exception is for scientists, for whom the negative effect of proximity to workers with limited education extends out to 50 miles. Each of the occupations also benefits from proximity to college educated workers. As before, each of these patterns attenuates with distance, approaching zero by 50 to 100 miles in nearly every case.

Scientists, followed by lawyers, are the most sensitive to proximity to human capital. For scientists, each additional 10,000 college educated workers within 5 miles boosts wages and productivity by roughly 6 percent. For lawyers the comparable measure is roughly 5 percent, while for mechanics, the analogous measure or close to 4 percent. For service workers and engineers the analogous measures are roughly 2.5 percent and 1 percent, respectively. Differencing the impact of proximity to college versus non-college educated workers as before, in Figure 7c the effects of human capital are even more evident. Note, for example, that wages for scientists would increase by 11 percent if within 5 miles, 10,000 workers with less than a college degree were replaced with college educated workers.

It is tempting to speculate as to what may be driving the observed differences across occupations. Certainly, scientists and lawyers are arguably the most information oriented occupations, requiring constant innovation and learning. It is possible that these results may indicate that the ability to learn from the local environment attenuates more rapidly than other forms of agglomeration economies. That would be consistent with the high degree of clustering of innovative activity reported by Audretsch and Feldman (1996) and the rapid geographic attenuation of patent citations noted by Jaffe et al (1996). Nevertheless, we present these patterns as suggestive but not definitive on this point.

V. Conclusions

This paper estimates the impact of agglomeration on wages. Our goal is to identify three features of that relationship. First, we measure the geographic scope of agglomeration economies. This is done by estimating the rate at which wages decline with reduced proximity to economic activity. Second, we identify the extent to which human capital generates positive spillover effects that elevate worker productivity and wages and study the attenuation of this effect as well. Third, we identify the relationship of a worker's education to the benefit enjoyed from agglomeration. In each exercise, a key feature of the work is to specify a set of concentric rings that describe the amount of different types of employment within a given distance of the worker. We further difference off MSA attributes common to an individual worker's occupation, in addition to controlling for the usual set of worker socio-demographic attributes. To allow for the possibility that talented workers within a given MSA/occupation category are endogenously drawn to agglomerated portions of the metro area, we instrument for the concentric ring employment agglomeration variables. For instruments we use a series of geological features that exogenously shift the cost of erecting buildings necessary to support agglomeration. These instruments are motivated by the Manhattan skyline which is known to have its distinct double peak in part because of the nature of the underlying bedrock. Additional instruments based on seismic hazard, landslide hazard, and surface water are also used.

Using data from the 2000 Census, results indicate strong urbanization effects: controlling for worker attributes and MSA/Occupation fixed effects, wages increase roughly 3.5 percent for every additional 100,000 full-time workers present within five miles. Moreover, it is clear that proximity to educated workers has an even larger positive impact on wages, while proximity to workers with less than a college degree has a negative impact that is smaller in magnitude. Keeping the number of workers within five miles constant and endowing 10,000 less-educated workers with college education raises wages by roughly 3 percent. Both the urbanization and human capital effects attenuate, with the effect of additional activity within five to twenty-five miles being roughly half to one-quarter as large as the effect of activity within five miles. Nevertheless, in some models, urbanization and human capital effects persist out to 100 miles, indicating that agglomeration economies extend well beyond city borders to the regional level. Additional findings further suggest that workers with less than a college degree benefit more from proximity to college-educated workers than do the college educated themselves. However, this is not always the case as effects differ markedly across occupations. Scientists and lawyers, for example, benefit most from proximity to college educated workers. For scientists, wages increase roughly 6 percent for every 10,000 college educated workers within five miles.

References

Acemoglu, D. and J. Angrist (1999), "How large are the social returns to education? Evidence from compulsory schooling laws," NBER Working Paper No. 7444.

Adamson, D.W., D.E. Clark, and M. D. Adamson (2004), "Do Urban Agglomeration Effects and Household Amenities Have a Skill Bias," *Journal of Regional Science* 44:2, 201-223.

Anderson, R., J. M. Quigley, and M. Wilhelmson (2004), "University decentralization as regional policy: the Swedish experiment," *Journal of Economic Geography* 4, 371-388.

Arzaghi, M. and J.V. Henderson (2004), "Networking Off Madison Avenue" Brown University Working Paper, November 2004.

Audretsch, D.B. and Feldman, M.P.(1996), R&D spillovers and the geography of innovation and production, *American Economic Review* 86:3, 630-640.

Bairoch, P. (1988), *Cities and Economic Development*, Chicago: University of Chicago Press.

Ciccone, A. and R.E. Hall (1996), "Productivity and the Density of Economic Activity," *American Economic Review*, 86: 54-70.

Cohen, W. M. and D.A. Levinthal (1990), "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Sciences Quarterly* 35, 128-152.

Combes, P.-P., G. Duranton, and L. Gobillon (2003), "Wage Differences Across French Local Labor Markets: Endowments, Skills, and Interactions," Working Paper.

Di Addario, S. and G. de Blasio (2004), "Do Workers Benefit From Industrial Agglomeration," Working Paper.

Diamond, C.A. and C.J. Simon (1990), "Industrial Specialization and the Returns to Labor," *Journal of Labor Economics* 8(2): 175-201.

Duranton, G. and D. Puga (2004), "Micro-foundations of urban agglomeration economies," in J.V. Henderson and J.-F. Thisse, eds., *Handbook of Urban and Regional Economics, Volume 4* (New York: North Holland), forthcoming.

Glaeser, E., J. Kolko, and A. Saiz (2001), "Consumer City," *Journal of Economic Geography* 1: 27-50.

Glaeser, E.L, H. D. Kallal, J. A. Scheinkman, and A. Shleifer (1992), "Growth in Cities." *Journal of Political Economy* 100: 1126-1152.

Glaeser, E.L., and D. C. Mare (2001), "Cities and Skills," *Journal of Labor Economics* 19(2): 316-342.

Gyourko, J. and J. Tracy (1991), "The Structure of Local Public Finance and the Quality of Life", *Journal of Political Economy*, 99(4): 774-806.

Henderson, J.V. (2003a), "Marshall's Scale Economies," *Journal of Urban Economics* 53: 1-28.

Henderson, J.V., A. Kuncoro and M. Turner (1995), "Industrial Development in Cities." *Journal of Political Economy* 103: 1067-1085.

Jaffe, A. B. M. Trajtenberg, and R. Henderson (1993), "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," *Quarterly Journal of Economics* 108: 577-598.

Krugman (1991), *Geography and Trade*, Cambridge, MA: MIT Press.

Marshall, A. (1920), *Principles of Economics*, London: MacMillan.

McMillen, D. and L. Singell Jr (1992), "Work location, residence location, and the urban wage gradient," *Journal of Urban Economics* 32, 195-213.

Moses, L. (1962), "Toward a theory of intra-urban wage differentials and their influence on travel patterns," *Papers and Proceedings of the Regional Science Association* 9, 53-63.

Moretti, E. (2000), "Estimating the social return to higher education," NBER Working Paper No. 9018.

Moretti, E. (2003), "Human Capital Externalities in Cities," in J.V. Henderson and J.-F. Thisse, eds., *Handbook of Urban and Regional Economics, Volume 4* (New York: North Holland), forthcoming.

Rauch, J. (1993b), "Does history matter only when it matters little?" *Quarterly Journal of Economics,*108: 843-867.

Roback, J. (1982), "Wages, rents, and the quality of life," *Journal of Political Economy* 90, 1257-1278.

Rosenthal, Stuart S. and William C. Strange (2003), "Geography, Industrial Organization, and Agglomeration," *Review of Economics and Statistics* 85:2, 377-393.

Rosenthal, Stuart S. and William C. Strange (2004), “Evidence on the Nature and Sources of Agglomeration Economies”, in Henderson, J.V. and J.-F. Thisse, eds., *Handbook of Urban and Regional Economics*, Volume 4. Amsterdam: Elsevier2119-2172.

Rosenthal, S. S. and W. C. Strange (2004), "Agglomeration and Hours Worked," Working Paper.

Wheaton, W. C. and M. J. Lewis, (2002), "Urban Wages and Labor Market Agglomeration," *Journal of Urban Economics* 51, 542-562.

Table 1: Urbanization and Wages - All Education Groups
(Dependent variable: log of individual wage; t-ratios in parentheses)

		Entire United States				25 Large MSAs			
		MSA Fixed Effects		MSA/Occ Fixed Effects		MSA Fixed Effects		MSA/Occ Fixed Effects	
		OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Number of Full Time Workers Aged 30 to 65	0 to 5 miles	2.35E-07	3.60E-07	1.95E-07	3.31E-07	1.43E-07	-4.04E-08	1.64E-07	9.65E-08
		(35.15)	(10.58)	(29.36)	(10.05)	(28.82)	(-2.00)	(32.01)	(4.01)
	5 to 25 miles	4.88E-08	-2.79E-08	3.24E-08	-3.99E-08	1.65E-08	7.29E-08	1.84E-08	3.75E-08
		(26.01)	(-2.31)	(18.94)	(-3.48)	(7.62)	(9.31)	(8.7)	(4.31)
	25 to 50 miles	3.28E-08	9.29E-08	2.69E-08	9.78E-08	1.90E-08	1.11E-08	1.23E-08	2.31E-08
		(21.91)	(9.05)	(19.08)	(9.98)	(8.53)	(1.78)	(5.66)	(3.45)
	50 to 100 miles	2.77E-08	-7.79E-09	2.55E-08	-1.08E-08	-4.45E-09	2.51E-08	-1.50E-08	7.11E-09
		(27.04)	(-2.30)	(25.59)	(-3.32)	(-2.14)	(6.26)	(-7.32)	(1.56)

*Each model was estimated separately and includes controls for additional worker attributes. Coefficients for these additional variables are not shown to conserve space. These variables include dummy variables for the worker’s education (less than a High School degree, High School degree, College degree, Masters degree, and more than a Masters). Also included are controls are also included for whether a child is present in the household, whether the worker is married, age and age squared of the worker, race of the worker (white, African American, Hispanic, Asian, and other), and the number of years the worker has been in the United States (less than 6 years, 6 to 10 years, 11 to 15 years, 16 to 20 years, 20 years or native citizen).

Table 2: Urbanization and Wages By Education Category Controlling for MSA/Occupation Fixed Effects
(Dependent variable: log of individual wage; t-ratios in parentheses)

		Entire United States				25 Large MSAs			
		Less Than College Deg		College Deg or More		Less Than College Deg		College Deg or More	
		OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Number of Full Time Workers Aged 30 to 65	0 to 5 miles	1.79E-07	3.94E-07	2.16E-07	2.39E-07	1.30E-07	1.44E-07	1.86E-07	6.32E-08
		(31.00)	(11.70)	(29.22)	(6.56)	(20.45)	(4.52)	(22.74)	(1.80)
	5 to 25 miles	3.44E-08	-4.41E-08	4.09E-08	-1.08E-09	2.25E-08	3.17E-08	1.39E-08	4.49E-08
		(25.26)	(-5.34)	(16.56)	(-0.07)	(9.19)	(3.31)	(3.62)	(2.93)
	25 to 50 miles	2.29E-08	1.04E-07	3.78E-08	9.15E-08	1.15E-08	2.42E-08	1.32E-08	3.31E-08
		(21.21)	(14.25)	(16.98)	(7.01)	(4.55)	(3.45)	(3.34)	(2.47)
	50 to 100 miles	2.55E-08	-2.17E-08	2.63E-08	1.76E-08	-1.18E-08	4.20E-09	-1.82E-08	1.54E-08
		(32.51)	(-8.42)	(17.56)	(3.78)	(-4.92)	(0.83)	(-4.92)	(1.76)

*Each model was estimated separately and includes controls for additional worker attributes. Coefficients for these additional variables are not shown to conserve space. These variables include dummy variables for the worker's education (less than a High School degree, High School degree, College degree, Masters degree, and more than a Masters). Also included are controls are also included for whether a child is present in the household, whether the worker is married, age and age squared of the worker, race of the worker (white, African American, Hispanic, Asian, and other), and the number of years the worker has been in the United States (less than 6 years, 6 to 10 years, 11 to 15 years, 16 to 20 years, 20 years or native citizen).

Table 3a: Human Capital Spillovers and Wages - All Education Groups
(Dependent variable: log of individual wage; t-ratios in parentheses)

		Entire United States				25 Large MSAs			
		MSA Fixed Effects		MSA/Occ Fixed Effects		MSA Fixed Effects		MSA/Occ Fixed Effects	
		OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Number of Full Time Workers Aged 30 to 65 With Less Than a College Degree	0 to 5 miles	-9.79E-08	-8.49E-07	-1.06E-07	-9.18E-07	-6.66E-07	-7.85E-07	-2.82E-07	-1.77E-07
		(-1.40)	(-2.59)	(-1.56)	(-2.89)	(-11.06)	(-3.93)	(-4.53)	(-0.74)
	5 to 25 miles	-1.19E-07	-4.07E-07	-1.26E-07	-4.22E-07	-6.86E-08	-5.16E-07	-1.21E-07	-2.80E-07
		(-5.04)	(-2.61)	(-5.48)	(-2.68)	(-3.33)	(-5.71)	(-4.72)	(-3.03)
	25 to 50 miles	2.14E-07	-5.76E-07	1.75E-07	-5.53E-07	8.19E-08	-2.87E-07	1.59E-07	3.61E-07
		(11.99)	(-4.92)	(10.07)	(-4.71)	(4.72)	(-3.35)	(7.18)	(2.63)
	50 to 100 miles	-1.37E-09	-3.69E-07	-1.93E-08	-3.73E-07	9.80E-09	-6.56E-08	-2.53E-08	1.57E-07
		(-0.17)	(-13.27)	(-2.48)	(-13.45)	(0.60)	(-1.40)	(-1.31)	(2.54)
Number of Full Time Workers Aged 30 to 65 With More Than a College Degree	0 to 5 miles	1.22E-06	1.88E-06	1.10E-06	2.04E-06	9.50E-07	1.03E-06	1.21E-06	8.46E-07
		(10.16)	(3.73)	(9.36)	(4.15)	(16.41)	(4.87)	(10.85)	(2.17)
	5 to 25 miles	6.94E-07	1.89E-06	6.54E-07	1.80E-06	1.71E-07	9.32E-07	4.26E-07	9.30E-07
		(12.08)	(5.21)	(11.64)	(4.89)	(5.53)	(7.00)	(6.33)	(3.88)
	25 to 50 miles	-2.26E-07	1.54E-06	-1.55E-07	1.49E-06	-7.55E-08	5.69E-07	-3.30E-07	-9.02E-07
		(-4.90)	(5.41)	(-3.46)	(5.24)	(-2.68)	(3.65)	(-5.45)	(-2.37)
	50 to 100 miles	1.19E-07	1.19E-06	1.61E-07	1.17E-06	-7.64E-09	2.24E-07	2.66E-08	-4.07E-07
		(5.45)	(16.00)	(7.60)	(15.91)	(-0.29)	(2.72)	(0.51)	(-2.34)

*Each model was estimated separately and includes controls for additional worker attributes. Coefficients for these additional variables are not shown to conserve space. These variables include dummy variables for the worker's education (less than a High School degree, High School degree, College degree, Masters degree, and more than a Masters). Also included are controls are also included for whether a child is present in the household, whether the worker is married, age and age squared of the worker, race of the worker (white, African American, Hispanic, Asian, and other), and the number of years the worker has been in the United States (less than 6 years, 6 to 10 years, 11 to 15 years, 16 to 20 years, 20 years or native citizen).

Table 3b: Human Capital Spillovers and Wages – By Education Category Controlling for MSA/Occupation Fixed Effects
(Dependent variable: log of individual wage; t-ratios in parentheses)

		Entire United States				25 Large MSAs			
		Less Than College Deg		College Deg or More		Less Than College Deg		College Deg or More	
		OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Number of Full Time Workers Aged 30 to 65 With Less Than a College Degree	0 to 5 miles	1.56E-07	-9.84E-08	-6.01E-07	-1.17E-06	-7.65E-08	-2.05E-07	-6.22E-07	1.53E-07
		2.81	-0.41	-6.48	-2.29	-1.04	-0.78	-5.53	0.32
	5 to 25 miles	-1.03E-07	-7.39E-07	-1.31E-07	-2.98E-07	-1.31E-07	-3.30E-07	-8.24E-08	-3.27E-07
		-5.41	-5.06	-4.33	-1.81	-4.24	-2.71	-1.9	-2.58
	25 to 50 miles	1.26E-07	-3.46E-07	1.52E-07	-4.67E-07	1.26E-07	2.46E-07	2.04E-07	4.51E-07
		9.12	-3.59	6.25	-2.76	4.74	1.63	5.34	1.89
	50 to 100 miles	-1.40E-08	-4.32E-07	-5.49E-10	-2.95E-07	-2.39E-09	1.20E-07	-4.85E-08	9.86E-08
		-2.32	-20.14	-0.04	-7.11	-0.11	1.71	-1.38	0.94
Number of Full Time Workers Aged 30 to 65 With More Than a College Degree	0 to 5 miles	5.57E-07	1.13E-06	2.03E-06	2.33E-06	7.45E-07	9.94E-07	1.86E-06	3.32E-07
		5.82	2.94	12.77	3.06	5.63	2.25	9.37	0.45
	5 to 25 miles	6.12E-07	2.55E-06	6.79E-07	1.45E-06	4.50E-07	1.04E-06	3.41E-07	1.02E-06
		13.15	7.39	9.2	3.86	5.49	3.27	3.03	3.12
	25 to 50 miles	-3.21E-08	1.01E-06	-1.00E-07	1.36E-06	-2.46E-07	-5.53E-07	-4.43E-07	-1.08E-06
		-0.9	4.29	-1.6	3.37	-3.37	-1.29	-4.3	-1.71
	50 to 100 miles	1.44E-07	1.27E-06	1.28E-07	1.02E-06	-2.54E-08	-2.98E-07	8.41E-08	-2.50E-07
		8.77	22.04	3.71	9.62	-0.42	-1.48	0.88	-0.86

*Each model was estimated separately and includes controls for additional worker attributes. Coefficients for these additional variables are not shown to conserve space. These variables include dummy variables for the worker's education (less than a High School degree, High School degree, College degree, Masters degree, and more than a Masters). Also included are controls are also included for whether a child is present in the household, whether the worker is married, age and age squared of the worker, race of the worker (white, African American, Hispanic, Asian, and other), and the number of years the worker has been in the United States (less than 6 years, 6 to 10 years, 11 to 15 years, 16 to 20 years, 20 years or native citizen).

Table 4: Human Capital Spillovers and Wages – By Occupation Controlling for MSA Fixed Effects for 25 MSAs
(Dependent variable: log of individual wage; t-ratios in parentheses)

		Service		Mechanics		Scientists		Engineers		Lawyers	
		OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Number of Full Time Workers Aged 30 to 65 With <u>Less</u> Than a College Degree	0 to 5 miles	-3.31E-07	-2.10E-06	-5.15E-07	-1.90E-06	-2.85E-06	-4.87E-06	-8.24E-07	-1.37E-06	6.57E-07	-4.61E-06
		(-1.74)	(-3.92)	(-0.75)	(-1.03)	(-4.30)	(-2.18)	(-2.39)	(-1.16)	(1.01)	(-2.03)
	5 to 25 miles	-2.08E-07	-2.97E-07	-2.81E-08	1.03E-06	-2.94E-07	-7.98E-07	-1.19E-07	-5.98E-08	5.00E-07	1.23E-06
		(-2.53)	(-0.84)	(-0.13)	(1.11)	(-1.20)	(-1.28)	(-1.17)	(-0.22)	(1.93)	(1.59)
	25 to 50 miles	4.85E-09	-4.81E-07	-6.73E-08	5.03E-08	-1.16E-07	-1.35E-06	2.32E-08	-6.48E-08	7.05E-07	-5.86E-07
		(0.07)	(-1.61)	(-0.35)	(0.08)	(-0.56)	(-1.90)	(0.28)	(-0.23)	(2.96)	(-0.54)
	50 to 100 miles	-1.85E-07	-4.11E-07	1.97E-07	6.83E-07	1.84E-07	2.52E-07	-7.03E-08	-9.93E-11	2.24E-08	-2.82E-07
		(-2.90)	(-2.63)	(1.36)	(1.58)	(0.73)	(0.41)	(-0.84)	(0.00)	(0.11)	(-0.51)
Number of Full Time Workers Aged 30 to 65 With <u>More</u> Than a College Degree	0 to 5 miles	6.04E-07	2.45E-06	4.84E-07	3.58E-06	2.62E-06	5.98E-06	1.03E-06	8.92E-07	-2.13E-07	4.84E-06
		(3.15)	(4.11)	(0.66)	(1.61)	(4.20)	(2.87)	(3.20)	(0.83)	(-0.34)	(2.11)
	5 to 25 miles	4.50E-07	6.29E-07	1.35E-07	-1.70E-06	5.86E-07	1.05E-06	2.79E-07	5.07E-07	-6.62E-07	-1.42E-06
		(3.57)	(1.21)	(0.38)	(-1.18)	(1.54)	(1.01)	(1.84)	(1.35)	(-1.79)	(-1.25)
	25 to 50 miles	7.66E-08	9.34E-07	1.57E-07	4.21E-09	1.60E-07	2.68E-06	-1.47E-08	7.76E-08	-1.05E-06	1.82E-06
		(0.67)	(1.68)	(0.48)	(0.00)	(0.46)	(2.18)	(-0.11)	(0.17)	(-2.94)	(0.92)
	50 to 100 miles	3.22E-07	7.14E-07	-3.08E-07	-1.16E-06	-1.91E-07	3.17E-08	1.19E-07	6.01E-08	-2.01E-07	6.39E-07
		(3.08)	(2.59)	(-1.32)	(-1.49)	(-0.46)	(0.03)	(0.89)	(0.19)	(-0.66)	(0.66)

*Each model was estimated separately and includes controls for additional worker attributes. Coefficients for these additional variables are not shown to conserve space. These variables include dummy variables for the worker's education (less than a High School degree, High School degree, College degree, Masters degree, and more than a Masters). Also included are controls are also included for whether a child is present in the household, whether the worker is married, age and age squared of the worker, race of the worker (white, African American, Hispanic, Asian, and other), and the number of years the worker has been in the United States (less than 6 years, 6 to 10 years, 11 to 15 years, 16 to 20 years, 20 years or native citizen).

Figure 1: Local Attributes, Wages, and Land Rents

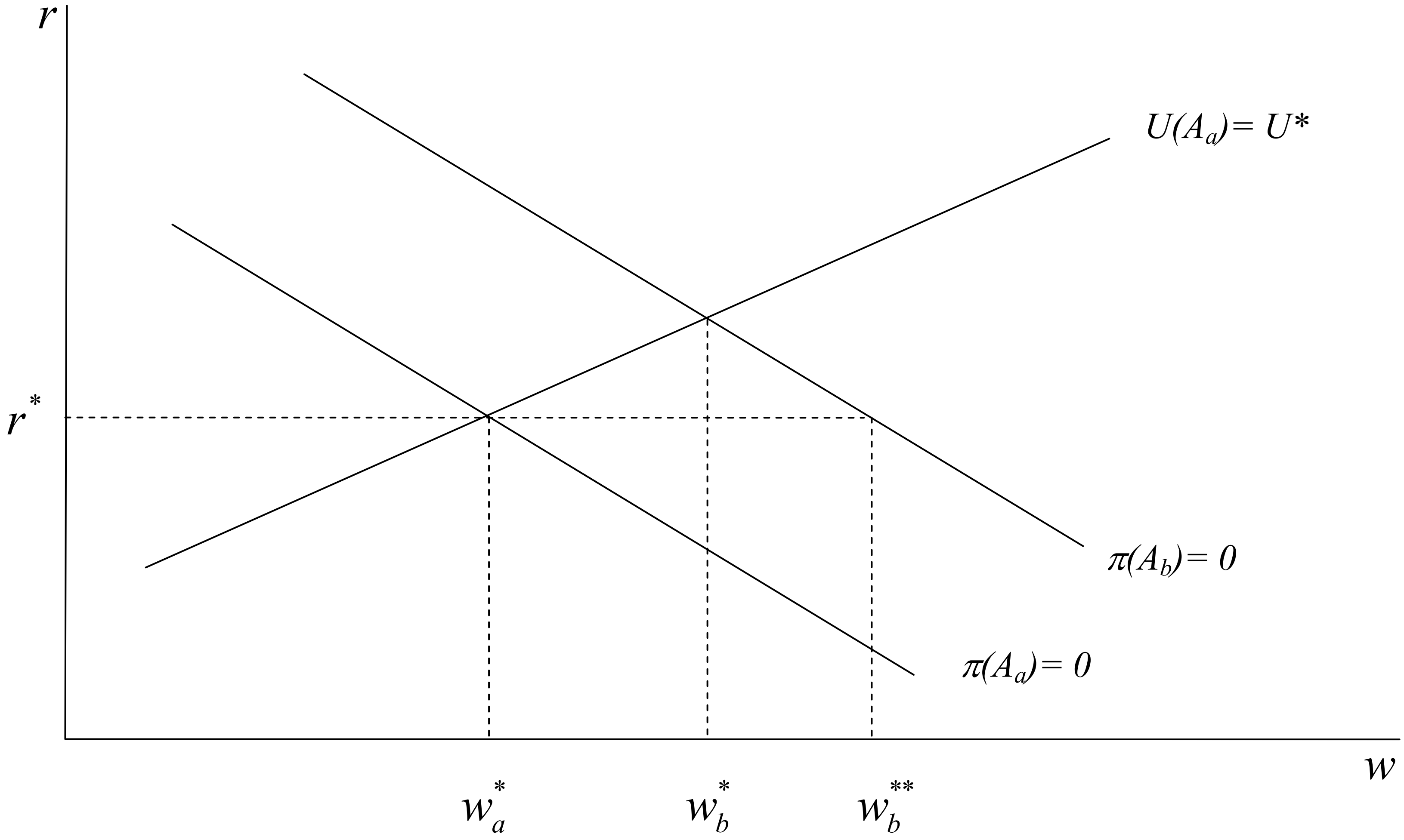


Figure 2a: Work PUMA Boundaries for the Continental United States

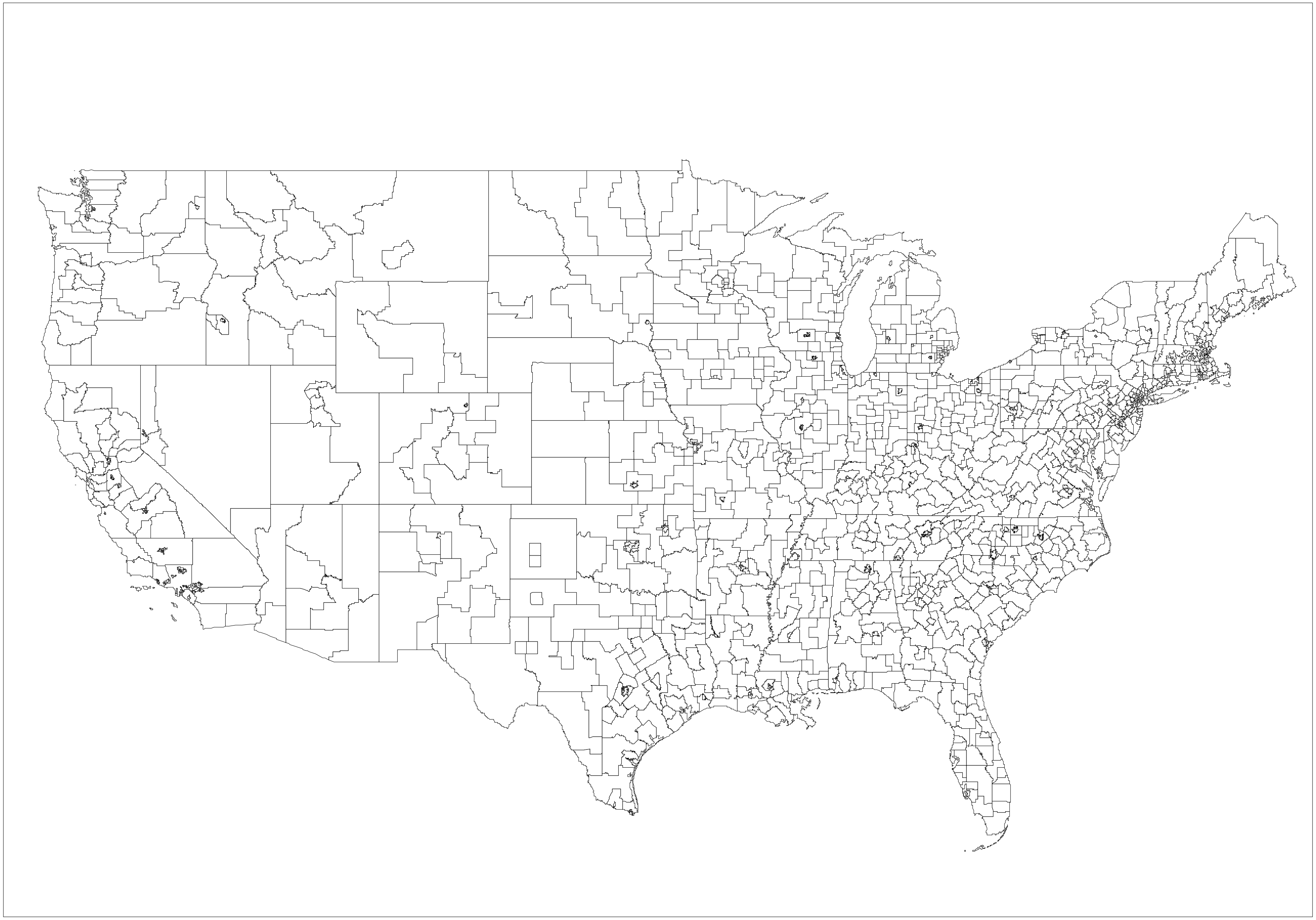


Figure 2b: Work PUMA Boundaries for the East and West Continental United States

Figure 2c: Work PUMA Boundaries for Selected Metropolitan Areas

Figure 3a: Bedrock in New York City

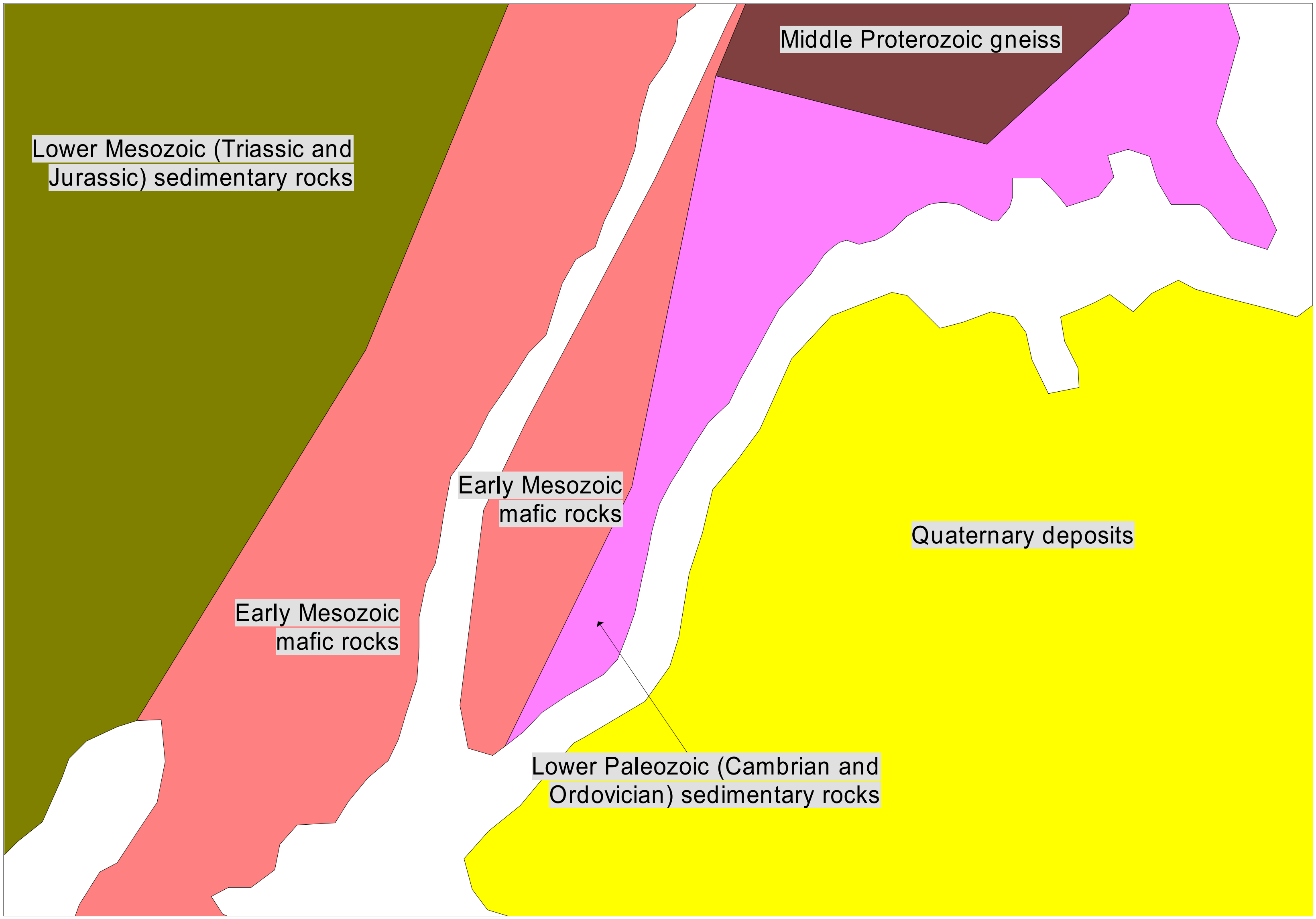


Figure 3b: Seismmic Hazrd in San Francisco
(Scale is from 0 to 100 with 100 the maximum)

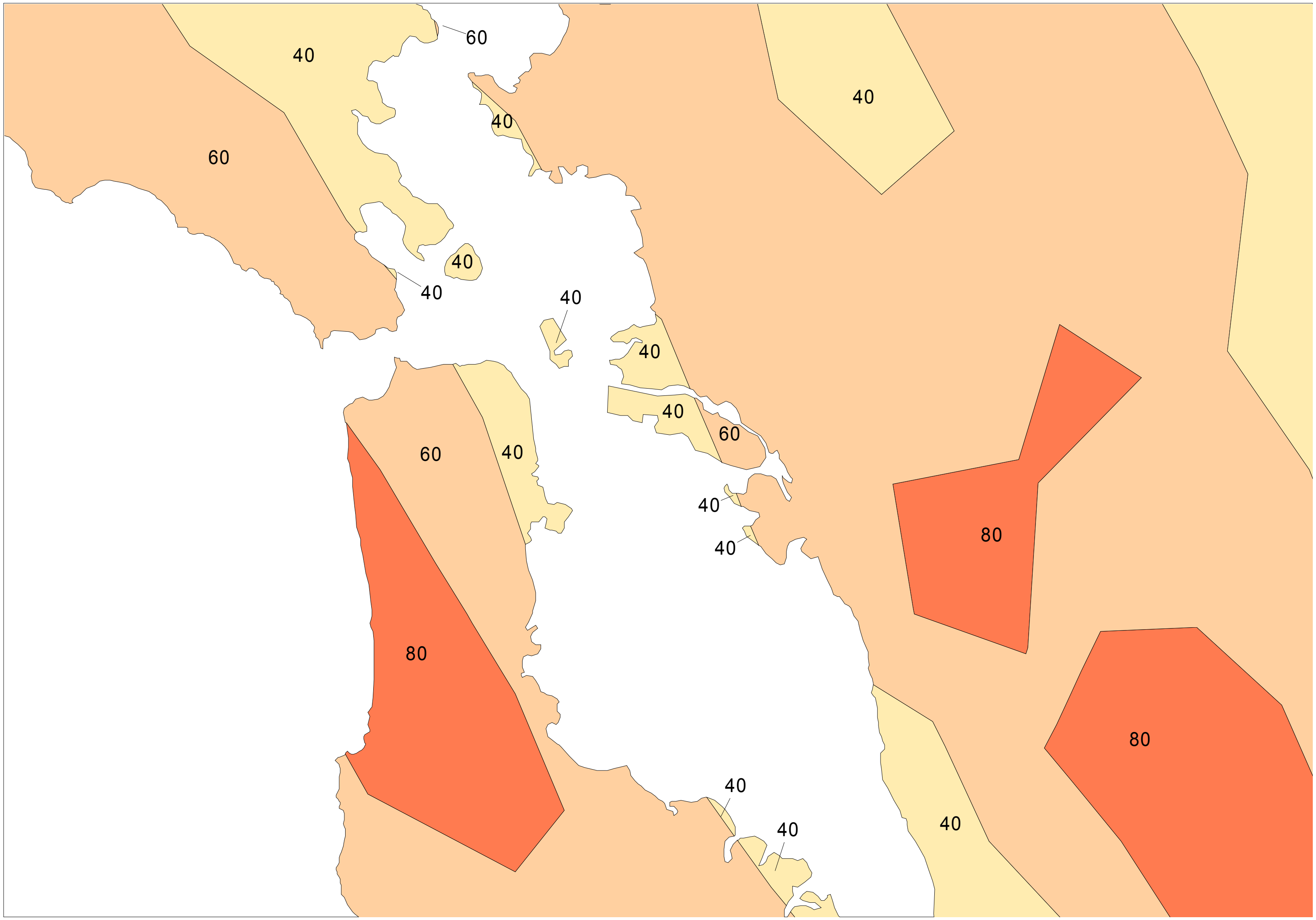


Figure 3c: Landslide Hazard in Los Angeles

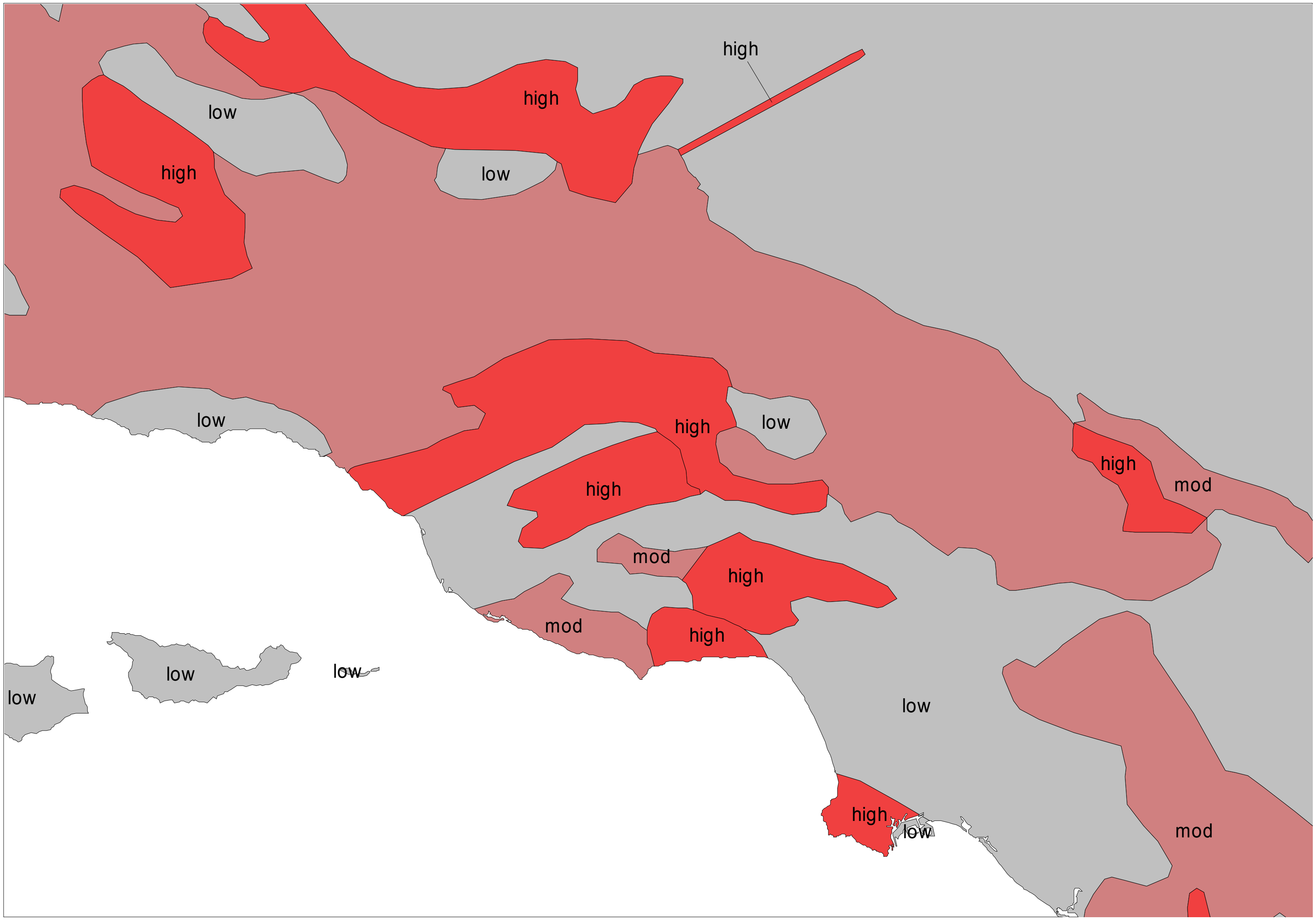


Figure 4a: Urbanization Effects For All Education Groups for Entire US - MSA Versus MSA/Occupation Fixed Effects 2SLS Estimates

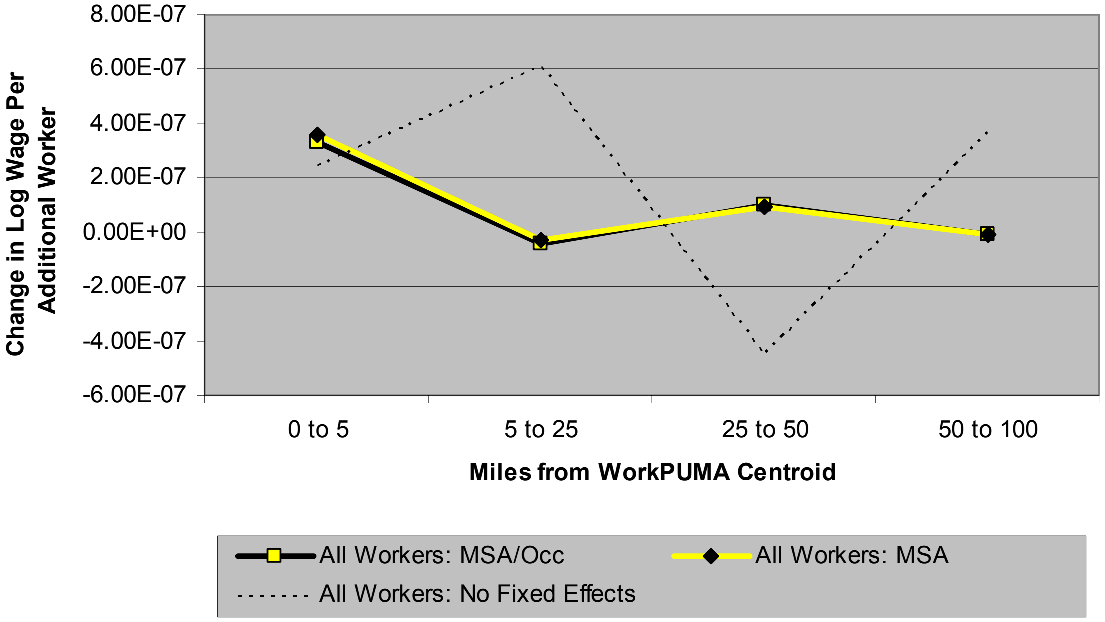
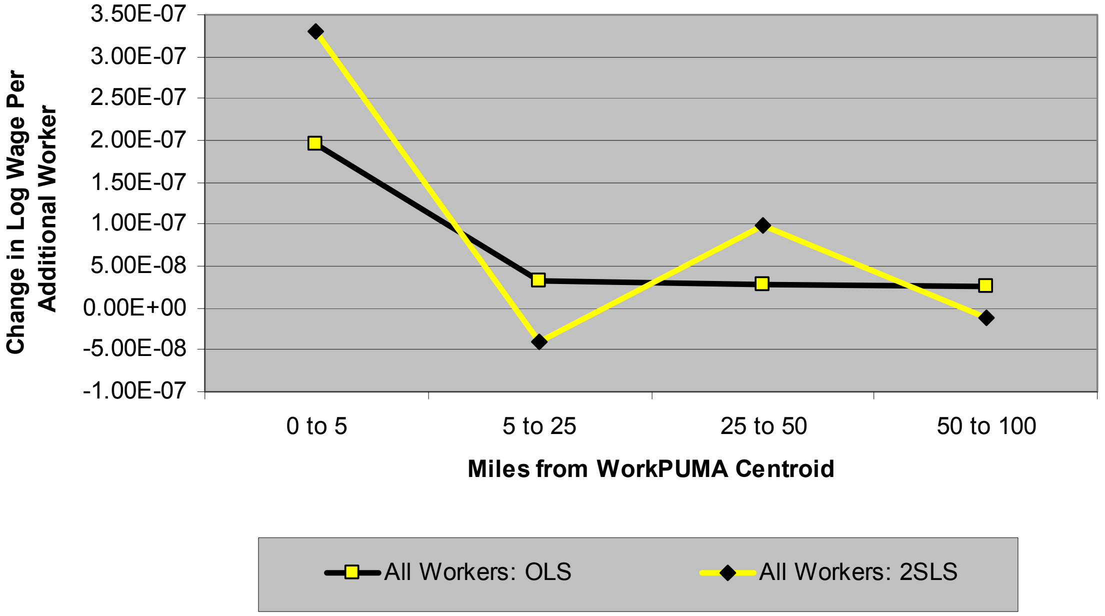


Figure 4b: Urbanization Effects For All Education Groups for Entire US With MSA/Occupation Fixed Effects OLS and 2SLS Estimates



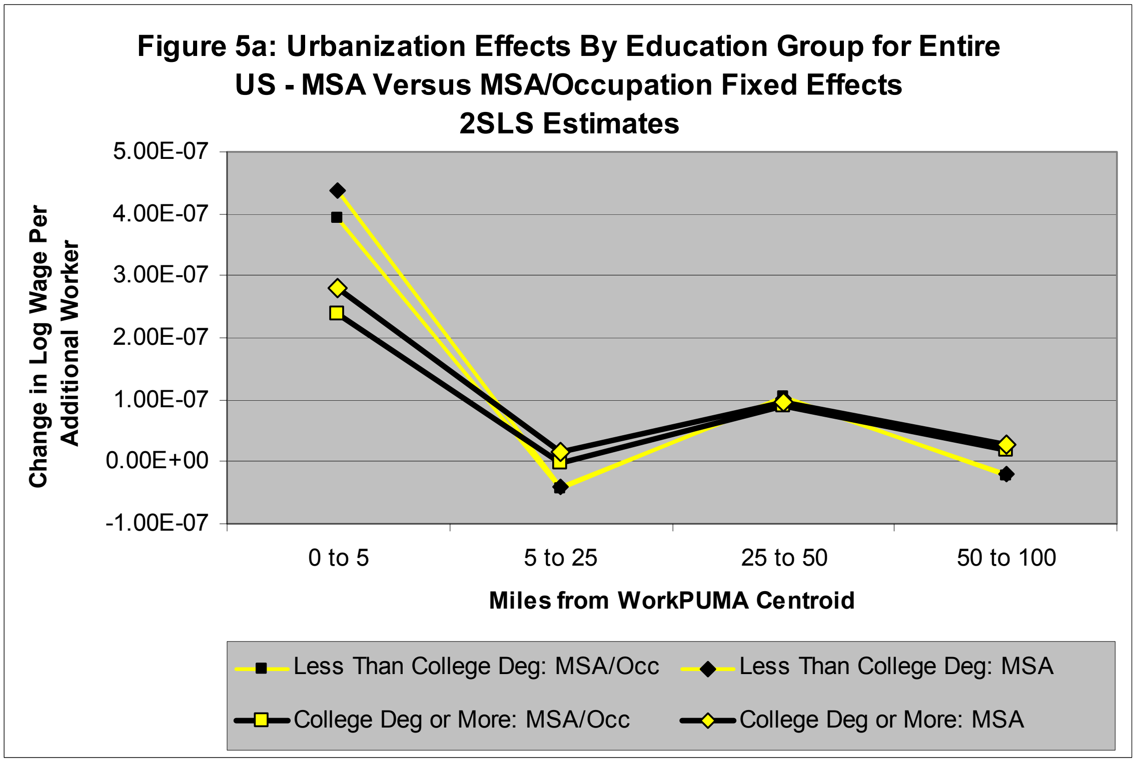


Figure 5a: Urbanization Effects By Education Group for Entire US - MSA Versus MSA/Occupation Fixed Effects 2SLS Estimates

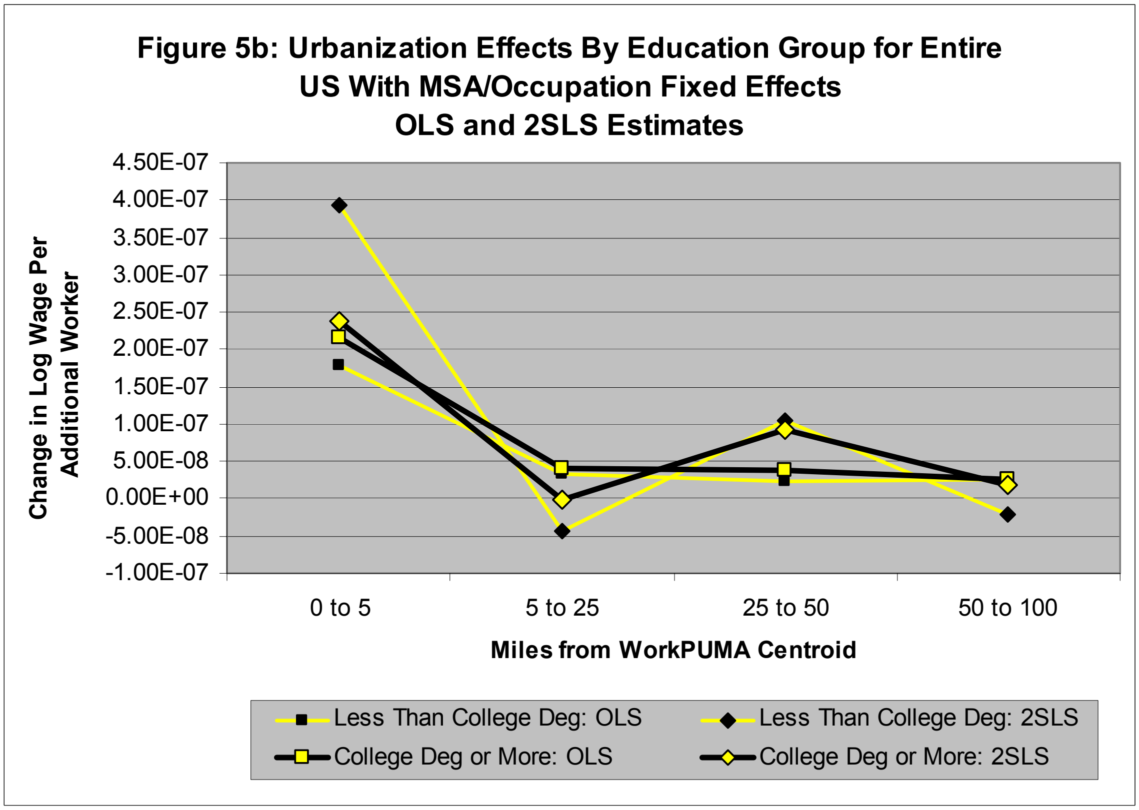


Figure 5b: Urbanization Effects By Education Group for Entire US With MSA/Occupation Fixed Effects OLS and 2SLS Estimates

Figure 6a: Human Capital Effects For All Education Groups for Entire US With MSA/Occupation Fixed Effects OLS and 2SLS Estimates

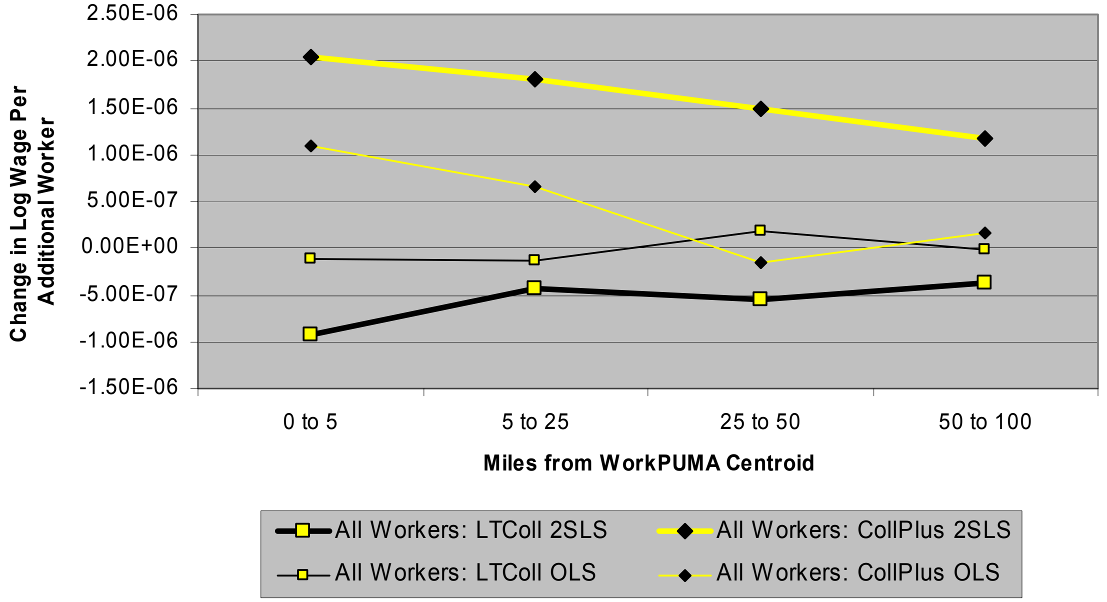


Figure 6b: Human Capital Effects For Workers With Less Than a College Degree; Entire US With MSA/Occupation Fixed Effects OLS and 2SLS Estimates

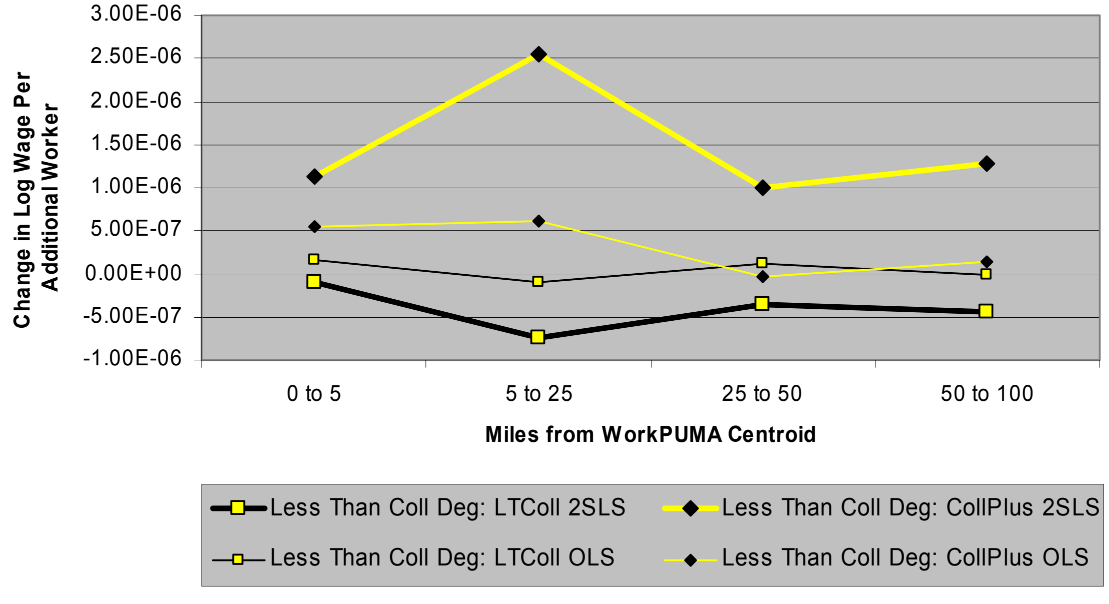


Figure 6c: Human Capital Effects For Workers With a College Degree or More; Entire US With MSA/Occupation Fixed Effects
OLS and 2SLS Estimates

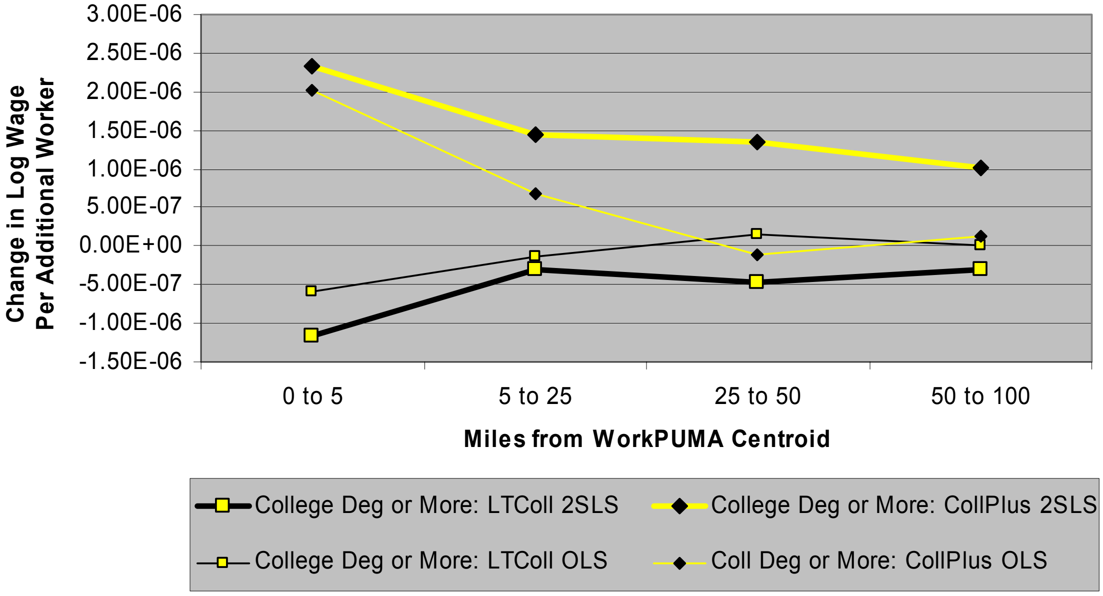


Figure 6d: Human Capital Effects By Education Group; Entire US With MSA/Occupation Fixed Effects
2SLS Estimates

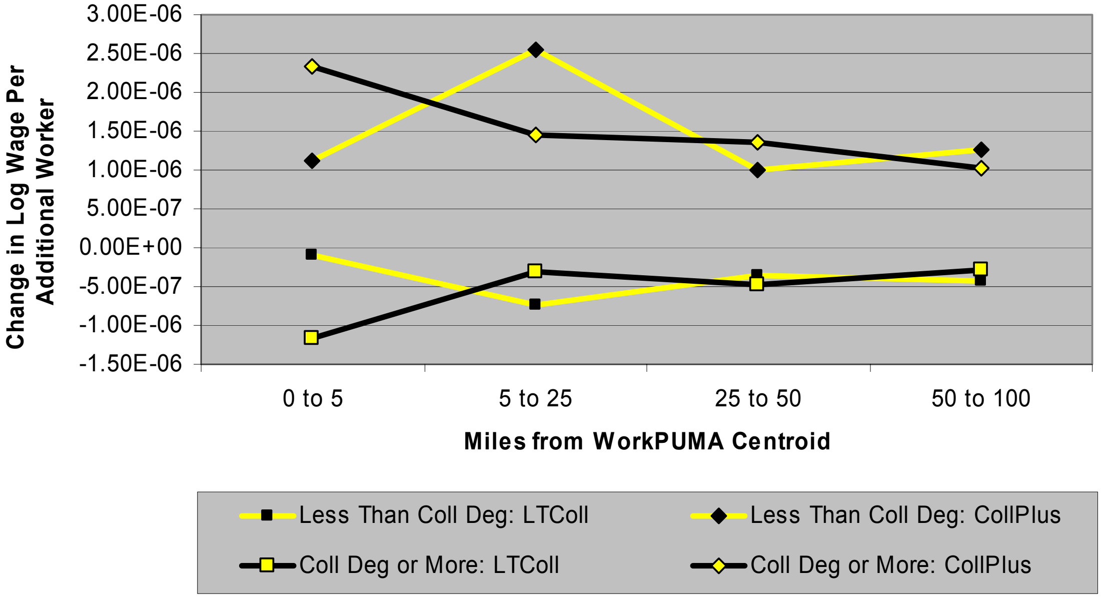


Figure 6e: Difference in Human Capital Effects From Proximity to College Versus Less Than College Degree Workers By Education Group; Entire US With MSA/Occupation Fixed Effects; 2SLS Estimates

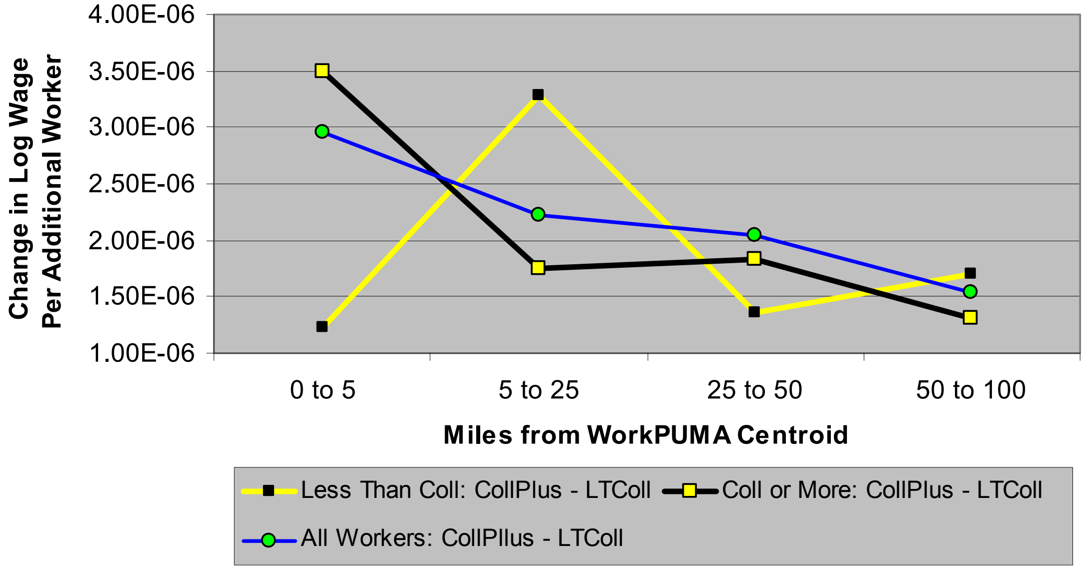


Figure 7a: Human Capital Effects From Less Than College Workers By Occupation Group for 25 MSAs With MSA Fixed Effects (2SLS Estimates)

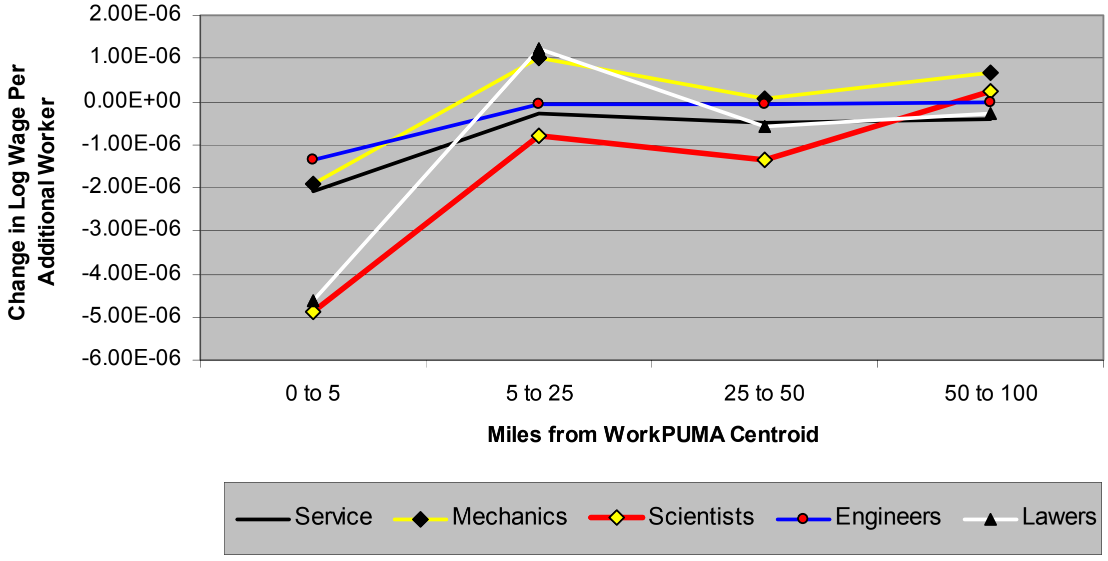


Figure 7b: Human Capital Effects From College or More Workers By Occupation Group for 25 MSAs With MSA Fixed Effects (2SLS Estimates)

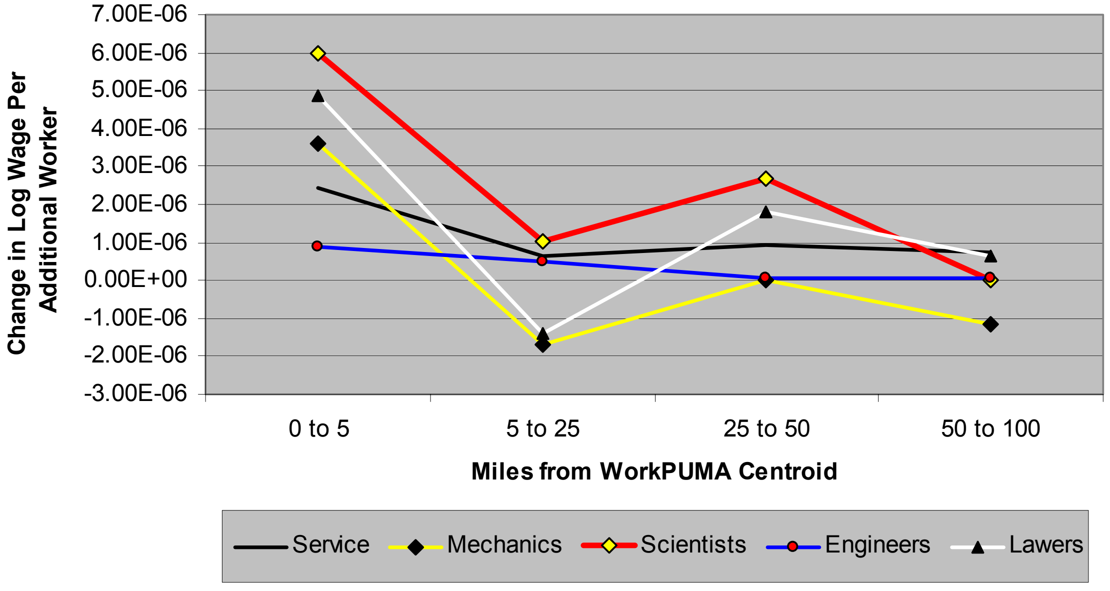


Figure 7c: Difference in Human Capital Effects From Proximity to College Versus Less Than College Degree Workers By Occupation Group for 25 MSAs With MSA Fixed Effects (2SLS Estimates)