WORKING PAPERS
RESEARCH DEPARTMENT

WORKING PAPER NO. 04-2
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December 2003

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Abstract

For more than a century, educated cities have grown more quickly than comparable cities with less human capital. This fact survives a battery of other control variables, metropolitan area fixed effects, and tests for reverse causality. We also find that skilled cities are growing because they are becoming more economically productive (relative to less skilled cities), not because these cities are becoming more attractive places to live. Most surprisingly, we find evidence suggesting that the skills-city growth connection occurs mainly in declining areas and occurs in large part because skilled cities are better at adapting to economic shocks. As in Schultz (1964), skills appear to permit adaptation.

[*] Glaeser thanks the National Science Foundation and the Taubman Center for State and Local Government for financial support. The paper was started when Saiz was an economist at the Federal Reserve Bank of Philadelphia, but the views in this paper do not necessary reflect the views of the Federal Reserve Bank of Philadelphia or the Federal Reserve System. Shannon Mail provided superb research assistance.

I. Introduction

Between 1980 and 2000, the population of metropolitan areas where less than 10 percent of adults had college degrees in 1980, grew, on average, by 13 percent. Among metropolitan areas where more than 25 percent of adults had college degrees, the average population growth rate was 45 percent. For more than a century, in both the United States and Great Britain, cities with more educated residents have grown faster than comparable cities with less human capital (Glaeser, 1994, Glaeser et al. 1995, Simon, 1998, Black and Henderson, 1999, Nardinelli and Simon, 1996, 2002). There is no consensus, however, on the causes or implications of this relationship.

Why have people increasingly crowded around the most skilled? Why does education seem to be an increasingly important ingredient in agglomeration economies? Three disparate, but not incompatible, visions of the modern city offer different answers to these questions. The Consumer City view (e.g. Glaeser, Kolko, Saiz, 2001)— cities are increasingly oriented around consumption amenities, not productivity—tells us that skills predict growth because skilled neighbors are an attractive consumption amenity. The Information City view (Jacobs, 1969)— cities exist to facilitate the flow of ideas— tells us we should expect cities to be increasingly oriented around the skilled because the skilled specialize in ideas. The Reinvention City view (Glaeser, 2003)— cities survive only by adapting their economies to new technologies— tells us that human capital predicts city growth because human capital enables people to adapt well to change (as in

Schultz, 1964, Welch, 1970). Understanding why skills predict city growth will help us determine if cities thrive because of consumption, information, or reinvention.

In Section II of this paper, we use four approaches to address the possibility that the rise of the skilled city is the result of a spurious correlation between local skills and other urban characteristics. First, we show that controlling for a wide range of other factors makes little difference to the impact of local skills on subsequent city growth and that local human capital is essentially orthogonal to many of the most important local amenities. Second, we show that the metropolitan area human capital effect is robust to including metropolitan area fixed effects. Third, we examine the connection between the number of colleges per capita in 1940 and growth between 1970 and 2000. The pre-World War II number of colleges seems considerably more exogenous than current skill levels, and it still correlates quite strongly with growth in the modern era.[1]

Fourth, we examine the timing of skills and growth and test whether skilled workers flock to cities that are growing. Individuals with low education are particularly prone to live in declining cities (as in Glaeser and Gyourko, 2001), but exogenous differences in positive growth rates do not predict changes in the percentage of the population with a college education. Reverse causation from growth to education seems to be present only in a handful of declining metropolitan areas and cannot account for much of the relevant effect. Overall, the evidence supports the view that skills induce growth.

[1] In this we follow Moretti (2003). Card (1995) uses proximity to college as an instrumental variable for the level of education of an individual.

In Section III of the paper, we present a framework for understanding the connection between skills and growth. The framework tells us that production-led growth should increase *nominal* wages and housing prices, while consumption-led growth should cause *real* wages to fall. Rising nominal wages are a sufficient condition for productivity growth, and declining real wages are necessary for the amenity story to be of relevance.

Our empirical work in Section IV shows that productivity drives most of the connection between skills and growth. At the metropolitan level, we find that education *levels* have a positive impact on future wage and housing price growth. With almost any reasonable set of parameter values, the connection between education and population growth is the exclusive result of rising productivity and has less to do with rising amenity levels. Indeed, real wages may actually be rising in high-education metropolitan areas, which suggests that consumer amenities are actually declining in high skill areas.

At the city level, the results are less clear. In small municipalities within metropolitan areas, low levels of human capital predict urban decline and falling housing prices. At the city level (not at the metropolitan area level), it is the bottom end of the human capital distribution that matters. High school dropouts predict urban decline. Moreover, this decline appears to be driven, at least in part, through consumption-related effects. Perhaps, unfortunately, poverty has come to be perceived as an increasingly negative amenity because of social problems or a higher tax burden.

The fact that skills increase metropolitan area growth through productivity increases is compatible with both the Information City and the Reinvention City hypotheses. In Section V, we try to distinguish between these two interpretations of the growth-skills connection. To test the Information City hypothesis, we turn to patent data. Previous research shows that areas with more human capital have higher rates of patenting per capita (Carlino et al., 2001). We find that controlling for patenting rates does not explain any portion of the effect of human capital on growth. This certainly does not disprove the Information City hypothesis, but it doesn't support it either.

One test of the reinvention hypothesis is to look at the cross-effect between skills and factors that have an independent effect on city growth. The Information City view predicts that skills should predict growth among all types of cities. The Reinvention City hypothesis predicts that skills should matter only among those cities that have received negative shocks. We test this implication by looking at the cross-effect between skills and the weather and between skills and immigration. Warm weather and immigration have been two of the most important drivers of contemporaneous metropolitan population growth in the United States. As Figure 4 shows, the correlation between skills and growth is essentially zero in warm cities. As Figure 5 shows, the correlation coefficient between skills and growth is over 50 percent. We also find that skills don't matter much in immigrant cities. There is a strong negative cross-effect between skills and either warmth or immigration, which means that human capital really only matters in potentially declining places, which in turns supports the reinvention hypothesis.

We also test the reinvention hypothesis by seeing whether skilled places shifted out of manufacturing more quickly. In the first part of the 20th century, urban success generally meant specialization in manufacturing. Declining transport costs and declining importance of manufacturing has meant that at the beginning of the 21st century, successful cities have moved from manufacturing into other industries. If the reinvention hypothesis is right, it should predict the speed at which cities reinvent themselves. Indeed, we find that metropolitan areas with high levels of education and significant manufacturing as of 1940 switched from manufacturing to other industries faster than high-manufacturing areas with less human capital. These results suggest that skills are valuable because they help cities adapt and change their activities in response to negative economic shocks.

II. Is the Skills-Growth Connection Spurious?

In this section, we confirm the empirical relationship between education and metropolitan statistical area (MSA) growth. We test whether the connection between skills and city growth is spurious, reflecting omitted variables. We use both cities and MSAs as our unit of analysis because there are advantages and disadvantages to both. MSAs are more natural labor markets, but cities are smaller and a better unit of analysis for understanding either amenities or real estate prices. We use the 1999 county-based boundaries (NECMA definitions in New England and PMSA definitions in the rest of the country).[2] Using county level data, we can obtain a complete and consistent panel for 1970, 1980,

[2] Using the most recent boundaries helps us avoid the endogeneity of current definitions to growth.

1990, and 2000. We select those cities with population over 30,000 in 1970. The Data Appendix details the sources of all variables

In Figure 1, we show the correlation between the growth of the logarithm of population between 1980 and 2000 and the share of adults in 1980 with college degrees among metropolitan statistical areas. In Table 1 (panel a) we show the correlation between metropolitan area level growth and the primary independent variables over the entire 1970-2000 period. Table 1 (panel b) shows similar correlations at the city level. In both cases, there is a significant association between initial education levels and later growth. The correlation between the share of college graduates and population growth is 18 percent in the case of cities and 30 percent in the case of metropolitan areas.

While we focus primarily on the share of the adult population with college degrees, an alternative measure of human capital, the share of adults who dropped out of high school, is a stronger (i.e., more negative) correlate of city growth but a weaker correlate of MSA growth. This suggests that the impact of higher education may be more important at the MSA level (maybe due to a productivity effect), whereas the impact of low education is more important at the city level (maybe because of localized social interactions). While these correlations are large, other variables such as heating degree days, annual precipitation, and the share of labor force in manufacturing have stronger correlations with population growth than the human capital variables.

Our baseline regressions use a panel of metropolitan areas (in Table 2) and cities (in Table 3) over three periods (the 70s, the 80s and the 90s).[3] The dependent variable is the difference in the log of population between census years. We focus on the coefficient on the share of the population with a college education.[4] All regressions include decade-specific fixed effects and allow each geographic unit's standard errors to be correlated over time. More precisely, we estimate the coefficients β and γ_j in regressions of the form:

(1) $$Log\left(\frac{Population_{i,t}}{Population_{i,t-10}}\right) = \beta \cdot \frac{College_{i,t-10}}{Population_{i,t-10}} + \sum_j \gamma_j Z_{i,j,t-10} + Y_t + \varepsilon_{i,t}$$

where $\frac{College_{i,t-10}}{Population_{i,t-10}}$ is the share of the population with a college degree in the initial year, $Z_{i,j,t-10}$ is the value of independent variable j in the initial year, Y_t is a decade-specific fixed effect, and $\varepsilon_{i,t}$ is the city-year error term, which we allow to be correlated across decades.

Regression (1) in Tables 2 and 3 shows the raw impact of percent college educated on later growth for MSAs and cities, respectively. In the case of the MSA-level regressions, a one-percentage-point increase in the share of the adult population with college degrees increases the decadal growth rate by, approximately, almost one-half of 1 percent. The standard deviation of metropolitan area growth is approximately 0.1 and the standard deviation of the college graduation variable is approximately 0.05: a one-standard-

[3] We have data for four years: 1970, 1980, 1990, and 2000. Since we are using population growth (the first difference in the log of population), we end up with three time periods.
[4] This corresponds to individuals with a bachelor's degree.

deviation increase in percent college graduates increases the expected growth rate by one-quarter of a standard deviation.

In the city-level regressions reported in Table 3, the basic effect of college education is weaker. A 1 percent increase in college graduates increases the expected growth rate by one-fifth of 1 percent. At the city level, the standard deviation of the percent college educated variable is approximately 0.1, and the standard deviation of decadal growth rates is about 0.15. This means that a one-standard-deviation increase in the percent college educated at the city level is associated with approximately one-seventh of a standard deviation increase in the expected growth rate. As suggested by the raw correlations, college education is a more powerful predictor of growth at the MSA level than growth at the city level.

In regression (2) of both tables, we include initial population, the log of heating degree days, the log of average precipitation, the share of labor force in manufacturing, trade and professional services,[5] and controls for the four census regions. Warm and dry weather have been shown to be among the important predictors of population growth in the United States at the end of the 20th century (Glaeser, Kolko, and Saiz, 2001, Glaeser and Shapiro, 2003). Heating degree days is a measure of cold weather severity (roughly, how many days would a household need to use heating to keep warm). Initial population is usually unrelated to later city growth (as in Glaeser, Scheinkman and Shleifer, 1995, Eaton and Eckstein, 1997), but it remains a natural control. The employment share

[5] These are the three major occupations in our sample, representing 63 percent of total MSA employment in 1990.

variables capture aspects of industrial orientation, and we know from Table 1 that specializing in manufacturing is a strong correlate of later decline.

For both cities and metropolitan areas we find that warm, dry places grow much more quickly than cold, wet places. There is a modest amount of mean reversion: bigger cities and metropolitan areas grow somewhat more slowly. Metropolitan areas with substantial manufacturing grow more slowly. While these correlations are interesting, we will not discuss them further because they have been considered at length elsewhere (Glaeser, Scheinkman and Shleifer, 1995, Glaeser and Shapiro, 2003). Our focus is the extent to which controlling for these variables changes the impact of college education on later city growth.

Including these controls has little impact on the coefficient on the college educated. Education does not predict growth because educated metropolitan areas have more employment in the service sector or better weather. In the case of metropolitan areas, including these factors actually causes the coefficient on percent college educated to rise. The fact that controlling for these major potential *omitted* variables causes the impact of college to rise shouldn't surprise us, because skilled workers are actually less likely to live in warm, dry places. Since more educated people have tended to live in areas of the country with less desirable climates, controlling for the weather variables makes the impact of education stronger, not weaker.

In specification three, we include state-specific fixed effects. In principle, these fixed effects should capture all time-invariant weather or geographic variables, as well as those state-level policies that change only slowly over time. In Tables 2 and 3, controlling for state-specific effects has only a modest impact. In the case of metropolitan areas, the state fixed effects regressions have almost exactly the same coefficient as the regression with no controls. In the case of cities, the state fixed effects cause the coefficient on education to drop 18 percent relative to the no control specification. We generally prefer not to work with state specific fixed effects, especially in the case of metropolitan area regressions, since many states have only a small number of metropolitan areas.

In the fourth regression, we include a city or metropolitan area fixed effect. This control is meant to address the possibility that skilled workers are just proxying for omitted variables that are pushing the area ahead. In this case, all of our identification comes from changes in the share of college educated over time within the city. In other words, during decades in which the city began with more college graduates (relative to its historical mean), did that city have a higher subsequent growth rate? In the case of metropolitan areas, these fixed effects have little impact on the coefficient, although the standard errors rise significantly.[6] In the case of the cities, the coefficient drops by 40 percent (relative to the no control benchmark) and becomes statistically insignificant, but the difference between the coefficient in regression (4) and the coefficient in regression (1) is not statistically significant.

[6] We understand that we cannot estimate the coefficient on the lagged dependent variable consistently in the fixed effects specification. However, the results on the other coefficients would not change very much if we omitted the lag of population in the fixed effects specification.

Including city-specific fixed effects is asking a great deal of the data, given the extremely high degree of persistence in human capital over time. The correlation coefficient in the share of the college educated in 1980 and 1990 is 97.3 percent across cities and 97.5 percent across metropolitan areas. As the fixed effects eliminate most of the variation in skills across space, we are amazed that we continue to find a positive effect, and we are not troubled that the effect gets somewhat weaker in the city specification.

In the fifth regressions of the two tables, we add two further controls to the specification in regression (2): share of the adult population without high school degree and the unemployment rate. We see both of these variables as added measures of human capital, but these measures capture the lower end of the human capital distribution. While high-frequency changes in the unemployment rate over time generally reflect time-varying labor market conditions, *differences* in the unemployment rate across cities (less so across metropolitan areas) are generally time invariant and reflect characteristics of the labor force and the industry structure in the city.[7] The correlation coefficient between city-level unemployment rates in 1980 and 1990 is 0.75; the correlation coefficient between MSA-level unemployment rates in 1980 and 1990 is 0.5.

In the case of metropolitan areas, the effect of the dropout rate is insignificant and the unemployment rate is marginally significant. Together these variables reduce the coefficient on percent college educated by 15 percent relative to regression (1). In Table

[7] Thus most of the time-series variation in unemployment rates is common to all cities, whereas the relative differentials between cities are quite stable.

3, controlling for these other variables severely reduces the impact of higher education on city growth. The natural interpretation of Table 2 and Table 3 is that an abundance of college graduates drives the success of a *regional* labor market, but a *local* neighborhood succeeds by avoiding large numbers of low educated workers. It seems that having high human capital matters most for the metropolitan area, but avoiding low human capital matters more for smaller units of geography.

Finally, in regression (6), we drop our measure of college graduation entirely and follow Moretti (2003) using instead the presence of colleges in the area prior to 1940. As seen in Figure 2, there is a remarkably strong relationship between the number of colleges per capita before World War II and the level of people with higher education in 2000. This variable has the advantage of being predetermined and not a function of recent events that might attract the well educated to a metropolitan area.

While we believe that this variable is less likely to reflect reverse causality or omitted factors than our share of college-educated variable, we are not confident that it is orthogonal to the error term. As such, using the variable as an instrument (as in Moretti, 2003) may give us quite misleading results because in instrumental variables regression, the correlation with the error term is essentially multiplied by the inverse of the first stage R-squared.[8] Instead, we present results using this variable directly instead of using it to instrument for the share of college graduates. In fact, both as an instrument and as a right-hand-side variable, the variable has a strong, significant impact on population

[8] Technically, this statement is only true in a univariate regression. Still, the basic point that correlation with the error term explodes in magnitude in instrumental variables regressions holds in all cases.

growth. The coefficient in Table 2 implies that as the number of colleges per capita doubles, the expected growth rate over the decade rises by roughly 4 percent for both MSAs and cities.[9]

In Appendix Table 2 we run similar regressions at the MSA level with a set of controls for other variables that may be correlated with initial high levels of education and find that the impact of education on growth is not driven by these *omitted* variables either.[10]

In Table 4, we look at reverse causality. In regression (1), we look at the relationship between population growth and the change in the share of the population with bachelor's degrees at the city level. Glaeser and Gyourko (2001) argue that durable housing causes uneducated people to move into declining cities for the cheap housing. As such, the relationship between population change and human capital change should be much

[9] We have also experimented with college enrollment over population in 1970 as an exogenous proxy for human capital with qualitatively similar results (see Appendix Table 2, column 1).

[10] In Appendix Table 2 we control for the possibility that the share of the highly educated may be simply capturing attributes of the age distribution in a city (for example, younger cities will tend to be more educated because of a cohort effect: younger cohorts are attaining higher education levels, or cities with lower education may be simply cities with elderly retired people). To address that issue we have augmented the MSA regression to control for the initial age distribution of the metropolitan area (variables for the shares of population in the following categories: age 0-21,22-34,35-44,45-54, and 54-65). We include in Appendix Table 2 other variables that are generally considered city amenities or disamenities. We also control for the murder rate. Higher education levels have been shown to reduce crime (Lochner, 1999, Lochner and Moretti, 2001). Crime is a very salient disamenity. For instance, Berry-Cullen and Levitt, (1999) show a causal link between crime and city depopulation. Murder rates are a good indicator of crime, because other crimes are not always reported, and reporting rates for other crimes may vary according to education levels. The number of museums, eating and drinking establishments per capita, health establishments per capita, the number of amusement and recreational service establishments, and the teacher/pupil ratio (a proxy for the quality of primary and secondary education in the metropolitan area) are included as local public goods or amenities that are likely to be provided in high human capital areas. We also include the number of membership organizations as a proxy for social capital. An alternative hypothesis to explain why the presence of highly educated people fosters growth hinges on the propensity of the highly educated to contribute to local social capital by participating in political and civic institutions (à la Putnam, 2000). Including these amenities, public goods, and controls for social capital does not seem to explain away the role of education on city growth. In fact, the amenity variables are mostly insignificant in this specification, although in line with previous research there is a very strong negative impact of crime on growth.

weaker among growing cities than among declining cities. This asymmetry occurs because durable housing means that housing prices fall sharply in declining cities and this attracts the unskilled. We estimate our regression with a spline at zero population growth.

Regression (1) does indeed find a strong relationship between growth and human capital among declining cities and little relationship among growing cities. In regression (4) we repeat this exercise with metropolitan areas and find similar results. Regressions (2) and (5) repeat regressions (1) and (4) with initial population and industry share controls and find little change in the coefficients on growth.

While these regressions point to a connection between decline and human capital change, the fact that we are regressing change in human capital on contemporaneous population growth is problematic. Obviously, the causal link is hard to determine from this regression. To address this issue, we instrument for growth using the omitted climate variables (heating days and annual precipitation). As shown above, these variables powerfully predict growth, and we use them as instruments in regressions (3) and (6). Clearly, interpreting the coefficients from the IV specification would become problematic if we believed that climate has a direct impact on the skill composition of an area. In regressions (3) and (6), the results are inconclusive, because the standard errors become quite large (especially for the coefficients on decline), but we see little evidence for population growth accompanying skill upgrading among growing cities.

Our interpretation of Table 4 is that there is significant potential for reverse causality among those cities that are actually in decline but little potential for reverse causality among growing cities. We see this as being more problematic for the city-level regressions because decline is more common at the city level. To ensure that a tendency for declining metropolitan areas to shed skilled workers is not driving our results in Tables 2 and 3, we have run regressions where we treat all declining cities as having zero population growth. This change has little impact on our estimated coefficient on schooling. We also omitted those areas that are predicted (on the basis of weather) to have population declines. This causes our coefficients to fall, but they generally remain statistically significant.

III. Productivity and Amenities: A Theoretical Framework

Tables 2, 3, and 4 suggest that the correlation between human capital and subsequent urban growth is a real phenomenon and not a spurious correlation driven by some obvious omitted variable or reverse causality. We now try to understand this correlation. In this section, we present a simple model that will help us to distinguish between consumption- and production-led urban growth. The main novelty of the model is to extend the framework of Glaeser et al. (1995) to multiple skill groups.

The spatial equilibrium concept is the appropriate starting point for empirical work on urban growth. This concept posits that identical people must be indifferent between alternative locations. We assume that there are a large number of cities, and we consider the equilibrium of a single city, denoted "j." There are two types of workers, high skill and low skill, who receive different wages in the city, denoted W_j^H and W_j^L.

Utility is Cobb-Douglas over a traded good, a non-traded good, and over a place-specific commodity, and as such, consumers choose the consumption of the non-traded good (denoted Q) to maximize $C_j(W_j^i - P_j^Q Q)^{1-\gamma} Q^\gamma$, where P_j^Q is the price of that good in city j, and C_j is a city-specific consumer amenity level. Optimization yields $P_j^Q Q = \gamma W_j$. We assume a fixed supply of the non-traded good in city "j" which is denoted $\overline{Q}_j$. If we let N_j denote total city population and $\hat{W}_j$ denote the average wage, then total utility for each person equals $(1-\gamma)^{1-\gamma} C_j W_j^i \left(\frac{\overline{Q}_j}{N_j \hat{W}_j} \right)^\gamma$, which must in turn be equal to $\underline{U}_i$, the reservation utility for each group H and L. This implies that the ratio of wages in every city equals the ratio of reservation utilities, or $\frac{W_j^H}{W_j^L} = \frac{\underline{U}_H}{\underline{U}_L}$.

We assume a Cobb-Douglas production function that uses capital (denoted K), effective labor units (denoted L and defined later), and a city-specific production input (which is meant to represent commercial land or access to waterways and is denoted F). Total output is therefore $A_j K^\alpha L^\beta F^{1-\alpha-\beta}$, where A_j is a city-specific productivity factor. Capital is available at a national price of r, but there is only a fixed amount, F_j, of the city-specific input.

Our primary focus will be on changes in the productivity level, A_j, and the consumer amenity level, C_j, and these are the only city-specific attributes that we will allow to change over time. Specifically, we will assume that $Log\left(\frac{A_{j,t+1}}{A_{j,t}}\right)=\sum_k \delta_A^k X_{j,t}^k + \varepsilon_{j,t}^A$ and $Log\left(\frac{C_{j,t+1}}{C_{j,t}}\right)=\sum_k \delta_C^k X_{j,t}^k + \varepsilon_{j,t}^C$, where $X_{j,t}^k$ are city-specific characteristics as of time t, which include the skill composition of the city. There are two interpretations of these equations. First, different variables may actually increase productive innovation or investment in consumer amenities. In this case, we should think of estimated coefficients as suggesting that certain characteristics have growth effects.

Alternatively, we can think of characteristics as having level effects that change over time. If $Log(A_{j,t})=\sum_k \psi_{A,t}^k X_{j,t}^k + \xi_{j,t}^A$ and $Log(C_{j,t})=\sum_k \psi_{C,t}^k X_{j,t}^k + \xi_{j,t}^C$, and $X_{j,t}^k \approx X_{j,t+1}^k$ (recall that the correlation of schooling levels over time is over 97 percent, and the climate is even more permanent), then $Log\left(\frac{A_{j,t+1}}{A_{j,t}}\right)\approx \sum_k (\psi_{A,t+1}^k - \psi_{A,t}^k) X_{j,t}^k + \varepsilon_{j,t}^A$ and $Log\left(\frac{C_{j,t+1}}{C_{j,t}}\right)\approx \sum_k (\psi_{C,t+1}^k - \psi_{C,t}^k) X_{j,t}^k + \varepsilon_{j,t}^C$. As these equations are identical to the growth equations above, they are empirically indistinguishable, and we cannot tell if a characteristic causes productivity growth because it has a growth effect or because it has a level effect that is increasing over time. This model will enable us to separate characteristics that impact consumption amenities and characteristics that impact production amenities, but not to separate growth effects from "increasing level" effects.

To allow for multiple skill categories, we assume that a unit of effective labor is produced via a constant elasticity of substitution technology that uses both high- and low-skilled workers, i.e. $L = \left(\theta_j^{1-\sigma} L_H^{\sigma} + L_L^{\sigma}\right)^{1/\sigma}$ where θ_j is a city-specific parameter increasing the relative returns to skilled workers, and L_H, L_L reflect the number of high- and low-skill workers, respectively. Cost minimization implies $\frac{L_H}{L_L} = \theta_j \left(\frac{W_j^L}{W_j^H}\right)^{\frac{1}{1-\sigma}} = \theta_j \phi^{\frac{-1}{1-\sigma}}$, where $\phi = \frac{\underline{U}_H}{\underline{U}_L}$ so the skill composition of the city is determined by the parameter θ_j. Manipulation of the first order conditions and using the notation $\eta = 1 - \alpha - \beta + \gamma\beta$ implies:

(2) $$N_j = A_j^{\frac{1-\gamma}{\eta}} F_j^{\frac{(\eta-\gamma\beta)(1-\gamma)}{\eta}} C_j^{\frac{1-\alpha}{\eta}} \overline{Q}_j^{\frac{\gamma(1-\alpha)}{\eta}} \Theta_j^N \Omega_N,$$

(3) $$\hat{W}_j = A_j^{\frac{\gamma}{\eta}} F_j^{\frac{(\eta-\gamma\beta)\gamma}{\eta}} C_j^{\frac{\alpha+\beta-1}{\eta}} \overline{Q}_j^{\frac{-\gamma(1-\alpha-\beta)}{\eta}} \Theta_j^W \Omega_W, \text{ and}$$

(4) $$P_j^Q = A_j^{\frac{1}{\eta}} F_j^{\frac{1-\alpha-\beta}{\eta}} C_j^{\frac{\beta}{\eta}} \overline{Q}_j^{\frac{-(1-\alpha-\beta)}{\eta}} \Theta_j^Q \Omega_Q$$

where Θ_j^i for i=N, W, Q refers to city-specific terms that are only a function of θ_j and ϕ, and where Ω_i i=N, W, Q refers to terms that are common across cities, including the reservation utilities, rent level, and the parameters, α, β, γ and σ. Both Θ_N^i and Ω_N are defined in Appendix B.

Equations (2), (3) and (4) yield standard results in the regional literature: (1) increases in urban productivity will cause increases in the population, average wages, and the price of non-traded goods (i.e., housing), (2) increases in the fixed factor of production will likewise increase population, wages, and the price of non-traded goods, (3) increases in the consumption amenity will raise population, lower wages, and raise housing prices and (4) increases in the endowment of non-traded goods will increase the population, decrease wages, and decrease the price of the non-traded good.

To manipulate these equations, we will assume that, within a city, the production and consumption amenities are changing over time, that all other city-specific factors are fixed, and that while reservation utilities are changing, the ratio $\frac{\underline{U}_H}{\underline{U}_L}$ is fixed. These assumptions tell us that:

(2') $$Log\left(\frac{N_{j,t+1}}{N_{j,t}}\right) = I^N + \sum_k \left(\delta_A^k \frac{1-\gamma}{\eta} + \delta_C^k \frac{1-\alpha}{\eta}\right) X_{j,t}^k + \mu_{j,t}^N$$

(3') $$Log\left(\frac{\hat{W}_{j,t+1}}{\hat{W}_{j,t}}\right) = I^W + \sum_k \left(\delta_A^k \frac{\gamma}{\eta} - \delta_C^k \frac{1-\alpha-\beta}{\eta}\right) X_{j,t}^k + \mu_{j,t}^W$$

(4') $$Log\left(\frac{P_{j,t+1}^Q}{P_{j,t}^Q}\right) = I^Q + \sum_k \left(\delta_A^k \frac{1}{\eta} + \delta_C^k \frac{\beta}{\eta}\right) X_{j,t}^k + \mu_{j,t}^Q$$

where I^i for i=N, W, Q is an intercept term that is constant across cities, and $\mu^i_{j,t}$ again for i=N, W, Q is an error term, which has a zero mean and is orthogonal to the X terms as long as the underlying error terms, $\mu^i_{j,t}$ are mean zero and orthogonal to the X terms.

Equations (2′), (3′), and (4′) show us how to use the differences in the coefficients from population, wage, and price growth regressions to determine the values of δ^k_A and δ^k_C for any X variable. The intuition behind this claim is that if a variable is increasing population and prices, but not wages, this implies that the variable is increasing consumption amenities. If a variable is correlated with increasing population and wages, more than with prices, this implies that the variable is increasing productivity.

We focus on a specific X variable— the share of skilled workers, which is itself a function of the ratio of reservation utility levels and the technology parameter θ_j. We will let δ^S_A and δ^S_C refer to the impact of this variable on the growth of productivity and consumption amenities, respectively. These equations will enable us to interpret the city-growth regressions (shown above) and regressions looking at changes in urban wages and changes in housing values.

Under the assumptions of the model, different values of θ_j will have no direct impact on growth if the ratio $\frac{\underline{U}_H}{\underline{U}_L}$ is fixed. As shown in the Appendix, if $\frac{\underline{U}_H}{\underline{U}_L}$ rises, we should expect skilled cities to grow less. The intuition behind this result is a pure price effect. For cities that specialize in the skilled, their primary form of labor has become more expensive, and as a result, they grow less. To understand these issues fully, a general equilibrium model would be necessary. For our purposes, though, it is enough to note that increases in $\frac{\underline{U}_H}{\underline{U}_L}$ (reflecting, perhaps, the rising skill premium) would cause relatively less population growth in more skilled cities.

Using calculations in the Appendix and the notation $\hat{B}_{Pop}$, $\hat{B}_{Price}$ and $\hat{B}_{Wage}$ to denote the coefficients on schooling in population growth, housing price growth and wage growth regressions, respectively, it follows that:

$$\text{(5)} \qquad \frac{\delta_A^S \frac{1-\gamma}{\eta}}{\delta_A^S \frac{1-\gamma}{\eta} + \delta_C^S \frac{1-\alpha}{\eta}} = \frac{\frac{\hat{B}_{Price}}{\hat{B}_{Pop}} - \frac{\beta}{1-\alpha}}{1 + \frac{\gamma}{1-\gamma} - \frac{\beta}{1-\alpha}} = \frac{\frac{\hat{B}_{Wage}}{\hat{B}_{Pop}} + 1 - \frac{\beta}{1-\alpha}}{1 + \frac{\gamma}{1-\gamma} - \frac{\beta}{1-\alpha}}$$

Equation (5) tells us that if we want to determine the reason why skills increase productivity growth, we need to know either $\frac{\hat{B}_{Price}}{\hat{B}_{Pop}}$ or $\frac{\hat{B}_{Wage}}{\hat{B}_{Pop}}$ and two other parameters: $\frac{\gamma}{1-\gamma}$ (the share of spending on non-traded goods divided by spending on traded goods) and $\frac{\beta}{1-\alpha}$ the ratio of producer spending on labor divided by producing spending on labor and non-traded capital goods.

IV. Distinguishing Between Productivity and Amenity Effects

We now use the equations in the previous section to measure the extent to which the connection between skill and growth stems from productivity or amenity effects. Since Rauch (1993) we have known that, holding one's own skill level constant, wages in a city rise with the skill level of that community. We also know that prices are higher in both cities and metropolitan areas with more skilled workers. Moretti (2003) extends Rauch (1993) and identifies human capital externalities by using instrumental variables related to human capital but plausibly exogenous to wages.[11] He finds that, after controlling for the private returns to education, a 1-percentage-point increase in the share of the college educated in a metropolitan area raises average wages by 0.6 percent-1.2 percent. The same author (Moretti, 2002) finds more direct evidence of human capital externalities by using plant-level production functions. Of course, it is arguable if the previous literature succeeds in addressing the problem that selection of more unobservable skilled workers into these cities might be driving the correlations.

In Figure 3, we show the relationship between wages, adjusted for both individual characteristics and local prices and local human capital across metropolitan areas in 1990. The individual characteristics include age, schooling, and gender, and we have used the American Chamber of Commerce Research Analysis data to correct for local price levels. The overall correlation is strong and positive. If we believe these price levels, it seems

[11] He uses the demographic structure of the city and the presence of "land-grant" colleges from the Morrill Act (1862).

appropriate to think that in the cross-section, the primary impact of human capital is to increase productivity, at least at the metropolitan area level.

Our focus is, of course, on changes over time, not on the level effects. So to address these changes we turn first to results looking at housing price growth at the city and metropolitan area levels. We are implicitly assuming that the relative home quality changes across metropolitan areas are small. The available evidence supports the idea that this assumption is not particularly problematic. Table 5 (panels A and B) reproduces Tables 2 and 3 with the change in the logarithm of median housing values as the dependent variable. These are self-reported housing values taken from the census. In these regressions, we add the initial housing values as an added control to correct for mean reversion.

Regressions (1)-(6) of Panel A in Table 5 show the impact that initial human capital has on later housing price appreciation at the metropolitan area level. The magnitude of the effect expands dramatically between regression (1) and regression (2) as the coefficient on percent college educated rises from 0.18 to 1.17. If we believe the coefficient in regression (1), a 10 percent increase in the percent college educated at the metropolitan area level is associated with a 1.8 percent increase in housing prices over the next decade. If we believe the coefficient in regression (2), a 10 percent increase in the percent college educated increases the expected growth rate of housing prices almost 12 percent over the next decade.

The difference between the two coefficients is entirely the result of controlling for the initial housing price in each community. There is an extraordinarily large amount of mean reversion in housing prices across metropolitan areas. In general, the high price areas have also had higher levels of human capital, so controlling for the natural tendency of high price places to mean revert causes the coefficient on initial share with college degrees to increase.

Regressions (3)-(6) show that at the metropolitan area level the coefficient on schooling in housing price growth regressions is extraordinarily robust statistically when we control for initial housing price. Even with state or metropolitan area fixed effects, the t-statistic never drops below four. Regression (6) shows that the presence of colleges prior to 1940 also predicts housing price growth during the past 30 years. Panel A in Table 5 certainly seems to make it clear that higher levels of education increase both the population of metropolitan areas and the price that this population is paying for the privilege of living in the area.

In Panel B (Table 5), we examine housing price growth at the city level, and the results essentially reproduce the findings of Panel A. Housing price growth is weakly positively associated with human capital when we fail to control for initial housing prices. When we control for mean reversion, the effect becomes extremely large and extremely robust. The only substantive difference between Panel A and B is that in Panel B, the presence of colleges prior to 1940 is not a good predictor of housing price growth over the last 30 years. We are certainly struck by the extraordinary power of human capital in predicting housing price growth.

In Panels C and D (Table 5), we look at the connection between income growth and human capital. Panels C and D essentially reproduce Tables 2 and 3 with the log of family income as the dependent variable. These regressions are useful in that they are directly comparable to the previous regressions, but they are flawed by the fact that these results will be biased because of the rise in returns to skill over this time period. Because the compensation for skilled workers has generally risen over the period, we should expect to see incomes rising more quickly in more skilled cities. Average family income, or other aggregate income measures, cannot control for the general change in skill premia. Nevertheless, for completeness we present these results.

Panels C and D show a systematic positive relationship between initial human capital levels and later growth in family income at both the metropolitan area and city levels. As in Panels A and B, there is a big difference in the coefficients between regressions (1) and (2) (in both Panels C and D) where the coefficient on schooling is much bigger in regression (2). Just as in the case of housing prices, there is substantial mean reversion in family incomes, and just as in the case of housing prices, skilled cities look much better once we account for this natural tendency of high income places to become relatively poorer over time.

In both Panels C and D, the baseline impact of having an extra 10 percent of an area's adult population with college degrees is an increase in expected income growth of 2 percent. When we control for mean reversion, that impact increases to more than 10 percent. Given that wages for workers with college degrees expanded (relative to non-college degree workers) by less than 50 percent over the entire 30-year period (see Katz and Murphy, 1992), the pure compositional effect of a 10-percentage-point increase in the share of adults with a college degree should be less than 2 percent per decade. Using a back-of-the-envelope estimate, if workers of category "X" have had their wages increase by "Y" percent over a time period, then an upper bound for the purely compositional effect of having an extra 10 percent of a place's labor force in category "X" is .1*Y.[12] Thus, the large magnitudes of the effects seem incompatible with the view that the only effect is that skilled workers are getting higher wages: workers in skilled cities are getting paid more relative to skilled workers elsewhere.[13]

To show this, in Table 6 column 1, we use the Census Individual Public Use Microsamples (IPUMS) from 1970 to 2000 to control for individual characteristics in a wage regression that includes MAS education levels. We look at the wages of males over 21, and we control for schooling, age and race, and metropolitan area fixed effects. In these regressions, the coefficients on schooling and age were allowed to differ by time period. We also include a control for the schooling in the area. We decided to use the lagged share of the percent of the area with college degrees as our measure of education.

[12] The initial share of the highly educated may also be positively correlated with changes in that share. The micro-data regressions will dispel any concerns in that direction.

The decision to use lagged value is both an attempt to make these results more comparable with the growth regressions and also an attempt to reduce the causality problems inherent with regressing wages on the population composition of an area. While this would certainly not eliminate causal issues, our results are essentially unchanged if we use schooling in 1970 as our measure of MSA schooling throughout the time period.

Since we are controlling for metropolitan area fixed effects, we can only estimate the coefficient on area-level schooling in three decades, and we chose 1970 as the excluded decade. As such, differences in our estimated coefficients on the interaction of schooling and decade should be interpreted as the extent to which the coefficient on average schooling in the area has increased over time. Our results suggest that the coefficient on schooling increased by 0.58 between 1970 and 1980, and then by 0.21 between 1980 and 1990. Between 1990 and 2000 the coefficient increased by 0.047.

On average over the three decades, the coefficient on the share with college degrees increased by 0.25 per decade, which is comparable to a coefficient in a growth regression of 0.25. This is comparable to the coefficient in the first regressions of Table 5 (Panels C and D), not the subsequent regressions, because Table 6 doesn't allow high wage cities to mean revert and become lower wage over time.

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[13] The results cannot be accounted for by the fact that more highly educated people have a higher propensity to be married and thus higher (median) family incomes: using income per capita at the MSA level we found very similar results.

In the second column of Table 6, we include housing value regressions that are similar in character to the wage regressions. In this case, we are able to control for housing characteristics and thus for any changes in the hedonic value of housing characteristics over time. Just as in the wage regression, we are able to control for metropolitan area fixed effects and we identify a tendency of the houses in high schooling metropolitan areas to increase over time. On average, the coefficient on schooling rises by over 0.5 each decade over the 30 years, but all of this increase occurs between 1970 and 1990. Between 1990 and 2000, the coefficient on schooling actually falls.

Interpreting the Coefficients with the Model

We first focus on metropolitan areas and then turn to cities and begin with our estimates of $\hat{B}_{Pop}$, $\hat{B}_{\Pr ice}$ and $\hat{B}_{Wage}$. At the metropolitan area level, the coefficient of schooling in the Table 2 population growth regressions ranges from 0.42 to 0.58. This is a fairly narrow band and not much is gained by focusing on the extremes, as such we will use 0.5 as value of $\hat{B}_{Pop}$.

The estimates of $\hat{B}_{\Pr ice}$ in Table 5 range from 0.2 to 2.4, but the bulk of them are clustered around 1. In Table 9 our estimate of $\hat{B}_{\Pr ice}$ is 0.55. We will use 0.5 and 0.75 as two estimates of $\hat{B}_{\Pr ice}$. Table 5 gives a range of estimates for $\hat{B}_{Wage}$ between 0.2 and 1.8. In the case of $\hat{B}_{Wage}$, we are inclined to put more weight on Table 6's estimate of 0.25, since this is the only estimate that controls properly for individual characteristics.

To produce a reasonable set of estimates, we rely on the fact that the model implies that $\hat{B}_{Pop} + \hat{B}_{Wage} = \hat{B}_{\Pr ice}$, the sum of the coefficients on wages and population should equal the coefficient on prices. It is not true that this holds perfectly empirically—for Table 6's estimates and for the estimates in regressions (2), (4) and (5) of Table 5, the value of $\hat{B}_{\Pr ice}$ - $\hat{B}_{Wage}$ ranges from 0.3-0.5. The two cases where the difference is outside this range are the case where there are no controls and the case where we have state fixed effects. So we will calibrate the model with a range of 0.1 to 0.5 for $\hat{B}_{Wage}$ and an associated range of 0.6 to 1 for $\hat{B}_{\Pr ice}$, which implies that $\frac{\hat{B}_{\Pr ice}}{\hat{B}_{Pop}}$ ranges from 1.2 to 2 or $\frac{\hat{B}_{Wage}}{\hat{B}_{Pop}}$ ranges from 0.2 to 1.

Equation (5) tells us that if we want to determine the reason why skills increase productivity growth, we need to know either $\frac{\hat{B}_{\Pr ice}}{\hat{B}_{Pop}}$ or $\frac{\hat{B}_{Wage}}{\hat{B}_{Pop}}$ and two other parameters: $\frac{\gamma}{1-\gamma}$ (the share of spending on non-traded goods divided by spending on traded goods) and $\frac{\beta}{1-\alpha}$

We must also have an estimate of $\frac{\gamma}{1-\gamma}$ -- the share of spending on non-traded goods divided by one minus the same share. We can estimate this parameter by using the 2001 Consumer Expenditure Survey to calibrate the share of shelter in overall expenditure, which is 0.19. Shelter is pretty clearly a non-traded good, but as there are other elements of consumption that are non-traded, this estimate qualifies as something of a lower bound.

The second way of estimating $\frac{\gamma}{1-\gamma}$ is to use a city-level price index (from the American Chamber of Commerce) and regress the log of this price index on the log of housing prices. If the Cobb-Douglas assumption is correct, and if we assume that the consumption amenity is constant then: $E(P_j, U) = \frac{U\left(P_j^Q\right)^\gamma}{\gamma^\gamma (1-\gamma)^{1-\gamma}}$ and $\frac{\partial Log(E(P,U))}{\partial Log(P_j^Q)} = \gamma$. Since price indices are supposed to measure the amount of money needed to provide a fixed level of utility, they are ideally the expenditure function, so another way of estimating γ is to estimate $\frac{\partial Log(E(P,U))}{\partial Log(P_j^Q)}$ (i.e. the extent that local price levels rise with increases in housing prices). Using the 2000 cross-section, we estimate:

$$\text{(6) Log(Price Level)} = \underset{(18)}{-2.2} + \underset{(.015)}{.29}\text{*Log(Median Housing Price)}$$

The R-squared is 0.63, and there are 220 observations. We can also estimate this relationship from a panel with MSA and year dummies:

$$\text{(6}'\text{) Log(Price Level)=MSA and Year Dummies} + \underset{(0.028)}{.21}\text{*Log(Median Housing Value)}$$

In this case, the R-squared is 0.986, and there are 505 observations. Together, these two methods confirm that a reasonable estimate of the share of spending on non-traded goods lies between 0.21 and 0.29, and we will use 0.33 $\left(\frac{0.25}{1-0.25}\right)$ as our estimate of $\frac{\gamma}{1-\gamma}$.

The value of $\frac{\beta}{1-\alpha}$ equals the ratio of producer spending on labor divided by producer spending on labor plus producer spending on non-traded capital goods. While we lack any compelling figures for this ratio, we don't believe that spending on non-traded capital goods can be more than one-third of the wage bill. Thus, this parameter is bounded between 0.75 and 1.

Using the parameter estimates $\frac{\gamma}{1-\gamma}$ equals one-third, we know that $\frac{\delta_A^S \frac{1-\gamma}{\eta}}{\delta_A^S \frac{1-\gamma}{\eta} + \delta_C^S \frac{1-\alpha}{\eta}}$ cannot fall below 1 as long as a $\frac{\hat{B}_{Wage}}{\hat{B}_{Pop}} \geq .33$ regardless of the value of $\frac{\beta}{1-\alpha}$. This result comes from the fact that if $\frac{\hat{B}_{Wage}}{\hat{B}_{Pop}} \geq \frac{\gamma}{1-\gamma}$ then real wages are increasing with initial schooling, which can only mean that amenity levels are falling. Even if $\frac{\hat{B}_{Wage}}{\hat{B}_{Pop}} = .2$, then the lowest possible estimate of $\frac{\delta_A^S \frac{1-\gamma}{\eta}}{\delta_A^S \frac{1-\gamma}{\eta} + \delta_C^S \frac{1-\alpha}{\eta}}$ is 0.6. To believe that the majority of the skills effect on growth comes from an amenity effect, it must be that

$\frac{\hat{B}_{Wage}}{\hat{B}_{Pop}} < .1$ or equivalently $\frac{\hat{B}_{\Pr ice}}{\hat{B}_{Pop}} < 1.1$. We don't believe that either of those conditions hold and as such, we are led to the view that the bulk of the skills-growth connection at the metropolitan area level comes from the fact that skills predict productivity growth.

As a final check on this, in Table 7, we look at the growth of real wages and the relationship to initial human capital. As argued before, if human capital increases amenities at the metropolitan area level, then real wages should be falling. We again use the American chamber of Commerce data for local prices levels. We use three different measures of MSA-level wages. First, we use the census' average wage in the area. Second, we use the average manufacturing wage in the area from the Bureau of Labor Statistics. Third, we use a wage variable that we construct using data from the Individual Public Use Micro-Sample, which corresponds to the MSA fixed effect of a regression of wages on individual characteristics. This can be interpreted as the average wage in the metropolitan area net of the impact of individual characteristics. We present results both with and without other controls. In all cases, we find either a positive or a zero coefficient on human capital. There is no regression where human capital is associated with declining real wages at the city level. This evidence again pushes us to the conclusion that rising wages at the city level have everything to do with rising productivity and nothing to do with rising amenities.

Results at the City Level

We can distinguish between the impact of human capital on the growth of metropolitan areas and the impact of human capital on the growth of cities (holding metropolitan area growth constant). The overall growth of cities is driven by factors similar to those that drive growth in the metropolitan areas that surround them. The growth of cities *holding metropolitan area growth constant* enables us to really focus on city-specific factors. There has been little work on this issue, but in many respects, it is a natural area for research on amenities. Cities within a metropolitan area have radically different levels of amenities but supposedly are part of the same labor market. After all, metropolitan areas are defined to capture a local labor market. Moreover, many people work outside of their city (within their metropolitan area), but their city still determines their quality of life, their housing prices, and their public goods.

Within the context of the previous model, if we assume that wages are the same across cities (within a metropolitan area), then $C_j\left(P_j^Q\right)^{-\gamma}$ must be constant across areas, i.e. the price of the non-traded good (housing) must offset the value of a higher level of consumption. This implies the following relationship:

$$(4'')\ Log\left(\frac{P_{j,t+1}^Q}{P_{j,t}^Q}\right) = I_{MSA}^Q + \sum_k \left(\gamma \tilde{\delta}_C^k\right) X_{j,t}^k + \mu_{j,t}^Q,$$

where I^{Q}_{MSA} is an MSA-specific intercept, and $\tilde{\delta}^{k}_{C}$ represents the impact of characteristic k on consumption amenity growth at the local level, which may be slightly different from the impact of the growth of this variable at the MSA level.

We also know that the market for the non-traded good must clear, so that $\frac{\gamma \hat{W}_j}{P^Q_j} = \frac{\overline{Q}_j}{N_j}$. If we use the notation that S_j denotes the share of population in the city that is highly skilled, then this equation implies that $C_j \left(\frac{N_j}{\overline{Q}_j} \right)^{-\gamma} \left(1 + \phi S_j\right)^{-\gamma}$ is constant within a metropolitan area. In this case, the model does not pin down the skill composition of the city or the population of the city, only the city's aggregate income. In principle the city can include only skilled workers or only unskilled workers or any combination of the two. To implement this empirically, we assume that $\left(1 + \phi S_j\right)^{-\gamma}$ is constant over time, and that implies that:

$$(2'')\ Log\left(\frac{N_{j,t+1}}{N_{j,t}} \right) = I^{N}_{MSA} + \sum_k \left(\gamma \tilde{\delta}^{k}_{C}\right) X^{k}_{j,t} + \mu^{N}_{j,t},$$

where I^{N}_{MSA} is an MSA-specific intercept. Somewhat surprisingly, the Cobb-Douglas utility function implies that the effect of consumption amenity growth on prices and people should be the same.

Equations (2″) and (4″) inspire us to run regressions within metropolitan areas controlling for MSA/decade fixed effects. These are shown in Table 8 and the regressions should be interpreted as capturing the impact of city-specific human capital controlling for the average growth rate of the metropolitan area over the decade. The first thing that the regressions show is that the impact of human capital on prices and population is not the same, despite the implications of the model. Human capital has a much stronger effect (at least when we control for initial price levels) on price growth than on population growth.

The second implication of the regressions is that human capital powerfully predicts both housing price and population growth. Interestingly, the impact of the highly educated residents (college graduates shown in regressions (1) and (3)) is stronger in the housing price growth regressions. High human capital workers appear to be highly correlated with rising prices. The impact of less educated residents (high school dropouts shown in regressions (2) and (4)) is stronger in the population growth regressions. All four regressions can be interpreted to mean that human capital is associated with rising consumer amenity levels at the local level, but the regressions do not tell us a simple story.

One possible way to reconcile these regressions is to drop our simple assumptions about housing supply being essentially perfectly elastic (subject to the constraint of the fixed amount of non-traded commodity). Indeed, the impact of housing supply is the most important missing element in understanding city growth. If we assume there are limits to new construction, such as zoning or land use regulation, and we assume that these were more binding in high skill, rather than low skill cities, then we might expect this pattern. In high skill cities, supply is relatively inelastic so increasing demand operates mainly by increasing prices. In low skill cities, supply is more elastic, so increasing demand operates mainly by increasing quantities. This is a possible reconciliation of the four regressions in Table 8, but it properly belongs as a subject for future research.

If we accept the assumption that a metropolitan area is a common labor market, with common wages, then Table 8 seems to imply that there is a significant impact of skills on consumption amenity growth at the local level. Of course, that assumption may not hold perfectly. Some sub areas of a metropolitan region may be much more productive than others, and productivity heterogeneity could explain the results. As such, these findings are best thought of as suggestive evidence supporting the link between skills and amenity growth at the local level.

V. Understanding the Productivity Effect

The evidence suggests that the skills-growth connection at the metropolitan area is fueled primarily by productivity effects. As suggested earlier, the basic data on wage, price and population growth cannot distinguish between different stories concerning the connection between human capital and productivity. However, we will use other available evidence to check the validity of two of these stories.

First, we address the hypothesis that an environment dense with highly educated people leads to faster technological innovation and that this explains the connection between metropolitan area growth and human capital. To test this idea, we turn to the patents data. We are able to measure patents by MSA for the period 1990-1999, so we will focus on growth during the 1990s. We first regress patents per capita on the human capital level, then see how much of the skills-growth connection is explained by greater patenting activity.

In Table 9, regression 1, we find (like Carlino, Chatterjee and Hunt, 2001) that the share with bachelor's degree is an important predictor of technological growth. We find that a 10 percent in increase the share of college graduates increases the number of patents by 0.09 log points (approximately 9 percent). This certainly supports the idea that the better educated are more technologically innovative.

Moreover, in regression (2), we show that there is a connection between patents and growth in regressions where we don't control for human capital. Of course, no causality is posited by these regressions. Patents are as much a sign of a healthy urban environment as a cause. However, the important fact is shown in regression (3). Once we control for human capital there is no meaningful relationship between patents and urban growth. As such, human capital may matter because it makes people more creative, but the important elements of this creativity must be in areas beyond the formal patenting sector.

The Reinvention Hypothesis

We finally turn to the puzzle created by Figures 4 and 5: human capital predicts growth much more sharply in cold places than in warm areas. Figure 4 shows the relatively mild (0.13) correlation between skills and growth among those metropolitan areas with January temperatures above 40 degrees on average. Figure 5 shows the 47 percent correlation between the initial share of the population with college degrees and the growth of the logarithm of population between 1980 and 2000 for those metropolitan areas with average January temperatures below 40 degrees. The regression (reported in the figure) suggests that as the share of college educated increases by 1 percent, the growth rate of the period increases by 1.3 percent. Previous literature (Glaeser, Kolko, and Saiz, 2001, Glaeser and Shapiro, 2003) has pointed to the role of warm weather as an exogenous amenity that has fostered growth in the late 20th century U.S. Sun, coupled with the availability of AC systems,[14] may have given some areas in the South and West a competitive advantage but skill appears to be a good substitute.

This fact may be explained by Jane Jacobs' (1969) view that cities need to constantly reinvent themselves. Specialization in one area may yield brief success but eventually the area fades or the city's comparative advantage in the area decays, and reinvention is necessary. Glaeser (2003) details at least four periods in Boston's history where the city

[14] Alternatively, the weather variable may be capturing the impact of other variables, though the effect of weather on population growth holds after controlling for state fixed effects. What matters for our argument is not so much the causal impact of weather but the strong predictive power of the part of the signal in this variable that is orthogonal to education.

reinvented itself. Conversely, in areas with positive exogenous growth shocks human capital may have less of a role, since reinvention is not necessary.

In Table 10, we look at this hypothesis more thoroughly. In regressions (1)-(3), we repeat our benchmark specifications for population, housing price, and wage growth and focus on the interaction between initial human capital and warmth. In all three cases, there is a statistically significant negative interaction between warmth and initial skills. The cross-effect is strongest in the population regressions, where the regressions imply that a doubling of the number of heating degree days causes the impact of skills to fall by about one-half. The effect on wages is also statistically significant but smaller in magnitude, at least relative to the benchmark coefficient. The effect on housing prices is the weakest. Although the cross-effect is still negative, it is not statistically significant.

One important omitted factor here is land use regulations, which appear to be tighter almost everywhere there is a high degree of human capital. This would explain why in warm places, skills still matter for housing price growth (because skills are correlated with less elastic housing supply), but not much for population growth. Indeed, if there is a correlation between skills and inelastic housing supply, this would tend to create a perverse negative effect where more skilled places actually grow less, despite increasing demand for these areas.

In regressions (4)-(6), we look at the share of the population (in the initial time period) that is composed of immigrants. Over this time period, immigration was a large source of urban growth, and immigrants tend to settle where other immigrants live (Altonji and Card, 1991, Saiz, 2003). If the reinvention hypothesis is correct, we should expect to see that human capital doesn't matter in places with large supplies of immigrants, but it should be important in areas where immigrants are not coming. Indeed, this is exactly what we find in regression (4). Human capital matters much more in predicting population growth in areas without immigrants than in areas with immigrants. One possible explanation for the strikingly different correlation between skills and growth in growing and declining places is that skills allow reinvention. The view that human capital is most valuable because it enables flexibility and the ability to respond to new circumstances was emphasized by Welch (1970). If this view is correct, we should not be surprised if a high skill New England city manages to reinvent itself while a low skill Rustbelt town does not.

One implication of this hypothesis is that places with high human capital should be better at switching out of declining industries. To test this hypothesis, we gathered data on education and industrial composition in 1940 by metropolitan area (contemporaneously defined). We then tested whether the impact of skills on contributing to the shift away from manufacturing over the next 30 years has been more important in industrial, colder areas of the country (Table 10, panel B). The regressions support the view that the skilled Rustbelt towns were better at reorienting themselves: the importance of education to explain the shift away from manufacturing (the change in the manufacturing share on the left-hand side) in the second half of the 20th century was stronger in colder areas (interaction between human capital and temperature) and in areas with an initially bigger share of manufacturing (interaction between education and share manufacturing).

VI. Conclusion

Human capital predicts population and productivity growth at the city and metropolitan area level as surely as it predicts income growth at the country level. High skill areas have been getting more populous, better paid, and more expensive. Indeed, aside from climate, skill composition may be the most powerful predictor of urban growth. This is both a boon to the skilled cities that have done spectacularly over the past two decades and a curse to the cities with less skilled workers that have suffered an almost unstoppable urban decline.

Why do skilled cities grow more quickly? At the metropolitan area level, the available evidence appears to show quite clearly that skills predict productivity growth and not an increase in amenity levels. The high skilled metropolitan areas are not seeing falling real wages. To the contrary, prices seem not to be rising quickly enough to offset the increases in wages. Standard economic reasoning tells us that this means that high skill levels are associated with decreasing levels of quality of life, perhaps because of increasing population levels.

Within metropolitan areas, at the very local level, there is some evidence that the prices of skilled places have risen sharply. If the standard assumption that a metropolitan area is a single labor market holds, then the skills-housing price growth connection is best understood as suggesting that skills increase amenities at the very local level, if not at the metropolitan area level. Thus, our results suggest that skills are important because they increase productivity at the metropolitan level and amenities at the local. On net, the productivity effects appear to be much stronger.

Why are skills so strongly associated with productivity growth at the metropolitan level? Certainly skilled cities are more innovative, but controlling for the rate of innovation doesn't impact the effect of skills. One clue may be the fact that skills are much more important in otherwise disadvantaged regions than in exogenously growing regions. This fact might reflect the idea that cities are constantly reinventing themselves - moving from one field of specialization to another. Skills may well be a crucial part of this reinvention process as skilled workers react more speedily to painful economic shocks and educated workers find it easier to switch techniques (as in Welch, 1970). While at this point the reinvention hypothesis is only a guess, the fact that skills are so important in the Northeast and almost irrelevant in the West suggests there is something very significant about the connection between skills and the process of urban decline.

The results in the paper suggest that city growth can be increased with strategies that increase the level of local human capital. At the regional or metropolitan level, attracting high human capital workers may require provision of basic services, amenities and quality public schools that will lure the most skilled. Conversely, redistributive policies *at the local level* have to be carefully designed as they may have the undesired side effect of repelling the skilled and deter growth. Generating new technologies *locally* does not seem as important as having the capacity to adapt them. Providing basic quality education (maximizing success rates in high school graduation) may both produce and attract the educated. Since local tax bases are heterogeneous, state and federal funds can play a role in avoiding “low education traps” in ailing cities.

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Appendix A: Data Appendix

General Notes: MSA data are for metropolitan areas as defined by the Office of Management Budget in 1999. We use the county MSA/NECMA definition. In most cases we need to aggregate data by county to obtain the appropriate MSA data. City data are from the HUD State of the Cities Data System. We select those cities with population over 30,000 in 1970, the initial year for which data are available.

Variable	Source	Details
Share of persons 25 or older with a bachelor's degree	HUD State of the Cities Data System (Census)	
Population	HUD State of the Cities Data System (Census)	
Average heating degree days (1961-1990)	County and City Data Books, 1994	We match MSAs to the corresponding major city
Average precipitation (1961-1990)	County and City Data Books, 1994	We match MSAs to the corresponding major city
Share workers in manufacturing	HUD State of the Cities Data System (Census)	Employment in manufacturing over total employment
Share workers in professional services	HUD State of the Cities Data System (Census)	Employment in professional services over total employment
Share workers in trade	HUD State of the Cities Data System (Census)	Employment in trade over total employment
Unemployment rate	HUD State of the Cities Data System (Census)	Unemployment over labor force
Share of persons 25 or older with less than high school degree	HUD State of the Cities Data System (Census)	
Colleges per capita in 1940	Peterson's College Guide (and Census)	Peterson's provides foundation dates for all colleges in the US. We use the foundation date to ascertain if a college was founded before 1940. We match the college zip code with the pertinent county, then assign counties to MSA using 1999 MSA/NECMA definitions. We have used the Department of Education IPEDS dataset for 1969-1999 and confirmed that attrition bias is not an issue: colleges do not seem to disappear from the IPEDS sample at a faster rate in stagnating metro areas.
Family income	HUD State of the Cities Data System (Census)	
Median house value	HUD State of the Cities Data System (Census)	
Wages	Bureau of Economic Analysis	Average wage and salary disbursements per worker
Manufacturing wages	Bureau of Labor Statistics	Average Hourly Earnings in the manufacturing industry
IPUMS wages	IPUMS (Census)	
IPUMS House values	IPUMS (census)	

Adjusted IPUMS wages	IPUMS (Census)	Obtained as the MSA fixed effects of independent cross-sectional regressions where we control for age, age squared, education dummies, sex, race, Hispanic ethnicity, marital status, and veteran status
ACCRA Price index	American Chamber of Commerce Research Analysis Data	A cross section of relative prices for 1970, 1980 (about 36 observations) and 1990 and 2000 (about 210 observations)
CPI-U	Bureau of Labor Statistics	Consumer Price Index - Urban
College enrollment in 1970	IPED/HEGIS Database (NCES)	HEGIS/IPEDS offers enrollment for each institution of higher education. We match zip code to counties and add up enrollments for all institutions in a metro area
Murders per 1,000 population	National Archive of Criminal Justice Data	Originally from FBI. By county, we generate data by MSA.
Teacher/pupil ratio	NCES Common Core of Data	The data are for 1990. We locate the county of each school and aggregate the number of pupils and teachers by county. Then we aggregate the county data to MSA.
Museums	County Business Patterns (1980, 1990)	
Eating and drinking establishments per capita	County Business Patterns (1980, 1990)	
Motion picture establishments per capita	County Business Patterns (1980, 1990)	
Health establishments per capita	County Business Patterns (1980, 1990)	
Amusement and recreational service establishments	County Business Patterns (1980, 1990)	
Membership organizations	County Business Patterns (1980, 1990)	
Patents per worker	US Patent and Trademark Office	Data on patents by county were generously provided by Robert Hunt. We aggregated at MSA level.

Appendix B: Additional Calculations

The terms in equation (2) are $\Theta_j^N = \left(\phi^{\frac{1}{1-\sigma}} + \theta_j\right)\left(\phi^{\frac{\sigma}{1-\sigma}} + \theta_j\right)^{\frac{-\sigma(1-\alpha)+\beta(1-\gamma)}{\sigma\eta}}$,

and $\Omega_N = \left(\underline{U}_H^{\alpha-1}\left((1-\gamma)\beta\right)^{(1-\gamma)(1-\alpha)}\left(\frac{\alpha}{r}\right)^{\alpha(1-\gamma)}\right)^{\frac{1}{\eta}}$.

The only places where $\frac{\underline{U}_H}{\underline{U}_L}$ or ϕ enters directly into the logarithm of population are in the terms Θ_j^N and Ω_N, so we can write $Log(N_j) = \Psi + Log(\Theta_j^N) + Log(\Omega_N)$, and $\frac{\partial Log(N_j)}{\partial \phi} = \frac{\partial Log(\Theta_j^N)}{\partial \phi} + \frac{\partial Log(\Omega_N)}{\partial \phi}$. Differences in the skill levels of cities is proportional determined entirely by θ_j, so for more skilled cities to grow more rapidly with an increase in ϕ, it must be the case that $\frac{\partial Log(N_j)}{\partial \phi \partial \theta_j} = \frac{\partial^2 Log(\Theta_j^N)}{\partial \phi \partial \theta_j} > 0$.

Differentiating once yields:

$$\Theta_j^N = \left(\phi^{\frac{1}{1-\sigma}} + \theta_j\right)\left(\phi^{\frac{\sigma}{1-\sigma}} + \theta_j\right)^{\frac{-\sigma(1-\alpha)+\beta(1-\gamma)}{\sigma\eta}}$$

(A1) $$\frac{\partial Log(\Theta_j^N)}{\partial \theta_j} = \frac{1}{\phi^{\frac{1}{1-\sigma}} + \theta_j} - \frac{(1-\alpha)\sigma + \beta(1-\gamma)}{\sigma\eta}\frac{1}{\phi^{\frac{\sigma}{1-\sigma}} + \theta_j}$$

Differentiating again yields:

(A2) $$\frac{\partial^2 Log(\Theta_j^N)}{\partial\theta_j\partial\phi} = \frac{(1-\alpha)\sigma+\beta(1-\gamma)}{\sigma\eta}\frac{\frac{\sigma}{1-\sigma}\phi^{\frac{2\sigma-1}{1-\sigma}}}{\left(\phi^{\frac{\sigma}{1-\sigma}}+\theta_j\right)^2} - \frac{\frac{1}{1-\sigma}\phi^{\frac{\sigma}{1-\sigma}}}{\left(\phi^{\frac{1}{1-\sigma}}+\theta_j\right)^2}$$

This term is negative if $\frac{1-\alpha+\beta(1-\gamma)}{(1-\alpha)\sigma+\beta(1-\gamma)}\left(\phi^{\frac{\sigma}{1-\sigma}}+\theta_j\right)^2 > \frac{1}{\phi}\left(\phi^{\frac{1}{1-\sigma}}+\theta_j\right)^2$

As $\frac{1-\alpha+\beta(1-\gamma)}{(1-\alpha)\sigma+\beta(1-\gamma)} > 1$ and

$$\left(\phi^{\frac{\sigma}{1-\sigma}}+\theta_j\right)^2 = \phi^{\frac{2\sigma}{1-\sigma}}+\theta_j^2+2\theta_j\phi^{\frac{\sigma}{1-\sigma}} > \phi^{\frac{2\sigma-\sigma^2}{1-\sigma}}+\frac{\theta_j^2}{\phi}+2\theta_j\phi^{\frac{\sigma}{1-\sigma}} = \frac{1}{\phi}\left(\phi^{\frac{1}{1-\sigma}}+\theta_j\right)^2,$$

the expression is negative and the impact of ϕ on population growth is lower for cities with higher levels of θ_j.

Figure 1
MSA growth (1980-2000) and human capital (1980)

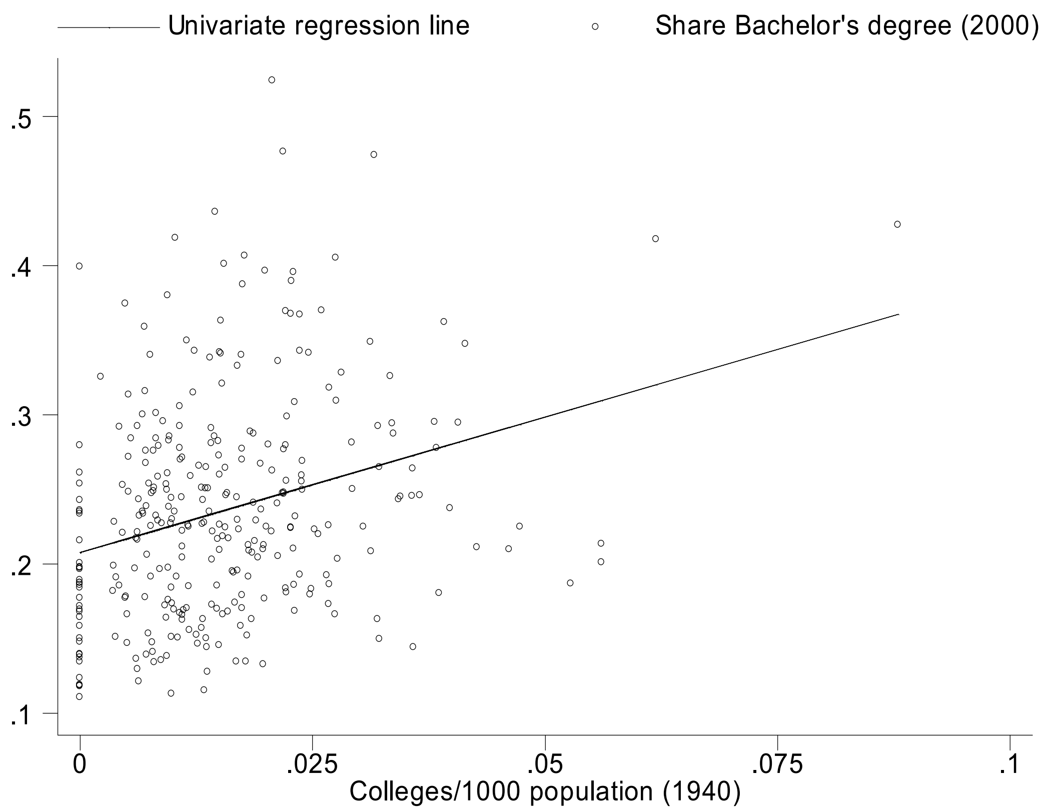
Fitted line from the regression:

Log(pop2000/pop1980) = 0.0611 + 1.001 × Share with bachelor's degree in 1980
(0.036) (0.209)

R-squared=0.067, N=318

Figure 2

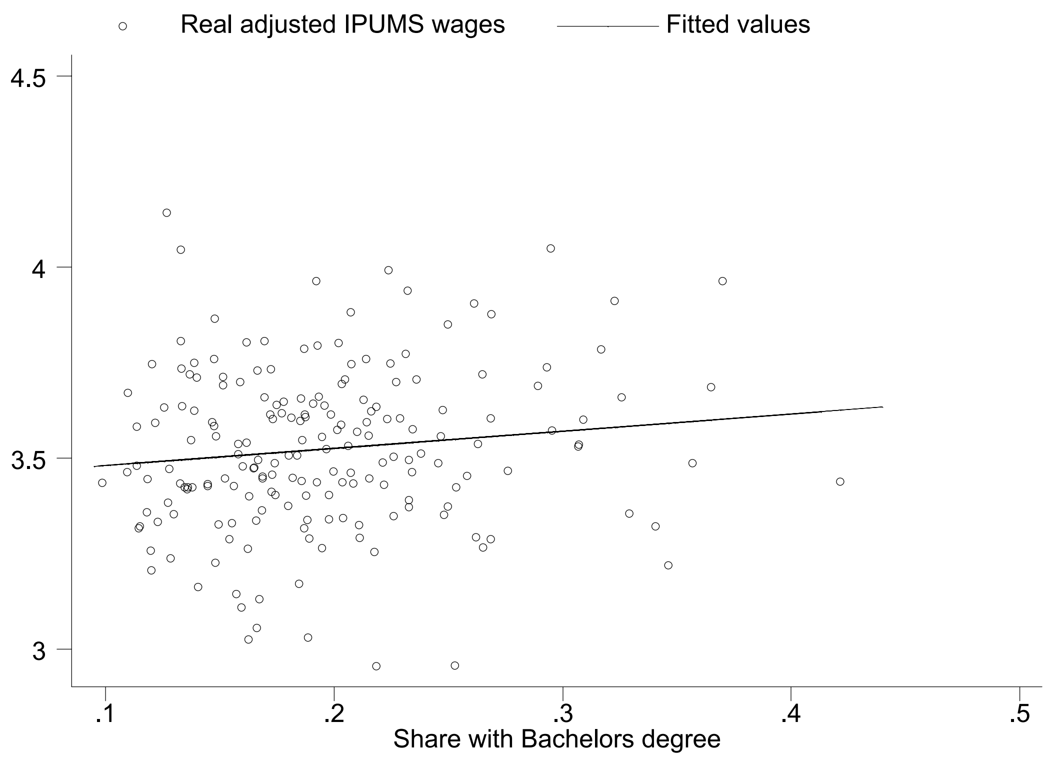
Colleges in the pre-WWII era and the share of college educated in 2000



Share with Bachelor's in 2000 = 0.207 + 1.816 × Colleges per 1,000 population in 1940
(0.006) (0.337)

R-squared=0.085, N=313

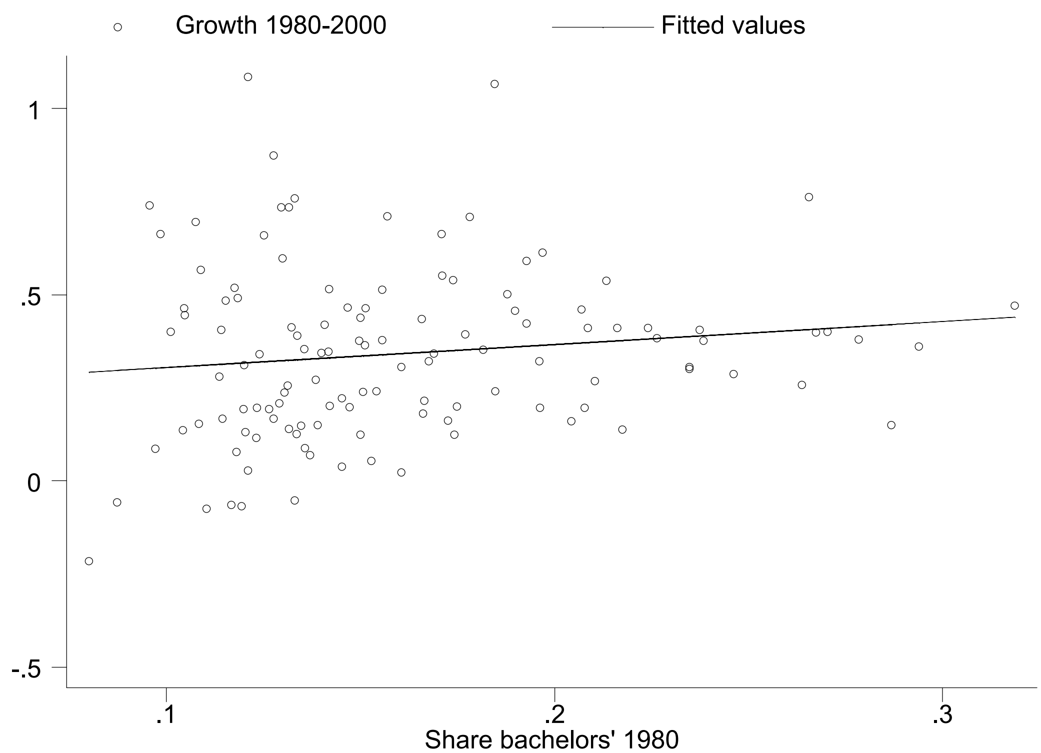
Figure 3
MSA IPUMS adjusted real wages and human capital (1990)



Real wage 1990 = 3.436+ 0.447× Share with bachelor's degree in 1990
(0.031) (0.175)

R-squared=0.015 N=191

Figure 4
MSA growth (1980-2000) and human capital (1980). Warm MSAs (January temperature over 40)



Log(pop2000)-log(pop1980) = 0.615 + 0.242 × Share with bachelor's degree in 1980
(0.429) (0.072)

R-squared=0.0171, N=120

Figure 5

MSA growth (1980-2000) and human capital (1980). Cold MSAs (January temperature under 40)

$$\text{Log(pop2000)-log(pop1980)} = \underset{(0.031)}{-0.064} + \underset{(0.175)}{1.317} \times \text{Share with bachelor's degree in 1980}$$

R-squared=0.222,   N=198

TABLE 1

1970-200 population growth and 1970 variables: correlations

	Log(population 2000)-log(population 1970)
Panel a: Metropolitan Areas	
Share with Bachelor's degree (age 25+) in 1970	0.30
Log population in 1970	-0.13
Log average heating degree days (1961-1990)	-0.56
Log average annual precipitation (1961-1990)	-0.31
Share workers in manufacturing in 1970	-0.56
Share workers in professional services in 1970	0.22
Share workers in trade in 1970	0.29
Unemployment rate in 1970	0.15
Share of high school drop outs (age 25+) in 1970	-0.18
Log colleges per capita in 1940	0.25
Log family income in 1970	-0.28
Log home value in 1970	0.02
Panel b: Cities	
Share with Bachelor's degree (age 25+) in 1970	0.18
Log population in 1970	-0.08
Log average heating degree days (1961-1990)	-0.44
Log average annual precipitation (1961-1990)	-0.45
Share workers in manufacturing in 1970	-0.33
Share workers in professional services in 1970	0.13
Share workers in trade in 1970	0.21
Unemployment rate in 1970	0.11
Share of high school drop outs (age 25+) in 1970	-0.28
Log colleges per capita in 1940	0.25
Log family income in 1970	-0.08
Log home value in 1970	0.07

TABLE 2

MSA growth and education

	Δlog(population)					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Share with Bachelor's degree (age 25+) at t-10	**0.47**	**0.582**	**0.456**	**0.508**	**0.414**	
	(0.096)***	(0.113)***	(0.117)***	(0.215)**	(0.153)***	
Log of population at t-10		-0.015	-0.011	-0.316	-0.014	0.003
		(0.004)***	(0.005)**	(0.030)***	(0.004)***	(0.005)
Log average heating degree days (1961-1990)		-0.082	-0.075		-0.084	-0.07
		(0.011)***	(0.020)***		(0.011)***	(0.011)***
Log average annual precipitation (1961-1990)		-0.026	-0.001		-0.026	-0.024
		(0.015)*	(0.014)		(0.015)*	(0.015)
Share workers in manufacturing at t-10		-0.173	-0.167	0.255	-0.162	-0.174
		(0.088)*	(0.073)**	(0.125)**	(0.085)*	(0.084)**
Share workers in professional services at t-10		-0.328	-0.166	0.148	-0.238	0.082
		(0.145)**	(0.132)	(0.203)	(0.142)*	(0.117)
Share workers in trade at t-10		0.034	0.113	0.229	0.007	-0.129
		(0.260)	(0.215)	(0.281)	(0.279)	(0.219)
Unemployment rate at t-10					-0.427	
					(0.235)*	
Share of high school drop outs (age 25+) at t-10					**-0.06**	
					(0.089)	
Log colleges per capita in 1940						**0.035**
						(0.008)***
Year fixed effects	yes	yes	yes	yes	yes	yes
Region fixed effects	no	yes	no	no	yes	yes
State fixed effects	no	no	yes	no	no	no
MSA Fixed effects	no	no	no	yes	no	no
Observations	918	918	918	954	918	816
R-squared	0.56	0.51	0.6	0.89	0.51	0.5

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

TABLE 3

City growth and education

	Δlog(population)					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Share with Bachelor's degree (age 25+) at t-10	**0.202**	**0.217**	**0.166**	**0.121**	**0.061**	
	(0.044)***	(0.053)***	(0.050)***	(0.086)	(0.078)	
Log of population at t-10		-0.009	-0.017	-0.512	-0.007	-0.010
		(0.004)**	(0.005)***	(0.017)***	(0.004)	(0.004)**
Log average heating degree days (1961-1990)		-0.021	0.000		-0.023	-0.028
		(0.009)**	(0.015)		(0.009)***	(0.009)***
Log average annual precipitation (1961-1990)		-0.097	-0.071		-0.097	-0.087
		(0.018)***	(0.025)***		(0.019)***	(0.021)***
Share workers in manufacturing at t-10		-0.032	-0.023	0.327	0.014	-0.042
		(0.060)	(0.059)	(0.091)***	(0.063)	(0.055)
Share workers in professional services at t-10		-0.113	-0.095	-0.851	-0.048	0.029
		(0.090)	(0.087)	(0.144)***	(0.102)	(0.077)
Share workers in trade at t-10		0.276	0.122	-0.393	0.181	0.200
		(0.151)*	(0.154)	(0.164)**	(0.154)	(0.149)
Unemployment rate at t-10					-0.043	
					(0.200)	
Share of high school drop outs (age 25+) at t-10					**-0.163**	
					(0.060)***	
Log colleges per capita in 1940						**0.033**
						(0.007)***
Year fixed effects	yes	yes	yes	yes	yes	yes
Region fixed effects	no	yes	no	no	yes	yes
State fixed effects	no	no	yes	no	no	no
City Fixed effects	no	no	no	yes	no	no
Observations	2160	2160	2160	2169	2160	2070
R-squared	0.11	0.26	0.36	0.8	0.27	0.26

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

TABLE 4

Reverse causation: human capital and growth

	Cities			MSA		
	Δshare bachelors					
	(1)	(2)	(3)	(4)	(5)	(6)
Spline growth for declining areas	**0.058**	**0.055**	**-0.311**	**0.121**	**0.087**	**1.249**
	(0.014)***	(0.016)***	(0.203)	(0.024)***	(0.020)***	(1.996)
Spline growth for growing areas	**0.011**	**-0.005**	**0.057**	**0.010**	**0.022**	**-0.155**
	(0.005)**	(0.006)	(0.065)	(0.007)	(0.007)***	(0.103)
Log of population at t-10		0.000	-0.001		0.007	0.006
		(0.001)	(0.001)		(0.001)***	(0.001)***
Share workers in manufacturing at t-10		-0.048	-0.063		0.023	-0.079
		(0.013)***	(0.017)***		(0.011)**	(0.031)**
Share workers in professional services at t-10		0.074	0.069		0.138	0.060
		(0.021)***	(0.023)***		(0.016)***	(0.051)
Share workers in trade at t-10		-0.081	-0.086		0.033	-0.038
		(0.037)**	(0.045)*		(0.034)	(0.054)
Year fixed effects	yes	yes	yes	yes	yes	yes
IV for growth (wheather instruments)	no	no	yes	no	no	yes
Observations	2709	2169	2160	954	954	918
R-squared	0.11	0.15		0.22	0.42	

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

TABLE 5

Education, home value and income growth

	(1)	(2)	(3)	(4)	(5)	(6)
	PANEL A: Δlog(MSA median house value)					
Share with Bachelor's degree (age 25+) at t-10	**0.185**	**1.166**	**2.324**	**2.258**	**0.902**	
	(0.083)**	(0.186)***	(0.237)***	(0.518)***	(0.220)***	
Log median house value at t-10		**-0.417**	**-0.71**	**-1.183**	**-0.422**	**-0.333**
		(0.036)***	(0.041)***	(0.060)***	(0.035)***	(0.036)***
Unemployment rate at t-10					**-0.881**	
					(0.344)**	
Share of high school drop outs (age 25+) at t-10					**-0.053**	
					(0.109)	
Log colleges per capita in 1940						**0.032**
						(0.012)***
	PANEL B: Δlog(city median house value)					
Share with Bachelor's degree (age 25+) at t-10	**0.226**	**1.619**	**2.25**	**1.869**	**1.097**	
	(0.045)***	(0.116)***	(0.118)***	(0.222)***	(0.151)***	
Log median house value at t-10		**-0.376**	**-0.602**	**-1.096**	**-0.41**	**-0.169**
		(0.024)***	(0.029)***	(0.026)***	(0.025)***	(0.017)***
Unemployment rate at t-10					**-1.483**	
					(0.279)***	
Share of high school drop outs (age 25+) at t-10					**-0.377**	
					(0.083)***	
Log colleges per capita in 1940						**-0.002**
						(0.008)
	PANEL C: Δlog(average MSA family income)					
Share with Bachelor's degree (age 25+) at t-10	**0.191**	**0.761**	**0.849**	**1.769**	**0.59**	
	(0.029)***	(0.082)***	(0.090)***	(0.171)***	(0.090)***	
Log average family income at t-10		**-0.291**	**-0.359**	**-1.155**	**-0.336**	**-0.143**
		(0.029)***	(0.036)***	(0.043)***	(0.030)***	(0.025)***
Unemployment rate at t-10					**-0.307**	
					(0.161)*	
Share of high school drop outs (age 25+) at t-10					**-0.186**	
					(0.054)***	
Log colleges per capita in 1940						**0.019**
						(0.004)***
	PANEL D: Δlog(average city family income)					
Share with Bachelor's degree (age 25+) at t-10	**0.275**	**0.632**	**0.671**	**1.624**	**0.434**	
	(0.020)***	(0.052)***	(0.056)***	(0.094)***	(0.057)***	
Log average family income at t-10		**-0.135**	**-0.167**	**-1.091**	**-0.231**	**0.042**
		(0.016)***	(0.020)***	(0.031)***	(0.020)***	(0.009)***
Unemployment rate at t-10					**-0.709**	
					(0.118)***	
Share of high school drop outs (age 25+) at t-10					**-0.313**	
					(0.041)***	
Log colleges per capita in 1940						**0.015**
						(0.003)***
Year fixed effects	yes	yes	yes	yes	yes	yes
Region fixed effects	no	yes	no	no	yes	yes
State fixed effects	no	no	yes	no	no	no
MSA Fixed effects	no	no	no	yes	no	no
Other variables in Table 2	yes	yes	yes	yes	yes	yes

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

TABLE 6

Human capital and wage/value growth: IPUMS

	Log IPUMS wage	Log IPUMS house value
	(1)	**(2)**
Share bachelor's at t-10*1980 Dummy	**0.527**	**0.389**
	(0.459)	(1.550)
Share bachelor's at t-10*1990 Dummy	**0.738**	**2.205**
	(0.347)**	(1.087)**
Share bachelor's at t-10*2000 Dummy	**0.785**	**1.698**
	(0.271)***	(0.855)**
MSA fixed effects	yes	yes
Year fixed effects	yes	yes
Observations	1026867	1222890
R-squared	0.33	0.64
Average growth in education effect per decade	**0.26**	**0.57**

Robust standard errors clustered by MSA-year in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Wage regressions include year and MSA fixed effects, controls for age, age squared, education dummies interacted with year, race, Hispanic ethnicity, marital status, and veteran status. Observations include males of age over 21 with complete observations.

Value regressions include year and MSA fixed effects, controls for number of rooms and bedrooms, quality of plumbing and kitchen facilties, and age of the building. The results to a 50% random sample of the IPUMS data for all single units with the relevant information.

TABLE 7

Human capital and real wages: direct approach

	Δlog(average wage/Accra prices)		Δlog(average manufacturing wage/Accra prices)		Δlog(IPUMS adjusted wage/Accra prices)	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Share with Bachelor's degree (age 25+) at t-10	**0.78**	**1.78**	**-0.003**	**0.213**	**0.045**	**0.057**
	(0.217)***	(0.239)***	(0.178)	(0.297)	(0.088)	(0.144)
Log of population at t-10		-0.03		-0.018		-0.018
		(0.011)***		(0.010)*		(0.005)***
Log average heating degree days (1961-1990)		-0.033		0.028		0.011
		(0.024)		(0.024)		(0.007)
Log average annual precipitation (1961-1990)		-0.03		0.024		0.031
		(0.029)		(0.040)		(0.014)**
Share workers in manufacturing at t-10		-0.029		0.188		-0.069
		(0.212)		(0.182)		(0.080)
Share workers in professional services at t-10		-1.362		0.203		-0.08
		(0.318)***		(0.389)		(0.177)
Share workers in trade at t-10		2.063		0.505		0.262
		(0.505)***		(0.476)		(0.371)
Decade fixed effects	yes	yes	yes	yes	yes	yes
Region fixed effects	no	no	no	no	no	no
Observations	238	234	135	135	130	129
R-squared	0.11	0.37	0.06	0.22	0.58	0.64

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Notes: We use Boston in 1990 as baseline, the evolution of Urban CPI and of relative prices from Accra to calculate prices by MSA and year.

TABLE 8

Within MSA regressions: minor civil divisions within MSA

	Δlog(population)		Δlog(median value)	
	(1)	**(2)**	**(3)**	**(4)**
Share with Bachelor's degree (age 25+) at t-10	**0.179**		**0.49**	
	(0.031)***		(0.035)***	
Share of high school drop outs (age 25+) at t-10		**-0.274**		**-0.079**
		(0.028)***		(0.025)***
Log of population at t-10	-0.03	-0.029	-0.019	-0.019
	(0.002)***	(0.002)***	(0.001)***	(0.001)***
Share workers in manufacturing at t-10	-0.12	-0.068	-0.099	-0.105
	(0.045)***	-0.045	(0.026)***	(0.027)***
Share workers in professional services at t-10	-0.512	-0.518	-0.264	0.033
	(0.059)***	(0.053)***	(0.041)***	-0.034
Share workers in trade at t-10	-0.245	-0.363	-0.143	-0.249
	(0.080)***	(0.082)***	(0.049)***	(0.051)***
Log median value at t-10			-0.111	-0.019
			(0.012)***	(0.011)*
Decade fixed effects	yes	yes	yes	yes
MSA-Year fixed effects	yes	yes	yes	yes
Observations	13752	13752	13645	13645
Minor civil divisions	4584	4584	4584	4584
R-squared	0.24	0.25	0.59	0.59

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

TABLE 9

Human capital and technological growth

	Log patents per worker	Δlog(population)	
	(1)	**(2)**	**(3)**
Share with Bachelor's degree (age 25+) at t-10	**9.135**		**0.781**
	(0.903)***		(0.119)***
Log patents per worker at t-10		**0.02**	**0.003**
		(0.006)***	(0.006)
Log of population at t-10	0.156	0.001	-0.011
	(0.040)***	(0.005)	(0.005)**
Log average heating degree days (1961-1990)	-0.208	-0.026	-0.037
	(0.080)***	(0.010)**	(0.010)***
Log average annual precipitation (1961-1990)	-0.014	-0.038	-0.05
	(0.107)	(0.017)**	(0.018)***
Share workers in manufacturing at t-10	5.894	-0.226	-0.047
	(0.740)***	(0.109)**	(0.122)
Share workers in professional services at t-10	-0.485	-0.213	-0.756
	(1.341)	(0.157)	(0.162)***
Share workers in trade at t-10	1.832	-0.229	0.232
	(2.367)	(0.287)	(0.297)
Region fixed effects	yes	yes	yes
Observations	304	304	304
R-squared	0.56	0.38	0.46

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

TABLE 10

The "reinvention" hypothesis

Panel A: All MSA

	Δlog(population)	Δlog(wage)	Δlog(house value)	Δlog(population)	Δlog(wage)	Δlog(house value)
Share with Bachelor's degree (age 25+) at t-10	**0.945**	**2.541**	**1.264**	**0.999**	**2.203**	**1.046**
	(0.138)***	(0.230)***	(0.209)***	(0.135)***	(0.226)***	(0.204)***
Temperature * Share bachelors' at t-10	**-0.396**	**-0.284**	**-0.121**			
	(0.112)***	(0.137)**	(0.133)			
Log of population at t-10	-0.013	0.424	0.04	-0.013	0.442	0.038
	(0.004)***	(0.051)***	(0.007)***	(0.004)***	(0.052)***	(0.007)***
Log average heating degree days (1961-1990)	-0.143	-0.075	-0.06	-0.093	-0.052	-0.021
	(0.022)***	(0.026)***	(0.023)***	(0.011)***	(0.014)***	(0.014)
Log average annual precipitation (1961-1990)	-0.027	-0.015	0.063	-0.026	-0.031	0.078
	(0.015)*	(0.018)	(0.017)***	(0.016)*	(0.019)*	(0.020)***
Share workers in manufacturing at t-10	-0.128	-0.151	0.138	-0.145	-0.185	0.074
	(0.087)	(0.115)	(0.114)	(0.082)*	(0.109)*	(0.112)
Share workers in professional services at t-10	-0.295	-1.266	-0.139	-0.456	-1.267	-0.198
	(0.145)**	(0.207)***	(0.178)	(0.143)***	(0.210)***	(0.180)
Share workers in trade at t-10	-0.004	0.088	0.119	-0.05	0.078	0.103
	(0.257)	(0.336)	(0.307)	(0.252)	(0.333)	(0.304)
Log Average Wage Receipts per Worker at t-10		-0.403			-0.417	
		(0.047)***			(0.048)***	
Log median house value at t-10			-0.414			-0.466
			(0.036)***			(0.042)***
Share immigrant at t-10 * Share bachelor's t-10				**-5.751**	**2.376**	**3.433**
				(1.201)***	(1.897)	(2.142)
Share immigrant at t-10				0.704	-0.901	-0.031
				(0.268)***	(0.352)**	(0.409)
Year fixed effects	yes	yes	yes	yes	yes	yes
Region fixed effects	yes	yes	yes	yes	yes	yes
Observations	918	918	918	918	918	918
R-squared	0.52	0.72	0.75	0.54	0.72	0.76

Panel B: 1940-2000

	Share manufacturing (1940-2000)		ΔLog(population) (1940-2000)
Share bachelors in 1940	-0.011	Share bachelors in 1940	0.094
	(0.006)*		(0.017)***
Share in manufacturing in 1940	-0.547	Log(population) in 1940	-0.139
	(0.084)***		(0.028)***
January mean temperature	-0.002	January mean temperature	0.032
	(0.0008)**		(0.002)***
Share manufacturing 1940 * Share bachelors in 1940	-0.048	Log average annual precipitation	-0.309
	(0.018)**		(0.058)***
January mean temperature * Share bachelors in 1940	0.0003	Share in manufacturing in 1940	0.046
	(0.0001)*		(0.29)
Log employment in 1940	-0.004	Constant	2.227
	(0.003)		(0.371)***
Constant	0.222		
	(0.050)***		
Observations	293	Observations	293
R-squared	0.78	R-squared	0.58

Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Panel A: Temperature =9.27-log(heating degree days); 9.27 corresponds to the city with max(log heating degree days)

TABLE A.1

Descriptive Statistics for the Main variables

MSA

	1970		**1980**		**1990**		**2000**	
	Mean	*Std. Dev.*	Mean	*Std. Dev.*	Mean	*Std. Dev.*	Mean	*Std. Dev.*
Log population- Log population at t-10	n.a	*n.a*	0.17	*0.15*	0.10	*0.13*	0.12	*0.10*
Share with Bachelor's degree (age 25+)	0.11	*0.04*	0.16	*0.05*	0.20	*0.06*	0.24	*0.07*
Population	504,782.90	*970,639.80*	560,354.40	*981,159.50*	626,707.90	*1,073,780.00*	712,948.90	*1,197,389.00*
Average heating degree days (1961-1990)	4,453.08	*2,192.30*	4,453.08	*2,192.30*	4,453.08	*2,192.30*	4,453.08	*2,192.30*
Average annual precipitation (1961-1990)	36.67	*13.89*	36.67	*13.89*	36.67	*13.89*	36.67	*13.89*
Share workers in manufacturing	0.23	*0.11*	0.21	*0.09*	0.17	*0.07*	0.14	*0.07*
Share workers in professional services	0.19	*0.06*	0.21	*0.05*	0.24	*0.05*	n.a	*n.a*
Share workers in trade	0.21	*0.03*	0.21	*0.02*	0.22	*0.02*	0.16	*0.02*
Unemployment rate	0.04	*0.01*	0.06	*0.02*	0.06	*0.02*	0.06	*0.02*
Share of high school drop outs (age 25+)	0.46	*0.09*	0.32	*0.08*	0.24	*0.07*	0.18	*0.06*
Colleges per 1,000 people in 1940	0.02	*0.01*	0.02	*0.01*	0.02	*0.01*	0.02	*0.01*
Home value	16,022.64	*4,189.95*	47,255.97	*15,616.03*	79,504.72	*45,484.25*	115,785.20	*53,119.58*
Median family income	9,170.65	*1,480.34*	19,585.52	*2,807.46*	34,153.75	*6,101.29*	48,929.87	*8,360.88*

N=318

CITIES

	1970		**1980**		**1990**		**2000**	
	Mean	*Std. Dev.*	Mean	*Std. Dev.*	Mean	*Std. Dev.*	Mean	*Std. Dev.*
Log population- Log population at t-10	n.a	*n.a*	0.03	*0.19*	0.05	*0.14*	0.06	*0.13*
Share with Bachelor's degree (age 25+)	0.13	*0.08*	0.18	*0.10*	0.22	*0.12*	0.26	*0.14*
Population	118,794.40	*363,363.60*	119,624.10	*334,524.10*	127,120.60	*348,124.00*	138,225.50	*378,873.30*
Average heating degree days (1961-1990)	4,460.59	*2,123.92*	4,460.59	*2,123.92*	4,460.59	*2,123.92*	4,460.59	*2,123.92*
Average annual precipitation (1961-1990)	35.00	*12.80*	35.00	*12.80*	35.00	*12.80*	35.00	*12.80*
Share workers in manufacturing	0.26	*0.12*	0.23	*0.10*	0.17	*0.08*	0.14	*0.07*
Share workers in professional services	0.19	*0.07*	0.22	*0.07*	0.25	*0.07*	n.a	*n.a*
Share workers in trade	0.21	*0.04*	0.21	*0.03*	0.22	*0.03*	0.15	*0.02*
Unemployment rate	0.04	*0.02*	0.06	*0.03*	0.07	*0.03*	0.07	*0.03*
Share of high school drop outs (age 25+)	0.43	*0.13*	0.31	*0.12*	0.24	*0.10*	0.20	*0.10*
Colleges per 1,000 people in 1940	0.01	*0.01*	0.01	*0.01*	0.01	*0.01*	0.01	*0.01*
Home value	19,569.85	*7,008.13*	54,847.72	*26,139.47*	113,982.90	*81,750.05*	146,108.90	*103,341.80*
Median family income	10,529.60	*2,299.21*	20,964.24	*4,954.75*	37,382.61	*11,299.83*	50,909.85	*16,288.94*

N=723

Appendix Table 2

Further robustness tests

	Δlog(population)		
	(1)	**(2)**	**(3)**
Share with Bachelor's degree (age 25+) at t-10		**0.686**	**0.505**
		(0.134)***	(0.166)***
Log of population at t-10	-0.003	-0.019	-0.014
	-0.004	(0.004)***	(0.008)*
Log average heating degree days (1961-1990)	-0.078	-0.09	-0.123
	(0.011)***	(0.011)***	(0.013)***
Log average annual precipitation (1961-1990)	-0.02	-0.033	-0.056
	-0.015	(0.015)**	(0.016)***
Share workers in manufacturing at t-10	-0.31	-0.11	-0.349
	(0.086)***	-0.09	(0.103)***
Share workers in professional services at t-10	-0.433	-0.442	-0.299
	(0.196)**	(0.144)***	(0.185)
Share workers in trade at t-10	-0.187	-0.005	-0.428
	-0.237	-0.257	(0.302)
College enrollment/Population in 1970	**0.477**		
	(0.126)***		
Museums			0.000
			(0.001)
Eating and drinking establishments per capita			-1.316
			(18.143)
Motion picture establishments per capita			64.137
			(187.538)
Health establishments per capita			-9.404
			(16.920)
Membership organizations			0.000
			(0.000)
Amusement and recreational service establishments			0.000
			(0.000)
Teacher/pupil ratio			-0.504
			(0.298)*
Murders per 100 inhabitants			-3.822
			(1.064)***
Year fixed effects	yes	yes	yes
Lagged Age Distribution	no	yes	no
Observations	909	915	550
R-squared	0.51	0.6	0.57

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%