Do smart cities grow faster?

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Abstract

Previous studies have found a strong positive correlation between human capital, measured as the share of the adult population with a college degree, and population growth in metropolitan statistical areas (MSA) in the U.S. In this paper, I corroborate that the human capital-growth connection is indeed statistically significant, although much weaker than previously thought. The evidence suggests that the main reason behind this bias lies on endogeneity issues that have not been thoroughly addressed in the literature. In particular, omitting lagged MSA growth in regressions of current MSA growth on human capital overestimates the impact of skills by 100 per cent. Given that past growth has been shown to be one of the main drivers of current MSA growth (Glaeser 1994a), omitting the former variable in growth-education regressions would bias our human capital estimates upwards. Upon further examination, however, I show that MSA-specific fixed effects explain away the alleged impact of past on current growth. This suggests that the individual characteristics of the city that made it grew in the first place, and not lagged MSA growth *per se*, are what drives future MSA growth. Yet, even after accounting for these MSA-specific fixed effects, the impact of human capital on MSA growth does not disappear: my estimates suggest that a decadal increase of 10 per cent in the share of the adult population with a college degree translates into a rise of between 3 and up to 5 per cent in the MSA population growth rate during the same period. Finally, instrumental variable regressions strongly support the direction from skills to growth, abating potential reverse causality concerns.

Resumen

Estudios previos han encontrado una fuerte correlación positiva entre capital humano, medido como la proporción de la población adulta con un título universitario, y crecimiento poblacional en las zonas metropolitanas en Estados Unidos (MSA por sus siglas en inglés). En este artículo, corroboro que existe una asociación estadísticamente significativa entre el crecimiento y el capital humano, aunque posiblemente más débil que lo que se pensaba. La evidencia concluye que la principal razón detrás de este sesgo radica en problemas de endogeneidad que la literatura no ha tratado a fondo. En particular, la omisión del crecimiento urbano rezagado en regresiones de crecimiento urbano actual sobre capital humano sobreestima el coeficiente del capital humano en un 100 por ciento. Dado que se ha demostrado que la variable de crecimiento urbano rezagado es un determinante crucial de la tasa de crecimiento urbano actual (Glaeser 1994a), su omisión en este tipo de análisis econométricos produce un sesgo positivo en los estimadores de capital humano. Sin embargo, un análisis más a fondo demuestra que el impacto de crecimiento pasado sobre crecimiento futuro desaparece una vez que tomamos en cuenta efectos fijos específicos a las zonas metropolitanas o MSA. Ello sugiere que lo que causa el crecimiento urbano en el presente no es en sí el rezago en la tasa de crecimiento, sino las características individuales de la ciudad que la llevaron a expandirse en un principio. No obstante, aun tomando en cuenta los efectos fijos de MSA, el impacto del capital humano sobre el crecimiento poblacional urbano no desaparece: mis estimaciones sugieren que un incremento del 10 por ciento en diez años en la proporción de adultos con un diploma universitario se traduce en un aumento de entre un 3 y hasta un 5 por ciento en la tasa de crecimiento poblacional del MSA durante el mismo periodo. Finalmente, la implementación de un procedimiento de estimación por variables instrumentales corrobora la dirección de causalidad de capital humano a crecimiento, y no al contrario.

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1 Introduction

The positive relation between city growth and human capital accumulated in metropolitan areas is not new to the urban economics literature. Only in the past decade, numerous studies have corroborated the link between these two variables (Glaeser 1994b; Glaeser, Scheinkman, and Shleifer 1995; Nardinelli and Simon 1996; Simon 1998; Simon and Nardinelli 2002). These analyses differ not only in their methodology but, perhaps more importantly, in the definition of their two underlying concepts. For instance, while Glaeser, Scheinkman, and Shleifer (1995) focus on the influence of initial schooling on subsequent metropolitan income growth, Simon (1998) analyzes the effect of educational attainment on the rate of growth of city employment.

Yet, whether an increase in the proportion of city inhabitants with a high school or a bachelor's degree positively impacts the economy through income or employment, it is always accompanied by an increase in population (Glaeser and Saiz 2004). Metropolitan areas for which less than 10 per cent of their adult population held college degrees in 1980, saw an increase in their population of only 8 per cent between 1980 and 2000. In contrast, cities whose college-educated adult population exceeded 25 per cent attracted 35 per cent of new residents within the same period. Several authors document this positive correlation between human capital and population growth, as well as the latter's comovement with other city growth variables such as income or labor demand (Glaeser, Scheinkman, and Shleifer 1995; Nardinelli and Simon 1996; Shapiro 2006; Simon and Nardinelli 2002). Nonetheless, little work has been done to understand the causes that lie beneath this link and the direction of causality.

Thus, this paper seeks to contribute to the literature in two ways. First, I corroborate that the positive correlation between skills and growth is not spurious. In particular, I explore the role of trends in population growth rates and that of the age structure in the MSA. Previous studies have confirmed the importance of these elements in the determination of urban growth, so their omission in regressions investigating the effect of human capital on MSA growth may significantly bias the human capital estimates. The results show that, even after accounting for these factors, the positive association between human capital and population growth remains strong. However, the analysis also suggests that it is not past growth *per se* what drives current growth at the MSA level, but the characteristics inherent to the metropolitan area, which made it grew in the first place. Moreover, the age distribution does not seem to have a significant impact on MSA population growth.

Having confirmed the strong link between urban growth and human capital, I set out to verify whether the ascribed impact of skills on growth is real or, alternatively, whether reverse causality is an issue. At an intuitive level, it is possible that the human capital estimates reflect feedback effects from growth to skills. For instance, if faster MSA population growth rates bring about more competition in labor markets, this may create incentives for city inhabitants to educate themselves and become more competitive job candidates. Similarly, urban expansion implies a greater need for infrastructure, from roads and bridges to skyscrapers and shopping areas, which would attract more engineers, lawyers, accountants, and architects, thus raising the share of skilled labor in the area. Hence, to address this potential concern, I implement an instrumental variables approach. Reassuringly, the IV estimates confirm that the direction of causality is from skills to growth, as initially stated.

The discussion is organized as follows. In Section 2, I present some of the reasons why understanding the link between human capital and growth is important and discuss some of the previous work that has been done in this area. Section 3 develops a simple theoretical model that serves as the backbone of the empirical analyses that follow. Next, Section 4 introduces the data. In Section 5, I estimate the effect of human capital on population growth at the MSA level. This section introduces the empirical methodology, reviews the skills-growth estimates reported in the previous literature, and explores the impact of trends in growth rates, the age structure, and MSA-specific fixed effects on the human capital coefficients. Finally, Section 6 considers the issue of reverse causality and Section 7 concludes.

2 Motivation

What makes a city an attractive place to live? How can local governments entice investors to establish businesses downtown and attract more workers, increase tax collection, and improve their own ability to offer residents a better standard of living? How can dying cities get out of their downward spiral and revitalize their economies? From Detroit and Saint Louis to Manchester and Copenhagen, many cities have experienced long periods of decline, with population levels being halved sometimes in a matter of years. Understanding the factors that lie behind cities' booms and busts should help us find a satisfactory answer to these and other related questions.

According to Lucas (1988), the ability to absorb existing knowledge and create new knowledge is one of the main factors that spur economic growth. In his own words, "What can people be paying Manhattan or downtown Chicago rents for, if not for being near other people?" Glaeser (2003) seems to adhere to this thought with his Reinvention City theory. Following Schultz (1976), he suggests that cities that are able to adapt to new technological inventions, that are flexible in their production systems and are able to reinvent themselves, are the ones that survive and prosper over time. In his view, human capital predicts city growth because it facilitates the adaptation process. Glaeser's perspective is, in this sense, a law of the fittest, a Darwinian-like natural-selection story where the skilled survive and the less skilled become the weakest link. Thus, human capital enables workers and firms to move on and progress by reacting promptly to severe economic shocks whose effects may linger in other cities where unskilled citizens are unable to find alternative production methods.

In order to introduce some of the issues that may tarnish the ascribed effect of human capital on MSA growth, I begin my depicting the relationship between initial levels of human capital in 1970 and subsequent MSA population growth between 1970 and 2000. One issue to consider is whether MSA size may play a role in this relationship, for instance, if large, "smart" cities such as Boston or San Francisco have grown at faster rates over time, thus driving the results. I tackle this concern by using analytic weights according to the relative population levels of MSAs when estimating the line of best fit. The scatter plot in Figure 1 shows a positive association between the share of the adult population with a bachelor's degree living in the MSA in 1970 and urban growth in the following thirty years. The population weights are represented in the graph by the size of the circles, where larger circles represent more populated metropolitan areas. Although this visual check is of course no proof of a statistically significant connection between the two variables, it does seem as though the distribution of MSAs in the skills-growth plane does not depend on city size. A simple population-weighed least-squares regression of MSA growth between 1970 and 2000 on the share of bachelors in 1970 suggests that a city with an additional 4.2 per cent of bachelors in 1970 (equivalent to one standard deviation), will see its population grow by 7.6 per cent in the next three decades. This preliminary test suggests that city size is not a crucial factor in determining the relationship between human capital and MSA growth.

Figure 1 also suggests that college towns may potentially play a role in the correlation between initial human capital and subsequent growth. In particular, note that the majority of the "smartest" cities shown at the rightmost extreme of the regression line are MSAs such as College Station TX or State College PA. These are relatively small cities which concentrate a sizable population of skilled people (e.g., graduate students and professors) due to the presence of a large university. Should we expect these places to experience greater-than-average population growth *because* of the higher concentration of "smart" people? It is hard to say. On the one hand, it is likely that, upon graduation, students will look for jobs elsewhere, without contributing permanently to the expansion of their *alma mater*'s hometown. On the other hand, anecdotal evidence suggests that college towns' businesses and government offices, as well as universities themselves, have increasingly sought to retain their own graduates and offer them attractive job opportunities. The idea behind this is that, while it may be hard to entice outsiders to settle permanently in a small city, those familiar with the college town may find it enjoyable to stay in a place they already know well. Moreover, evidence suggests that companies' increasing reliance on cutting-edge technology has pushed them to invest more heavily in research and development, and settle around major universities in search for a steady supply of highly educated workers. In their 2006 Knowledge Worker Quotient survey, *Expansion Management*, a major business publication, compares all 362 MSAs for their ability to satisfy companies' technology needs and, perhaps surprisingly, lists Ithaca NY, Boulder CO, and Ann Arbor MI—all major college towns—as the top three Knowledge Worker metropolitan areas.[1] Finally, recent research shows that retirees have become more eager to settle in relatively small urban areas with good colleges that offer them the possibility to continue to learn and enrich their lives.[2] If true, this effect, together with the aging of the U.S. population, would further strengthen the skills-growth connection in college towns over time.

To ensure that college towns are not driving the results, I exclude them from the sample and repeat the analysis. In my selection of college towns, I follow Gumprecht's (2003) methodology, which defines a college town based on a number of indicators that gauge the college's influence on a town. These indicators attempt to distinguish areas where universities exert a clear dominance in the city's culture by asking questions such as, "Is the college the largest employer in town?" or "What is the enrollment of the college, compared with the population of the city?" Places whose socioeconomic diversity reduces the influence of a collegiate culture, such as Austin TX or Tempe AZ, remain in the sample. Excluding college towns, the graph depicting the relationship between the share of bachelors in 1970 and MSA population growth between 1970 and 2000 is not too different from what we observe in Figure 1. The association between the two variables becomes slightly stronger, a one-standard-deviation (4.2 per cent) increase in the level of human capital now having an impact of 8.3 per cent on subsequent growth. Hence, college towns do not seem to have a significant impact on the relationship between human capital and growth. Recall also that the units of analysis are MSAs, which often encompass several other areas beyond the college's town.[3] This

[1] See *http://www.expansionmanagement.com/smo/articleviewer/default.asp?cmd=articledetail&articleid=17277&st=5*.
[2] For instance, see *http://www2.ljworld.com/news/2007/sep/16/college_towns_lawrence_tout_continuing_education_c*.
[3] For instance, Bridgeport, Danbury, Stamford, and Waterbury CT are all covered under the New Haven MSA, home to our beloved Yale University.

would further dilute the potential "college-town" effect in the human capital-growth link. Thus, I conclude that these observations do not pose a problem to my empirical analysis.

As a last check, I made sure that other outliers are not driving this correlation. For instance, note that various MSAs, such as Naples FL, McAllen TX, or Steubenville OH, lie relatively far from the line of best fit. When I exclude these observations from the sample and redo the analysis, the general results do not change. Finally, I estimate the same relationship between initial schooling and subsequent growth for the periods 1980-2000 and 1990-2000 and ensure that these results do not hinge on the period choice. It is reassuring to observe that, if anything, the growth-skills connection seems to become stronger in these alternative periods.

3 Theoretical Framework

To formalize the connection between human capital and growth, in this section I present a model based on Roback (1982) and first introduced by Shapiro (2006). Consider an economy composed of various locations. Each location $i \in \{1,2,...,I\}$ is endowed with certain unique features that affect its productivity and its quality of life, denoted A_i and Q_i, respectively. Firms in each location produce a homogeneous good using a constant-returns-to-scale production function $Y = AF(L, R^f)$, where L denotes the quantity of labor and R^f the quantity of land used in production. This consumption good is then sold in world markets at the numeraire price of 1. Labor and land markets are competitive and their prices are given by W_i and P_i, respectively. Firms then face a constant per-unit marginal cost given by $C(W_i, P_i)/A_i$ which implies that, in equilibrium:

$$C(W_i, P_i) = A_i \quad \forall i \tag{1}$$

On the other hand, consumers' preferences are represented by a standard utility function $U = U(X, Q_i, R^c)$, where X stands for the amount of the consumption good enjoyed by the individual and R^c is the quantity of land consumed. In equilibrium, the implied indirect utility function must be constant across locations:

$$V(Q_i, W_i, P_i) = \overline{U} \quad \forall i \tag{2}$$

for some constant $\overline{U}$.

Now, assuming that A_i and Q_i change exogenously over time, we can totally differentiate the two equilibrium conditions (1) and (2) above to derive expressions for the changes in wages and land rents over time:

$$\frac{dp_i}{dt} = K_1 \frac{V_Q Q}{V_W W} \frac{dq_i}{dt} + K_2 \frac{da_i}{dt}, \tag{3}$$

$$\frac{dw_i}{dt} = K_3 \frac{da_i}{dt} - K_4 \frac{V_Q Q}{V_W W} \frac{dq_i}{dt}, \tag{4}$$

where small letters denote logs and the Ks are constants that depend on the share of land in the consumer's budget constraint and the shares of land and labor in the firm's cost function. Moreover, given the assumed supply curve of land, population (or employment) growth can be written as:

$$\frac{dl_i}{dt} = K_5 \frac{V_Q Q}{V_W W} \frac{dq_i}{dt} + K_6 \frac{da_i}{dt}, \tag{5}$$

where K_5 and K_6 are constants that also depend on the shares of land and labor in the consumer's and the firm's constraints as well as on the elasticity of land rents with respect to local population levels.[4]

The above conditions provide a framework for assessing how changes in productivity and amenities are associated with a particular correlate of population growth. Here, our variable of interest is the concentration of human capital in a given location, which I measure as the share of college-educated adults in an MSA. Following Shapiro (2006) we can assume that the two terms in parentheses in equation 5 depend individually on $H_{i,t}$, the concentration of human capital in location i at time t, other covariates denoted by $X_{i,t}$, and corresponding shocks drawn independently of H and X. This implies:

$$\Delta l_{i,t+1} = H_{i,t}\beta + X_{i,t}\gamma + \varepsilon_{i,t+1}, \tag{6}$$

where β and γ represent the effects of human capital and other city characteristics, respectively, on population growth. Using the framework provided above, these effects can be further decomposed into productivity growth and quality of life (or amenities) growth components. Of course, understanding what drives the correlation between human capital and population growth at the MSA level is important, but in order to do this we need to make sure that this relationship is not spurious. In particular, a positive association between $H_{i,t}$ and $\Delta l_{i,t+1}$ could arise if $H_{i,t}$ is correlated with an omitted component of $X_{i,t}$, which is also correlated with $\Delta l_{i,t+1}$. In this case, controlling for this omitted variable in the regression could potentially explain away the alleged link between human capital and population growth.

4 Data Sources

I obtained data for all available counties in the United States for the years 1970, 1980, 1990, and 2000. Then all variables were aggregated individually into *primary* MSAs (PMSAs) following the Census's 1999 county-based boundaries definitions. In the sample, there are 317 MSAs for each

[4] The exact functional form of these constants is irrelevant for our purposes. To see how these Ks depend on the various parameters, see Shapiro (2006).

decade, adding up to a total of 1,268 observations. Some descriptive statistics for the main variables used throughout this study are shown in Table 1.

All data come primarily from the Census's HUD State of the Cities Data System, with the exception of the two weather controls and the colleges per capita in 1940 variable. The weather controls are available for the years 1961-1990 from the County and City Data Books 1994. The colleges per capita in 1940 variable, on the other hand, comes from the Peterson's College Guide.[5]

5 The Growth-Human Capital Connection

This section evinces the connection between population growth and human capital. The empirical analysis draws from Glaeser and Saiz (2004). I first present the raw correlation between the two variables, always accounting for decadal fixed effects. Then I show that this coefficient does not change even after considering other controls that the literature has shown to affect population growth rates. These include, among other things, MSA population levels, weather variables, and labor market shares by industrial sectors. Next, I argue that omitted variables, such as trends in population growth and the age composition of the MSA, may potentially tarnish the human capital estimates. The results show that, although the effects of skills on MSA growth are somewhat smaller relative to what the literature has found, they remain strongly positive and significant.

The basic regressions are based on equation 6 and take the following form:

$$\Delta l_{i,t+1} = H_{i,t}\beta + X_{i,t}\gamma + \tau_t + \varepsilon_{i,t+1}, \tag{7}$$

where $\Delta l_{i,t+1}$ denotes the decadal population growth in location i, $H_{i,t}$ refers to its share of college-educated adults over 25 years of age, $X_{i,t}$ is a set of other controls such as weather and industry shares, and τ_t is a decade-specific fixed effect with $t = \{1980, 1990, 2000\}$. The error term $\varepsilon_{i,t+1}$ is allowed to be correlated within MSAs across decades.

The first set of results is shown in Table 2. Column (1) reports the raw impact of skills on growth, conditioning only on decadal fixed effects. This raw estimate suggests that an increase of 10 per cent in the proportion of college-educated adults in the initial year translates into a subsequent rise of 5 per cent in population growth during the next ten years. This estimate is strongly significant and corroborates the relationship portrayed in Figure 1.

In the next few columns, I add a number of controls that the literature has traditionally considered when estimating the impact of human capital on MSA growth. As discussed in Section 2, city size remains a natural control, so I introduce the log of population in the initial year as an explanatory variable. Warm and dry weather have been shown to be two crucial predictors of

[5] The colleges per capita in 1940 data were provided by Glaeser and Saiz. Colleges' foundation dates, as provided by Peterson's, were used to ensure that a college existed prior to 1940. Existing colleges' zip codes were matched with their respective counties, and then counties were matched to the corresponding MSA using 1999 MSA/NECMA definitions. Utilizing the Department of Education IPEDS data set for 1969-1999, Glaeser and Saiz (2004) confirm that attrition bias is not an issue: colleges do not seem to disappear from the IPEDS sample at a faster rate in stagnating metropolitan areas.

population growth (Glaeser, Kolko, and Saiz 2001; Glaeser and Shapiro 2003), so I include, correspondingly, the log of average heating degree days—the number of days that a household uses artificial heating to keep it warm—and the log of average annual precipitation. Additionally, I include the initial shares of workers in the manufacturing, professional services, and trade sectors. Such controls seem reasonable given certain well-known trends in the period of study, such as the decline of manufacturing cities in the 70s and 80s, particularly in the Rust Belt, and the ascent of the financial services, health care, and information industries. Glaeser and Saiz (2004) justify the use of these variables given that the three sectors combined consistently represent almost two thirds of employment within MSAs every decade. However, as suggested by Faberman (2005), regional variation in industry mix cannot fully explain the observed differences in growth across metropolitan areas, so it is unclear what we should expect regarding the direction of these estimates. Finally, the inclusion of region, state, and MSA fixed effects attempts to control for geographic factors that are invariant over time but which may be of significance in explaining the different rates of population growth across the country.[6]

As the results in Columns (2)-(4) show, the inclusion of these controls does not have a major impact on the human capital estimates. Comparing the coefficients across specifications, we observe that they all remain strongly significant and a generalized Hausman test corroborates that they are not statistically different from each other. On the other hand, the negative estimate of lagged city size suggests that an increase in the initial population level of the MSA is associated with a decrease in the population growth rate the following decade, which highlights the characteristic mean reversion of growth. Also, the negative and highly significant coefficients of the log average heating degree days and the log average annual precipitation reflect people's preferences to settle in warm, dry areas. Finally, in agreement with Faberman (2005), the industry shares have a rather imperceptible bear on the human capital estimate.

Up to this point, the relationship between skills and MSA growth seems to be quite robust. Glaeser and Saiz (2004) consider two alternative overall measures of human capital to ensure that these results do not depend crucially on the choice of the share of bachelors as the preferred measure of skills. First, they include the share of adult high school dropouts and the unemployment rate in the initial year as additional controls in order to capture the lower tail of the human capital distribution. Thinking ahead, we expect the coefficients of these two additional regressors to be negative, implying that a greater number of high school dropouts and a greater unemployment rate would force individuals to move out of the city and seek employment opportunities elsewhere. As shown in Column (5) of Table 2, these estimates validate our expectations, although the high school dropouts coefficient is statistically insignificant.[7] Nonetheless, it is interesting to note that the negative effect of the initial unemployment rate on growth is significant only when regional fixed effects are considered, which is the specification that Glaeser and Saiz (2004) present. Accounting for MSA fixed effects instead, however, the statistical evidence supporting this negative correlation disappears. As will be argued later, the former specification should be preferred given that both observable and unobservable time-invariant factors at the MSA level seem more relevant to local labor markets and migration patterns. Thus, neither of the additional regressors considered seems to

[6] The four regions are Northeast, Midwest, South, and West, and are defined according to the U.S. Census Bureau. See Census Regions and Divisions map at *http://www.census.gov/geo/www/us_regdiv.pdf* for further details.

[7] One interesting observation is that this estimate is negative and significant when excluding the share of bachelors, which reflects the strong multicollinearity between the two complementary human capital measures. The correlation between the share of bachelors and the share of high school dropouts in every decade is between -0.70 and -0.80.

have any significant impact on MSA growth. Moreover, the magnitude of the share of bachelors coefficient remains unchanged, which is hardly suprising given the statistical irrelevance of the two additional controls.

The second alternative measure of human capital considered is the number of colleges in 1940. Glaeser and Saiz (2004) justify this specification by arguing that this surrogate metric has the advantage of being predetermined and not a function of recent events, which might draw the skilled to the city. Moretti (2004) shows that these two human capital measures are positively correlated and this relationship becomes apparent in Figure 2. However, one may wonder how it is that the number of colleges in 1940 is even connected with MSA population growth rates 60 years later. The absence of a clear association between these two variables becomes evident in a regression of MSA population growth on the log of colleges in 1940. The estimated skills coefficient shown in Column (6) of Table 2 implies that even by doubling the number of colleges that existed in the MSA back in 1940, equivalent to about five additional colleges for the average metro area, the decadal population growth rate 50 years later would only rise by a mere 3.5 per cent. More importantly, it is hard to see what mechanism, other than an increase in the proportion of "skilled" residents, could be responsible for such an effect on population growth rates. Hence, if we believe that the number of colleges in 1940 has no bearing on the rate of growth of population, and given the seemingly strong correlation between the former variable and the share of bachelors, perhaps a better approach would be to use the log of colleges in 1940 as an instrument for education in our reverse causality tests. This possibility is thus explored in Section 6.

5.1 Trends in Population Growth

The regressions considered above suggest that human capital together with other explanatory variables can only explain about 50 per cent of the variation in population growth rates at the metropolitan level. One obvious question to ask is, what might explain the remaining 50 per cent of this variation? More importantly, and given that our focus is on the effect of human capital on MSA growth, the issue at hand is whether any omitted variables that may have a significant effect on population growth rates could explain away the impact of skills that has proved so robust up to now.

One possible variable that may influence our skills estimates is the presence of trends in population growth rates. For instance, Glaeser (1994a) claims that the best predictor of whether a city will grow in the following 20 years is whether it grew the previous 20 years. This finding is consistent with Krugman (1991) and Lucas (1988), who suggest that the mere presence of other people in a city is one of its main attractions. In order to capture the persistence of population growth, I expand equation (7) as follows:

$$\Delta l_{i,t+1} = H_{i,t}\beta + \Delta l_{i,t}\xi + X_{i,t}\gamma + \tau_t + \varepsilon_{i,t+1}, \qquad (8)$$

where the coefficient ξ in the second term measures the effect of last decade's growth rate on current decadal MSA growth.[8] This term is precisely what I refer to (admittedly, somewhat imprecisely) as "population growth trend," and its omission from the regressions in Table 2 would

[8] Note that Glaeser (1994a) defines growth rates over a 20-year span, while I define these same population growth rates over a decade. In the empirical estimations, this distinction proves inconsequential.

bias the skills coefficient upwards if we believe that the two are positively correlated. Of course, such relationship would stir up even further possible concerns about simultaneity or reverse causality. For now, I leave these issues aside since I address them in Section 6.

Panel A in Figure 3 depicts the positive relationship between current and lagged population growth rates at 10-year intervals. A simple regression between just these two variables shows that an increase of 10 per cent in MSA population growth last decade would translate into a rise of 6 per cent in the same variable during the current decade. Such regression also shows that past 10-year growth explains almost 50 per cent of the variation in current 10-year growth at the metropolitan area level. As suggested by Panel B in the same figure, this relationship becomes even stronger when considering 20-year rates, which supports the view of persistence in population growth rates over time. Can the lagged rate of growth explain the remainder of the variation in current growth that skills, weather, and the MSA industry composition were unable to explain?

As the results in Table 3 suggest, it cannot. Column (2) shows that the coefficient of variation of a specification that includes the full set of controls, regional fixed effects, and lagged population growth, is only 58 per cent. This number is only 7 percentage points higher relative to the adjusted R^2 of a specification with the exact same covariates but excluding our lagged growth variable. Note that the estimates suggest a strong positive relationship between past and current growth, a result that is consistent with the literature. Nonetheless, trends in growth are seemingly unable to explain the variation in current MSA population growth once we account for human capital, weather, and the industry composition of the metropolitan area.

Going back to our main issue of interest, we now examine the stability of the skills coefficient after controlling for lagged growth. As is inferred from the comparison between Columns (1) and (2), the mere inclusion of past MSA growth in our typical regression with the full set of controls and regional fixed effects reduces the impact of human capital on MSA population growth by 50 per cent, which implies that the earlier estimates reported in the literature may have significantly overestimated this effect. To be sure, in Columns (3) and (4) I isolate the individual effects of skills and lagged growth on current growth, respectively, and then consider them jointly in Column (5). Observe that when skills are added to the specification that includes only lagged growth, the magnitude of the lagged growth coefficient barely changes. In contrast, the inclusion of the past growth variable in the specification that contains the share of bachelors as the sole regressor leads to a reduction of 75 per cent in the latter coefficient and a considerable loss in its statistical significance. Moreover, while lagged growth alone explains about 56 per cent of the variation in current MSA growth rates, we observe no change at all in the coefficient of determination when skills are added in Column (5). These signs are a clear indication of omitted variable bias and, given Glaeser's (1994a) strong advocacy in favor of the "persistence of growth," it is surprising that his growth-skills regressions do not take into account this effect.

Now, given that the inclusion of lagged growth seems to explain away a considerable portion of the effect of human capital on MSA growth, we may wonder, how is it that the rates of population growth 20 years ago can explain current growth rates? An explanation by Glaeser (1994a) is that there are good and bad cities, and good cities just keep growing, while bad cities keep declining. Of course, this seems to suggest that slumping cities would eventually vanish, while flourishing agglomerations would experience explosive growth. This logic seems hard to believe. Even Glaeser's own result of mean reversion in population levels by itself hints to the notion of a "stationary" state or, at least, to the Malthusian idea of positive checks that keep cities from growing indefinitely. However, it would be plausible to think that there are other factors inherent to each individual metropolitan area, and that these may play an important role in both past and current growth.

To account for these city-specific factors, I run the same basic regression of MSA population growth on the full set of controls and MSA-specific fixed effects. These results are shown in Column (6) of Table 3. In contrast to the finding of persistent population growth observed in the specifications above with region- and state-specific fixed effects, when MSA fixed effects are considered, the impact of lagged population growth on current growth rates is *negative* and strongly significant. Notice also that the inclusion of MSA fixed effects brings about a much stronger regression to the mean relative to the region fixed effects specification. The implication of this result is that, once we capture the effect of unmeasured locational attributes that individually affect population growth rates at the metropolitan area level, the positive impact of growth on growth vanishes. That is, cities do not keep growing forever *because* they experienced positive population growth rates 10 or 20 years ago. Rather, it seems as though any inherent city-specific characteristics, such as geographic features or particular policies and laws issued at the local level, which favored MSA growth 10 or 20 years ago, will also encourage growth for the next 10 or 20 years. It is worth mentioning that most of these coefficients, although not shown in Table 3, are significant at the 1 per cent level. To support the appropriateness of the inclusion of city-specific dummies, I performed likelihood ratio and goodness-of-fitness tests, and they all backed up this specification.[9] Finally, observe that while accounting for trends in MSA population growth reduced the impact of human capital on current growth by 50 per cent, considering fixed effects at the MSA level brings back the estimated skills coefficient closer to its original level.

5.2 Impact of the Age Structure

One additional consideration that deserves more attention in establishing the skills-growth connection is that the share of the population with a college degree might be closely related to the proportion of the population that is young. Just like in the case of lagged growth, if we believe that younger cohorts may be better educated and, at the same time, be a substantial driver of population growth, omitting the age structure of the MSA in our specifications would contaminate our skills estimates.

I account for the MSA age structure as follows. First, I calculate the shares of the total population in the metropolitan area within 5-year intervals: those less than 5 years old, those between 5 and 9 years old, and so on. People who are 85 years of age and over are excluded from the regression since they never account for more than 1.5 per cent of the population within a decade. I then include these age bins directly in my regressions of MSA growth on the share of bachelors, lagged growth, and the full set of controls considered earlier. As the results in Table 4 show, accounting for the age distribution in this manner actually strengthens the link between skills and growth, even in the presence of lagged growth and MSA fixed effects. Could this be due to the way in which I control for the MSA age structure?

[9] The likelihood ratio test yields a χ^2 statistic of 1210.04, which strongly rejects the no-MSA-fixed-effects specification. Moreover, the Akaike Information Criterion also supports the model with MSA fixed effects, yielding a statistic of -2614.3 for this specification vs. -2008.3 for the alternative.

To corroborate that the chosen methodology is not driving the results, I explore alternative ways to account for the age structure in the metropolitan area. After all, although breaking down the population age range into 5-year bins may provide a better snapshot of the age distribution in the MSA, we should expect a significant reduction in the degrees of freedom caused by the extra 17 regressors. To address this issue, I first used wider age windows, which did not change the general results described above. Next, I considered larger groups such as "the share of the population that is young," or "the share of the population that is in the active labor force," using different age cutoffs. Finally, I also allowed for education-age interactions that would allow me to separate out the effects of skills on growth by age category. Surprisingly, neither of these approaches showed any significant impact of the MSA age structure on population growth, just as they were unable to wipe away the effect of human capital on growth.

Of course, it is possible that the MSA age structure affects urban growth non-linearly. A partially linear regression allows for a more flexible specification that may combine both parametric and non-parametric components to determine how the age structure is being affected. Consider the following semi-parametric model:

$$Y_i = X_i^T \beta + g(Z_i) + \varepsilon_i \tag{9}$$

where $X_i = (x_{i1}, x_{i2}, ... x_{ip})^T$ and $Z_i = (z_{i1}, z_{i2}, ..., z_{id})$ are vectors of explanatory variables, (X_i, Z_i). β, of course, is a vector of unknown parameters, g is a function from R^d to R^1, and $\varepsilon_1, ..., \varepsilon_n$ are independent errors with mean zero and finite variances $\sigma_i^2 = E\varepsilon_i^2$. The main assumptions behind the concept of partially linear estimation are that g is a smooth, single-valued function with a bounded first derivative, and that the model's parametric $(X_i^T \beta)$ and non-parametric $(g(Z_i))$ components are additively separable.

The partially linear regression model I estimate is shown in Column (PL) of Table 4 and follows my preferred specification including the share of bachelors, lagged growth, MSA fixed effects, and the full set of controls. The additional *Z* regressor I consider is the average age of the population. As before, controlling for the age structure does not impact our previous findings. Moreover, in all specifications, the age structure coefficients are statistically insignificant. These findings are also robust to other choices for *Z*, such as the share of young people in the MSA, the proportion of working-age individuals, and the share of "qualified" (with bachelors degree or above) working-age individuals. Hence, I conclude that the age structure is not a major driver of population growth at the MSA level and, consequently, that the effect of human capital on MSA population growth is not tarnished by the omission of the age structure in the city.

6 Reverse Causality

The assumption throughout the preceding analysis has been that people are attracted to locations that concentrate higher shares of smart individuals. This could be rationalized if migrants feel that the more educated would make them more productive or if we believe that more skilled residents promote growth in amenities and consumer services, which in turn makes metropolitan areas more attractive places to live. However, the direction of causality might go the other way. For instance, an increasing population may bring about more competition for job opportunities, creating incentives for individuals within the MSA to educate themselves, get access to better work possibilities, and increase their income prospects. City growth may also translate into a greater need for roads, bridges, skyscrapers, and shopping areas, which would motivate engineers, lawyers, accountants, and architects from outside to move into expanding metro areas.

In what follows, I utilize an instrumental variables approach that supports the causal relationship from human capital to MSA population growth. Such methodology should abate concerns about omitted variables and, especially, reverse causation. The variable I use to instrument for human capital is land-grant institutions in an MSA, which goes back to Moretti (2004). This is a dummy variable that indicates whether a metropolitan area contains a land-grant institution, an entity assigned by the federal Morrill Act of 1862 that had in charge the funding and creation of colleges and institutions of higher studies. The correlation coefficient between the presence of land-grant institutions and the share of bachelors is about 45 per cent. On the other hand, the correlation of this instrumental variable with MSA growth is only about 10 per cent, which, interpreted with the first correlation, already suggests that land-grant institutions may be a good instrument for human capital. Moreover, Moretti reports that the distribution of land-grant institutions across the United States is quite even and that the demographic characteristics of MSAs with and without a land-grant school are quite similar, which rules out other potential concerns about the validity of this instrument.

The IV estimates support the direction of causality from human capital to MSA growth. These results appear in Table 5. The first-stage regression of the IV estimation suggests a strong positive correlation between land-grant institutions and human capital as proxied by the share of bachelors in the MSA. In the second-stage regression, the IV estimate of 0.556 is statistically significant at the 5 per cent level. This implies that an exogenous variation in human capital at the MSA level does have a strong and significant effect on population growth. Most importantly, I perform a simple Hausman test to compare the magnitudes of the IV and the OLS estimates presented earlier and confirm that both coefficients are not statistically different from each other.

One last recourse to which we can resort to validate our previous findings is to use the log of colleges in 1940 as an additional instrumental variable. As discussed in Section 5, Glaeser and Saiz (2004) utilize this variable as an alternative measure of human capital to make sure that the positive association they find between MSA growth and human capital does not hinge on the use of the share of bachelors as their proxy for skills. Nonetheless, the authors do not elucidate the link between the number of colleges in a particular metropolitan area in 1940 and its population growth rate 50 or 60 years later. The lack of a clear relationship between these two variables and the strong association between the number of colleges in 1940 and the future share of bachelors in the MSA documented by Moretti (2004), suggest that the former may be a good candidate to proxy for skills in our MSA growth regressions.

Once again, when I use this variable and the land-grant institution dummy as instruments for the share of bachelors, the results support the causal effect that an exogenous increase in the proportion of skilled residents in an MSA has on population growth. Moreover, an overidentification test confirms that the two instruments are indeed uncorrelated with the error term and that the exclusion restriction holds. Note, however, that the estimated IV coefficients are slightly larger than our least-squares estimates. This minor discrepancy is most likely due to the fact that MSA fixed effects are not considered in our 2SLS regressions since our instruments do not allow us to distinguish between variations in levels of human capital across decades. In other words, the number of colleges in 1940 and the presence of a land-grant institution do not differ for different years within an MSA, which leads to a significant reduction in sample size. Yet, the results are robust to the inclusion of regional and state fixed effects, which implies that the advocated causal link from skills to growth is preserved.

7 Conclusions

The empirical evidence in this paper is supportive of other studies that find a positive association between human capital, defined as the share of the population over 25 years old holding a bachelor's degree, and MSA population growth. However, one factor that seems to be relevant in estimating the impact of skills on growth and which has been overlooked by the previous literature is the existence of trends in population growth rates at the MSA level. The omission of lagged metropolitan growth seems to overestimate the human capital effect by up to a factor of two. This effect is strongly robust across various specifications, a finding that is in line with Glaeser (1994a).

Upon further examination, however, we observe that it is not past growth itself what drives future growth. Instead, it seems as though those characteristics of the city, both observable and unobservable, which made it grew in the first place are what determines the rate of expansion of the metro area. Controlling for MSA-specific fixed effects, the impact of lagged on current growth remains strongly significant but is reversed, which is consistent with a more plausible story, if not of a steady-state level of population, of non-explosive growth. The results thus suggest that growth does not draw on growth, but on geographical, topographical, cultural, or other features inherent to the MSA and which have historically influenced its population growth.

Hence, the growth-human capital connection appears to be real. Depending on the specification, the estimated impact of skills on MSA growth can be up to 50 per cent smaller than the earlier estimates suggested. Nonetheless, not only does the positive association between the two variables survive the inclusion of MSA fixed effects and lagged growth, as described earlier. It also stands even after controlling for the age structure of the MSA, which is strongly correlated with the proportion of skilled residents in the metro area. Moreover, the IV estimates corroborate that the direction of causality is indeed from skills to growth.

Having admitted the overwhelming evidence that has given place to what Glaeser and Saiz (2004) call "the rise of the skilled city," we wonder what mechanisms lie behind the growth-skills connection. One obvious question that arises is, what has driven people to crowd around locations in which the better educated, more skilled individuals reside? Glaeser and Saiz (2004) and Shapiro (2006) shed some light on the nature of this relation, although their results are somewhat contradictory. On the one hand, the former suggest that productivity seems to be the key to understanding the growth-human capital connection at the MSA level. Recurring to Schultz's (1976) reinvention hypothesis, the authors explain how skilled workers react faster to severe economic shocks and are able to switch techniques that may show the way out of the crisis. These more innovative metropolitan areas are consequently more productive and more attractive for those who are actually able to perform the new jobs and adapt to the new circumstances—the skilled. Shapiro, on the other hand, places more emphasis on consumer amenities and quality of life and asserts that these factors are responsible for about 40 per cent of the effects of skills on growth.

This apparent dichotomy provides an area of opportunity for future research. To begin with, the definitions of growth used by Glaeser and Saiz (2004) and by Shapiro (2006), although closely related, are different. It would be easy to extend Shapiro's model to use MSA population growth instead of growth in employment, and use similar MSA definitions. Furthermore, if metropolitan areas with high human capital are better able to reinvent themselves and switch out of declining industries, then we should be able to make a connection between skills and productivity measures in different sectors of the economy. By looking at the empirical relationship between alternative productivity measures, such as gross metropolitan product, earnings, or income in per-employee terms, and different human capital measures, we might be able to better gauge the importance of productivity to the growth-human capital connection. Moreover, Schultz's (1976) reinvention hypothesis, originally imputed to technological improvements in agriculture, could be applied at the MSA level. For instance, we could examine how high- and low-skilled locations react to various aggregate negative shocks. Finally, since the ultimate effect of increased aggregate human capital is on population growth, understanding how migration, fertility, and other drivers of population growth are affected seems like a goal worth pursuing. Most importantly, these extensions need not apply exclusively to cities in the United States. Carrying out similar analyses in other countries would help us better understand the impact of greater human capital on growth and other socioeconomic variables. In particular, developing nations such as Mexico, which have yet much to do to improve their overall levels of human capital, would benefit the most from understanding how a significant increase in the proportion of skilled workers would impact their economies.

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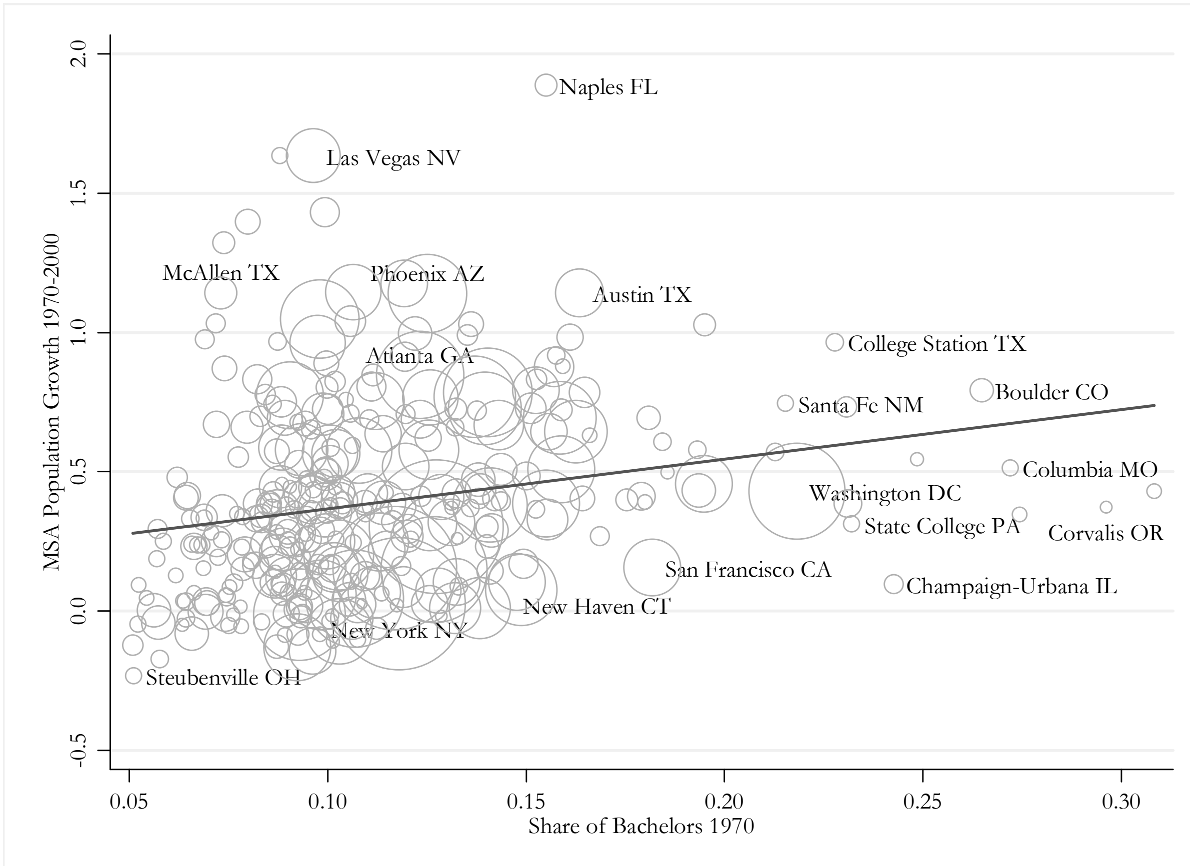


Figure 1. Initial Levels of Human Capital (1970) vs. Subsequent MSA Population Growth (1970-2000)

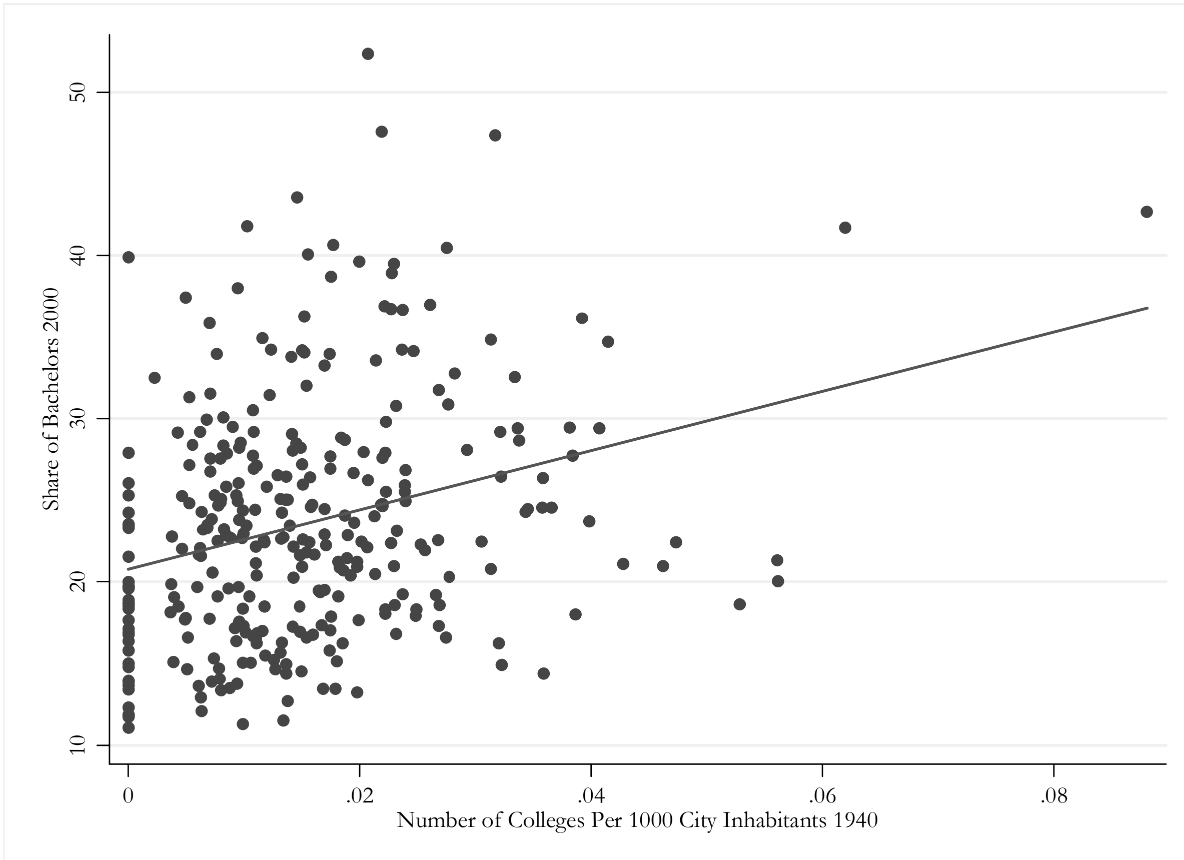
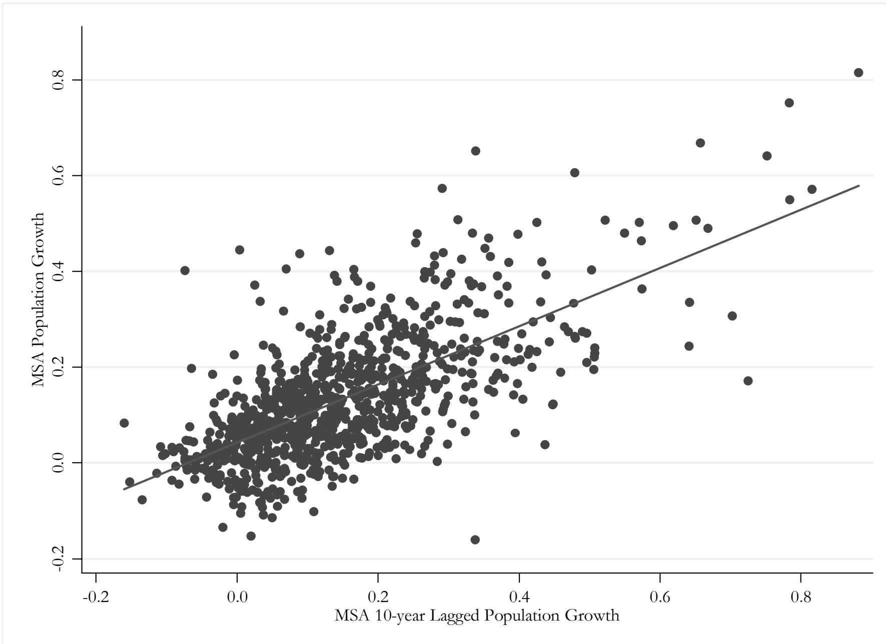
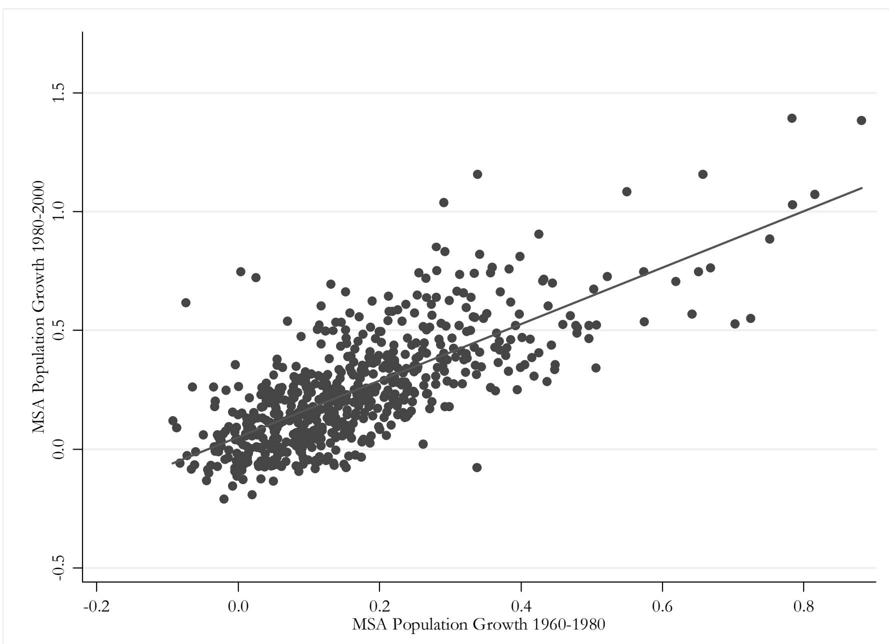


Figure 2. Number of Colleges Per Capita 1940 vs. Share of Bachelors 2000



Panel A



Panel B

Figure 3. Current vs. Lagged MSA Population Growth Rates
(A) Using 10-year Growth Rates
(B) Using 20-year Growth Rates

Table 1. Descriptive Statistics

N = 317 per decade	1970		1980		1990		2000	
Variable	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*
Population % change	n.a.	n.a.	0.16	0.15	0.10	0.13	0.12	0.10
Share with bachelor's degree	0.11	0.04	0.16	0.05	0.20	0.06	0.24	0.07
Population (in thousands)	504.97	970.71	560.10	980.43	625.90	1070.00	712.89	1200.00
Average heating degree days (1961-1990)	4443.77	2189.81	4443.77	2189.81	4443.77	2189.81	4443.77	2189.81
Average annual precipitation (1961-1990)	36.73	13.87	36.73	13.87	36.73	13.87	36.73	13.87
Share workers in manufacturing	0.23	0.11	0.21	0.09	0.17	0.07	0.14	0.07
Share workers in prof. services	0.19	0.06	0.21	0.05	0.24	0.05	0.24	0.05
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 dropouts	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

	Total	
Variable	*Mean*	*Std. Dev.*
Population % change	0.13	0.13
Share with bachelor's degree	0.18	0.07
Population (in thousands)	600.96	1,060.00
Average heating degree days (1961-1990)	4,443.77	2,187.12
Average annual precipitation (1961-1990)	36.73	13.85
Share workers in manufacturing	0.19	0.10
Share workers in prof. services	0.22	0.06
Share workers in trade	0.20	0.03
Unemployment rate	0.06	0.02
Share of high school dropouts	0.30	0.13
Colleges per 1,000 people in 1940	0.02	0.01

Table 2. MSA Growth and Human Capital Regressions

	Δlog(population)					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Share of population over 25 with bachelor's degree at *t-10*	**0.496**	**0.586**	**0.464**	**0.501**	**0.408**	
	[0.099]***	[0.113]***	[0.117]***	[0.215]**	[0.152]***	
Log of population at *t-10*		-0.015	-0.012	-0.314	-0.014	0.003
		[0.004]***	[0.005]**	[0.030]***	[0.004]***	[0.005]
Log of average heating degree days (1961-1990)		-0.082	-0.075		-0.084	-0.070
		[0.011]***	[0.020]***		[0.011]***	[0.011]***
Log of average annual precipitation (1961-1990)		-0.026	-0.001		-0.025	-0.023
		[0.015]*	[0.015]		[0.016]	[0.015]
Share of workers in manufacturing at *t-10*		-0.171	-0.166	0.271	-0.161	-0.172
		[0.088]*	[0.073]**	[0.126]**	[0.085]*	[0.084]**
Share of workers in professional services at *t-10*		-0.333	-0.174	0.136	-0.233	0.083
		[0.145]**	[0.132]	[0.202]	[0.143]	[0.117]
Share of workers in trade at *t-10*		0.035	0.117	0.213	0.011	-0.132
		[0.260]	[0.215]	[0.281]	[0.279]	[0.220]
Unemployment rate at *t-10*					**-0.487**	
					[0.234]**	
Share of population over 25 that dropped high school at *t-10*					**-0.054**	
					[0.089]	
Log of colleges per capita in 1940						**0.035**
						[0.008]***
Fixed Effects						
Decade	Yes	Yes	Yes	Yes	Yes	Yes
Region	No	Yes	No	No	Yes	Yes
State	No	No	Yes	No	No	No
MSA	No	No	No	Yes	No	No
Observations	951	915	915	951	915	813
R-squared	0.55	0.51	0.61	0.89	0.51	0.51

Robust standard errors in parentheses.

Asterisks show significant coefficients at: 10% (*), 5% (**), and 1% (***).

Table 3. Impact of Lagged MSA Population Growth and MSA Fixed Effects on Human Capital Estimates

	Δlog(population)					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Share of bachelors at *t-10*	0.586	0.288		0.399	0.096	0.451
	[0.113]***	[0.087]***		[0.088]***	[0.053]*	[0.225]**
Decadal population growth rate at *t-10*		0.334	0.513		0.503	-0.140
		[0.041]***	[0.040]***		[0.043]***	[0.046]***
Log of population at *t-10*	-0.015	-0.011				-0.288
	[0.004]***	[0.003]***				[0.033]***
Fixed Effects						
Decade	Yes	Yes	Yes	Yes	Yes	Yes
Region	Yes	Yes	Yes	Yes	Yes	No
MSA	No	No	No	No	No	Yes
Observations	915	914	950	951	950	950
R-squared	0.51	0.58	0.56	0.34	0.56	0.90

Except for regressions in columns (3) through (5), all specifications include weather and industry controls.
Robust standard errors in parentheses.
Asterisks show significant coefficients at: 10% (*), 5% (**), and 1% (***).

Table 4. Impact of the Age Distribution on the Effect of Human Capital on MSA Population Growth

	Δlog(population)	
	(1)	**(PL)**
Share of bachelors at *t-10*	0.684	0.310
	[0.230]***	[0.128]**
Decadal population growth rate at *t-10*	-0.020	-0.165
	[0.054]	[0.024]***
Log of population at *t-10*	-0.253	-0.327
	[0.035]***	[0.018]***
Fixed Effects		
Decade	Yes	Yes
MSA	Yes	Yes
Observations	950	949
R-squared	0.91	0.92

Regression (1) displays OLS estimates and accounts for the age distribution using 5-year age group bins.
Column (PL) shows results from a partially-linear regression that accounts for non-linear age effects.
All specifications include industry controls. Robust standard errors in parentheses.
Asterisks show significant coefficients at: 10% (*), 5% (**), and 1% (***).

Table 5. OLS vs. Instrumental Variable Regressions

	Dependent Variable: MSA Population Growth 1990-2000		
Second-stage:	**OLS**	**IV 1**	**IV 2**
Share of bachelors in 1990	0.367	0.556	0.833
	[0.082]***	[0.214]***	[0.230]***
First-stage:		**Instrumenting for: Share of bachelors in 1990**	
Land-grant institution		0.079	0.073
		[0.011]***	[0.011]***
Log of colleges in 1940			0.015
			[0.006]***
Observations	317	250	224
F-statistic	20.26	52.53	12.97
Hansen J-stat			5.54
P-value			0.018

Robust standard errors in parentheses.
Asterisks show significant coefficients at: 10% (*), 5% (**), and 1% (***).