What makes cities bigger and richer? New Evidence from 1990–2000 in the US

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Abstract: This paper analyses the determinants of growth of American cities, understood as growth of the population or of per capita income, from 1990 to 2000. This empirical analysis uses data from all cities with more than 25,000 inhabitants in the year 2000 (1154 cities). The results show that while a common convergence behaviour is observed in both population and per capita income growth, there are differences in the evolution of the distributions: population distribution remains almost unchanged, while per capita income distribution makes a great movement to the right. We propose two hypotheses related with the influence of service activities and geography on urban growth, and test them with different empirical methods: linear models and Multinomial Logit Models.

Keywords: City growth, Multinomial logit.

JEL: R00, R11, R12.

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1. Introduction

Jacobs (1969) was the first to suggest that cities are the basic economic units of each country when she stated 'cities are also primary economic organs'. Later, other writers would argue in the same way[1] (Duranton, 2000; Quigley, 1998; Fujita and Thisse, 2002). And indeed, some very special characteristics coincide in the city as an economic unit. First, among cities there is complete freedom of movement in labour and capital (they are completely open economies). Also, it is in cities that knowledge spillovers are most easily generated and transmitted, as documented both at the theoretical level (Loury, 1979; Garicano and Rossi-Hansberg, 2006) and empirical level (Glaeser et al., 1992; Henderson et al., 1995). Finally, the New Economic Geography adds that cities are a source of agglomeration economies (Duranton and Puga, 2004).

The starting point for this work is the idea that the city has a double nature, on the one hand as a population centre and on the other as an engine of economic growth, and that the different external effects generated in cities can potentially have different effects on population growth and per capita income growth. In particular, this paper analyses the determinants of growth of American cities, understood as growth of the population or per capita income, from 1990 to 2000.

The American case has already been dealt with in earlier literature, using different econometric techniques and considering different periods and sample sizes. The two most direct precedents are Glaeser et al. (1995) and Glaeser and Shapiro (2003).

Glaeser et al. (1995) examine the urban growth patterns in the 200 most populous cities in the US between 1960 and 1990 in relation to various urban characteristics in 1960. They show income and population growths are positively related to initial schooling, negatively related to initial unemployment, and negatively related to the initial share of employment in manufacturing. Glaeser and Shapiro (2003), using a slightly larger sample size (they imposed a minimum population threshold of 25,000 inhabitants, considering the 1,000 most populous cities), conclude that this behaviour would have continued during the decade 1990–2000. During this decade the three most relevant variables would be human capital, climate and individuals' transport systems (public or private). Our aim is to introduce and test two new hypotheses about urban growth in this period.

Hypothesis 1. Employment in services has greater influence on urban growth than that of other sectors (especially manufacturing).

This would be especially true for the largest cities, as the productive structures of these cities are characterised by a higher proportion of employment in services. Most studies on industry location, agglomeration and urban growth focus nearly exclusively on manufacturing (one exception is Kolko, 2007) although, nowadays, service industries dominate the economies of large cities. The shift of employment from the manufacturing sector to services is a documented fact, and, by the end of the twentieth century, the percentage of employment in services in the US reached almost three times that of manufacturing (see Kolko, 1999).

Hypothesis 2. Geography (city location) has a strong influence on cities' per capita income or population growth rate.

[1] A good commentary on the relationship between cities and national economic growth can be found in Polèse (2005).

We disaggregate ‘geography’ into physical geography (e.g., temperature, rainfall) and socio-economic environment (differences in economic and productive structures). The problem is that these differences are hardly exogenous (unlike factors such as rainfall and temperature). These structures themselves are the results of the previous round of economic and productive activities; in other words, structures and agency are mutually constituted (see Plummer and Sheppard, 2006).

Part of this second hypothesis has already been tested. Glaeser and Shapiro (2003) find that people moved to warmer, drier places. Moreover, in related work, Glaeser et al. (2001) argued that the correlation between weather and growth is evidence of the growing importance of consumers, relative to producers, in determining the location of cities. Therefore, a consumer city view would predict that weather variables are becoming more important in the 1990s. Black and Henderson (1998) conclude that the extent of city growth and mobility is related to natural advantage, or geography. Beeson et al. (2001) show that access to transportation networks, either natural (oceans) or produced (railroads) was an important source of growth over the period 1840–1990, and that weather is one of the factors promoting population growth. And Mitchener and McLean (2003) find that some physical geography characteristics account for a high proportion of the differences in state productivity levels.

Other empirical studies exist analysing the growth of American population and per capita income, although the geographical unit analysed is not the city. At the county level, Beeson et al. (2001) studied the evolution of population from 1840 to 1990, while Young et al. (2008) analyse the evolution of income distribution from 1970 to 1998. Mitchener and McLean (2003) use data beginning in 1880 to study variations among states in labour productivity. Finally, Yamamoto (2008) examined the disparities in per capita income in the period 1955–2003 using different geographical levels (counties, economic areas, states and regions).

Moreover, studies about the evolution of income distribution in the United States in terms of β-convergence have a long tradition. Barro and Sala-i-Martin (1992), Evans and Karras (1996a, 1996b), Sala-i-Martin (1996), and Evans (1997) find statistically significant β-convergence effects using US state-level data, and Higgins et al. (2006) use US county-level data to document statistically significant β-convergence effects across the United States.

The next section presents the data used. We will follow a two-step strategy. First, in Section 3 we analyse whether the city population and city per capita income distributions have followed similar paths in the 1990s. The results show that, while a similar convergence behaviour is observed in both population and per capita income growth, there are differences in the evolution of the distributions: population distribution remains almost static, while per capita income distribution makes a great movement to the right. Second, to test the two hypotheses proposed and to try to explain the differentiated behaviours observed in the evolution of the distributions of cities’ per capita income and population, we examine the relationship between urban characteristics in 1990 and city growth (both in population and in per capita income) using two empirical methodologies; in Section 4 we estimate linear models (a model of spatial equilibrium and a conditional β-convergence regression) and in Section 5 a Multinomial Logit Model is used. The work ends with our conclusions.

2. Data Description

We use data for all cities in the Unites States with more than 25,000 inhabitants in the year 2000 (1154 cities). The data came from the census[2] for 1990 and 2000. We identified cities as what the US Census Bureau calls incorporated places. Two census designated places (CDPs) are also included (Honolulu CDP in Hawaii and Arlington CDP in Virginia). The US Census Bureau uses the generic term incorporated place to refer to a type of governmental unit incorporated under state law as a city, town (except in the New England states, New York, and Wisconsin), borough (except in Alaska and New York), or village and having legally prescribed limits, powers, and functions. On the other hand there are unincorporated places (which were renamed Census Designated Places, CDPs, in 1980), which designate a statistical entity, defined for each decennial census according to Census Bureau guidelines, comprising a densely settled concentration of population that is not within an incorporated place, but is locally identified by a name. They are the statistical counterpart of the incorporated places. The difference between them in most cases is merely political and/or administrative. Thus for example, due to a state law of Hawaii there are no incorporated places there; they are all unincorporated.

The geographic boundaries of census places can change between censuses. As in Glaeser and Shapiro (2003), we address this issue by controlling for change in land area. Although this control may not be appropriate because it is also an endogenous variable that may reflect the growth of the city, none of our results change significantly if this control is excluded. Moreover, we also eliminated cities that either more than doubled their land area or lost more than 10 percent of their land area[3]. This correction eliminates extreme cases where the city in 1990 is something very different from the city in 2000.

The explanatory variables chosen are similar to those in other studies on city growth in the US and city size, and correspond to the initial 1990 values. The influence of some of these variables on city size has been empirically proven by other works (Glaeser et al., 1995; Glaeser and Shapiro, 2003). Our aim is to introduce variables to control for some of the already known empirical determinants of city growth (human capital, density, or weather), and other variables to be able to test the two hypotheses proposed. Table 1 presents the variables, which can grouped in four types: urban sprawl variables, human capital variables, productive structure variables, and geographical variables.

Urban sprawl variables are basically intended to reflect the effect of city size on urban growth. For this we use the population density (inhabitants per square mile), the growth in land area from 1990–2000 (as a control for the change in boundaries), and the variable median travel time to work (in minutes), representing the commuting cost borne by workers. Commuting time is endogenous and depends in part on the spatial organisation of cities and location choice within cities. The median commuting time may reflect traffic congestion in larger urbanised areas, but might also reflect the size of the city in less densely populated areas, or the remoteness of location for rural towns. This is one of the most characteristic costs of urban growth, explicitly considered in

[2] The US Census Bureau offers information on a large number of variables for different geographical levels, available on its website: www.census.gov.

[3] Land area data also comes from US Census Bureau: http://www.census.gov/population/www/censusdata/places.html, and http://www.census.gov/geo/www/gazetteer/places2k.html.

some theoretical models; that is, the idea that as a city's population increases, so do costs in terms of the time taken by individuals to travel from home to work.

Regarding human capital variables, there are many studies demonstrating the influence of human capital on city size, as cities with better educated inhabitants tend to grow more. We took two human capital variables: percentage of the population 18 years and over who are high school graduates (includes equivalency) or have a higher degree, and percentage of the population 18 years and over who have some college or higher degree. The former represents a wider concept of human capital, while the latter centres on higher educational levels (some college, Associate degree, Bachelor's degree, and graduate or professional degree).

The third group of variables, referring to productive structure, contains the unemployment rate and the distribution of employment by sectors. The distribution of labour among the various productive activities provides valuable information about other characteristics of the city. Thus, the employment level in the primary sector (agriculture, forestry, fishing and hunting, and mining) is a proxy of the natural physical resources available to the city (cultivable land, port, etc.). This is also a sector which, like construction, is characterised by constant or even decreasing returns to scale.

Employment in manufacturing informs us of the level of local economies of scale in production, as this is a sector which normally presents increasing returns to scale. The level of pecuniary externalities also depends on the size of the industrial sector. Marshall put forward that (i) the concentration of firms of a single sector in a single place creates a joint market of qualified workers, benefitting both workers and firms (labour market pooling); (ii) an industrial centre enables a larger variety at a lower cost of concrete factors needed for the sector which are not traded (input sharing), and (iii) an industrial centre generates knowledge spillovers. This approach forms part of the basis of economic geography models, along with circular causation: workers go to cities with strong industrial sectors, and firms prefer to locate near larger cities with bigger markets. Thus, industrial employment also represents a measurement of the size of the local market. Another proxy for the market size of the city is the employment in commerce, whether retail or wholesale.

To test hypothesis 1, information is also included on employment in the most relevant activities in the services sector: finance, insurance, real estate; education, health and other professional and related services; and employment in the public administration.

Regarding hypothesis 2, we disaggregate 'geography' into physical geography and socio-economic environment. We try to control for both kinds. We use two measures of weather[4]: annual precipitation (inches), and a temperature index. The temperature discomfort index (TEMP_INDEX) represents each city's climate amenity, and is constructed as in Zheng et al. (2009) or Zheng et al. (2010). It is defined as:

$$TEMP\_INDEX_k = \sqrt{\begin{aligned}&(Winter\_temperature_k - \min(Winter\_temperature))^2 + \\ &+ (Summer\_temperature_k - \max(Summer\_temperature))^2\end{aligned}}\ .$$

[4] These data are the 30-year average values computed from the data recorded during the period 1971–2000. Source: U.S. National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center (NCDC), Climatography of the United States, Number 81 (http://cdo.ncdc.noaa.gov/cgi-bin/climatenormals/climatenormals.pl).

It represents the distance of the k-city's winter and summer temperatures from the most mild of the winter and summer temperatures across the 1154 cities. A higher TEMP_INDEX means a harsher winter or a hotter summer, which makes the city a harder place in which to live.

Finally, we include several dummies which give us information about geographic location, and which take the value 1 depending on the region (Northeast Region, Midwest Region, South Region or West Region) and the state in which the city is located. These dummies show the influence of a series of variables for which individual data are not available for all places, and which could be directly related to the geographical situation (access to the sea, presence of natural resources, etc.), or, especially, the socio-economic environment (differences in economic and productive structures).

3. Population and per Capita Income: Twin paths or not?

Our first step is to determine whether city population and city per capita income distributions followed similar paths in the 1990s. Figure 1 shows scatter plots of city population growth and city per capita income growth (logarithmic scale) against initial levels in 1990 and 1989. We use data from all cities with more than 25,000 inhabitants in the year 2000, 1154 cities.

We can observe that in both cases there is a negative relationship between the initial level and the growth rate. This implies that a larger initial population or per capita income means less growth (convergence growth). This negative effect is greater in the case of population growth than in per capita income growth. Thus, while the slope β of the line adjusted with OLS in the case of population growth is a clearly significant and negative coefficient (-0.070), with per capita income growth this coefficient (-0.016) is significantly different from zero only at the 10% level, not the 5%. Moreover, income's growth rates present a higher variance.

We would expect this convergent behaviour to have consequences in the evolution of distributions. Figure 2 shows the estimated empirical distributions using an adaptive kernel of city size, whether in per capita income or in population. It highlights an important change in the distribution of city per capita income. The negative relationship observed earlier between initial city per capita income and growth, which we can identify with convergent growth, has clearly produced a rightwards displacement of the distribution[5]. Meanwhile, there is hardly any change in the population distribution of the cities, even though there was also a negative relationship between the initial population and the growth rate. Therefore, despite the common convergence evolution observed in the growths of both population and per capita income, there are differences in the evolution of the distributions; the population distribution remains almost static, while per capita income distribution makes a great movement to the right.

Finally, Figure 3 relates city population growth and city per capita income growth, showing the well-known positive relationship in large cities between per capita income and city size. There is an extensive literature reporting the benefits of urban

[5] Everything seems to indicate that this behaviour has persisted for decades. Figure 2 of Young et al. (2008), corresponding to the evolution of the Distribution of U.S. Counties' Log Per Capita Incomes from 1970 to 1998, presents a very similar effect to that observed in our estimated kernel of city per capita income distribution from 1989 to 1999.

agglomeration on city income or productivity[6], see the surveys on this subject by Puga (2010) and Rosenthal and Strange (2004).

However, the differentiated behaviour observed in the evolution of the distributions of cities' per capita income and population could corroborate our initial idea: the different external effects generated in cities may produce different effects in population growth and per capita income growth. Therefore, the next sections analyse the relationship between city characteristics in 1990 and city growth, both in population and in per capita income, using different approaches.

4. A Model of Spatial Equilibrium

In this section, we follow the theoretical framework of urban growth put forward in Glaeser et al. (1995), and further explicated in Glaeser (2000). This is a model of spatial equilibrium similar to the Roback (1982) model, where the relationship between population growth and initial characteristics is determined by changes in the demand for some aspect of the city's initial endowment in production or consumption, or by the effect of this initial characteristic on productivity growth.

The exposition follows closely Glaeser and Shapiro (2003). The basic assumption is that we are *always* in a spatial equilibrium where (1) individual utility and (2) the returns to capital are equalised across space.

The production function for city i at time t is $A_{it} f\left(K_{it}, L_{it}\right) = A_{it} K_{it}^{\alpha} L_{it}^{\phi}$, where A_{it} is city-level productivity, K_{it} is city-level capital, and L_{it} is city-level labour, which we assume equals z times total city population $\left(N_{it}\right)$, where $0 < z \leq 1$. The price of this output is normalised to equal unity. The z parameter is meant to capture the fact that there exists a nonworking population in each city. Capital earns an exogenous rent r (equal to its marginal product assuming perfect competition).

Utility is equal to $\frac{C_{it} W_{it}}{P_{it}}$, where C_{it} is a city-level consumption amenity index, W_{it} represents city-level wages, and P_{it} represents city-level prices. In equilibrium, this must be equal to some utility level u that is constant across cities $\left(u = \frac{C_{it} W_{it}}{P_{it}} \right)$. We can obtain the following equality, which must hold for every city:

$$Log\left(N_{it}\right) = \Theta_t + \frac{1}{1-\alpha-\phi} Log\left(A_{it}\right) + \frac{1-\alpha}{1-\alpha-\phi} Log\left(\frac{C_{it}}{P_{it}} \right),$$

where Θ_t is a term that is constant across cities, $\Theta_t = -Log(z) + \frac{1}{1-\alpha-\phi}\left[Log\left(\alpha^{\alpha}\phi^{1-\alpha}\right) - \alpha Log(r) - (1-\alpha) Log(u)\right]$. Thus, in this model the city-level population is increasing in city-level productivity and city-level consumption amenities and declining in city-level prices.

We suppose that each city i has a set of K scalar time invariant characteristics, denoted X_{i1}, …, X_{ik}, …, X_{iK}. Letting X_i be the vector of these characteristics, we

[6] Although there is a great deal of variability in the results reported in the literature, see the meta-analysis by Melo et al., (2009).

assume that $Log(A_{it}) = X_i^{'}\phi_t + \delta_{it} + \varepsilon_{it}$ and that $Log\left(\frac{C_{it}}{P_{it}}\right) = X_i^{'}\gamma_t + \mu_{it}$, where ε_{it} and μ_{it} are error terms that are orthogonal in both levels and changes to any observable characteristics, and where ϕ_t and γ_t are the vectors of coefficients corresponding to the city-level characteristics. The term δ_{it} is orthogonal in levels, but $\delta_{it+1} - \delta_{it} = \mathbf{X}_i^{'}\theta + \xi_{it}$ where ξ_{it} is a completely orthogonal error term. Using these terms, and combining the orthogonal error terms, it is possible to find that

$$Log\left(\frac{N_{it+1}}{N_{it}}\right) = \Delta\Theta + \frac{1}{1-\alpha-\phi} \cdot \sum_k^K \left[\phi_{kt+1} - \phi_{kt} + (1-\alpha)(\gamma_{kt+1} - \gamma_{kt}) + \theta_k\right] X_{ik} + \zeta_{it}, \qquad (1)$$

where ζ_{it} is a completely orthogonal error term. Thus, if a characteristic X_k (such as human capital or weather) positively predicts growth, there are three possible explanations: (1) this X_k variable may have become more important in the production process $(\phi_{kt+1} > \phi_{kt})$, (2) this X_k variable may have become more important to consumers either by lowering the cost of living or raising the general set of local amenities $(\gamma_{kt+1} > \gamma_{kt})$, or (3) this X_k variable may increase the rate of technological growth $(\theta_k > 0)$. But we will not attempt to determine why any particular variable is associated with later growth[7]. Therefore, the estimates should be seen as parameter estimates of $\left[\phi_{kt+1} - \phi_{kt} + (1-\alpha)(\gamma_{kt+1} - \gamma_{kt}) + \theta_k\right] / (1-\alpha-\phi)$.

Table 2 presents the OLS estimates of equation (1). We present the results for three possible specifications, as the geographical dummy variables are introduced in a progressive way (the explicative power of the model, measured by R^2, increases up to 0.702 when all dummies are included). We also control for the initial per capita income in 1989 and for the city population growth rate in the previous period (1980–1990), as one of the facts highlighted by Glaeser and Shapiro (2003) is the persistence of growth rates.

Results obtained in previous studies are confirmed. For example, higher levels of human capital (some college or higher degree) have a positive and significant effect on population growth (Glaeser and Shapiro, 2003), or the percentage of employment in manufacturing has a negative effect (Glaeser et al., 1995), although the coefficient is not significant in specification (3). The sign of the travel time coefficient is positive; although no theory of urban growth predicts that commuting time (that is, congestion) should have a positive effect on growth. A more plausible explanation[8] for this result is that some relevant variables are missing. Cities that are more spread out have both more developable land (so that there is space for construction of new homes and room for the city to grow) and also have a larger distance between the residential fringe and the central business district. The key omitted variable here is the percentage of developable land[9].

Regarding our two main hypotheses, we find support for hypothesis 1 and evidence in favour of hypothesis 2, although this latter is weaker. Employment by

[7] Wage and rent data are necessary for this purpose.
[8] The author thanks one anonymous referee for this argument.
[9] Omitted because of data scarcity, although part of this variable could be captured by the city land area growth, already included.

sectors reveals that one of the traditional sectors, manufacturing, has lost weight: other economic sectors have a greater influence on growth, and some services (professional services and public administration) are among them. Thus, in specification (3), employment in manufacturing has no significant effect, while the coefficients corresponding to the primary sector, trade activities, professional services and public administration remain significant. All of them are negative, except agriculture's coefficient.

The influence of geography on population growth is slighter. Temperature index has a negative effect on growth, as expected: a higher index means that the city is a harder place in which to live. However, this coefficient lost significance when all the geographical dummies were included. Precipitation is not significant in any case. Some particular locations have an effect on population growth, as five state dummies are significant at the 5% level[10]: Idaho (0.257), Mississippi (-0.161), Nevada (0.268), South Carolina (-0.158), Utah (0.255).

We also estimate equation (1) using city per capita income growth (y_{it}) as the dependent variable. Then, equation (1) changes to:

$$Log\left(\frac{y_{it+1}}{y_{it}}\right) = \eta + \beta y_{i0} + \varphi' Z_{ik} + v_{it}, \qquad (2)$$

the well-known expression of the conditional β-convergence[11] (Evans, 1997; Evans and Karras, 1996a; 1996b). η is a constant, Z_{ik} is a vector of variables that control for cross-city heterogeneity in determinants of the steady state growth rate (we use exactly the same independent variables as in the population growth model), φ is a vector of coefficients, and v_{it} is a zero-mean finite-variance error.

Table 3 presents the OLS estimates of equation (2), using the same exogenous variables that in the spatial equilibrium model (although the table structure is the same, in this model city per capita income is the main explanatory variable and the rest are controls). Again, we present the results for three possible specifications, introducing the geographical dummy variables in a progressive way.

The estimate of the β-coefficient corresponding to the initial level of per capita income is negative and clearly significant, finding evidence in favour of convergence across cities, as in the previous section. The difference is that here, when controlling for cross-city heterogeneity, the coefficient is greater (-0.085 instead -0.016), indicating a stronger convergence, which better describes the behaviour observed in the evolution of the distributions of city per capita income (Figure 2).

Most of the coefficients in Table 3 keep the same sign as in the spatial equilibrium model for population growth—for example, high levels of human capital still predict per capita income growth—although there are some differences. It is notable that the unemployment rate has no significant effect on income growth, but a clearly negative influence on population growth. This means that unemployment's main effect concerns basically the individual's movements rather than the city's productivity; cities with high unemployment experience lower population growth rates.

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[10] Results for the other states or regions are not shown, as the coefficients are not significant.

[11] There are several theoretical economic growth models that can produce equation (2) at the state-, county-, or region- level. For a neoclassical growth model, see Barro and Sala-i-Martin (1992).

Focussing on our hypotheses, again some services (professional services and public administration) are sectors with higher influence on income growth than manufacturing: in this model, manufacturing and construction's coefficients are significant (and negative). Manufacturing's negative effect on income growth was previously found by Glaeser et al. (1995) for the period 1960–1990; its explanation is related to the depreciation of capital, suggesting that cities followed the fortunes of the industries that they were initially devoted to.

Regarding hypothesis 2, physical geography seems to be more important in income growth than in population growth. Thus, the two weather variables are significant, even when controlled with state dummies. The effect of the temperature index is again negative, indicating that a higher index means that the city is a harder place in which to produce. However, the socio-economic environment, captured by region and state dummies, is less important than in the population growth model, as no state dummy is significant at the 5% level.

5. A Multinomial Logit Model

In this section we use an alternative approach, a Multinomial Logit Model (MNLM), to try to explain the different evolutions of city per capita income and city population distributions in the 90s. The main difference is that here, we neither impose spatial equilibrium (which could be a strong assumption when only one decade is considered), nor any particular functional form.

The MNLM has been used to study location decisions since the pioneering housing location choice model of McFadden (1978). These models require data from (1) agents' movements from one location to another, (2) individual's characteristics, and (3) location characteristics. For example, Gabriel and Rosenthal (1989) use disaggregated household data from the Washington, DC, metropolitan area to evaluate the extent to which differences in socio-economic characteristics between black and white households explain urban housing market racial segregation.

We use an MNLM relating cities' probability of being located in any of the distribution quartiles according to growth (both in per capita income and in population) to urban characteristics in 1990. We propose two separate models, one for the growth of city per capita income and another for city population growth, although, as the explanatory variables are the same, we can compare the results of both models.

Hence the exercise we carry out in this section is not specifically a study of individuals' or firms' decisions, as we only have data from location characteristics. And, although individual data from agents' movements is not available, we can observe their aggregate behaviour, that is, which cities grow more than others, and these movements are the result of behaviours with microeconomic foundations[12] (although it is beyond the scope of this paper to offer new theoretical foundations).

We use data from 1154 cities, so it is necessary to reduce the number of possible locations. We define four kinds of city, according to their growth patterns, transforming our dependent variable (the growth of city per capita income or of city population) into categories, which, to facilitate interpretation (and to ensure the groups are as homogeneous as possible in size), we make coincide with the sample quartiles.

[12] Agglomeration economies could be driven by sharing, matching or learning mechanisms (Duranton and Puga, 2004), while increases in city per capita income or productivity could be explained by labour market pooling, input sharing or knowledge spillovers (Marshall, 1920). Recently, the role of sorting and selection has also been emphasised (Combes et al., 2008; Combes et al., 2009).

If city i grows more than city j, $Log\left(\frac{N_{it+1}}{N_{it}}\right) > Log\left(\frac{N_{jt+1}}{N_{jt}}\right)$, this indicates that characteristics from city i offer greater utility to consumers than those of city j. In terms of per capita income, if $Log\left(\frac{y_{it+1}}{y_{it}}\right) > Log\left(\frac{y_{jt+1}}{y_{jt}}\right)$, characteristics of city i make city-productivity growth higher than in city j. Thus, we rank the cities in descending order according to growth, and assign a value 1 (bottom quartile), 2, 3 or 4 (top quartile) according to which quartile the city's growth rate falls in, with 1 and 4 corresponding to 25% of all cities, those with the least and the most growth, respectively. Figure 4 shows the box plots representing these quartiles graphically, and Table 4 shows the concrete values separating some quartiles from others. It can be seen that the distribution of income growth is much more concentrated than population growth, which at the upper tail shows values very far from the median. To complete the information on the quartiles, Table 5 relates both distributions. The first conclusion to be extracted is that, as shown in Figure 3, there is a relationship between growth in city per capita income and in city population, as the most numerous group, 9.71%, indicates that most of the cities with the highest income growth also possess the highest population growth.

With the MNLM we estimate a separate binary logit for each pair of categories of the dependent variables. This allows the results of the estimations to give us information about the probability (but not causality) of each variable's affecting each category. Formally, the MNLM can be written as

$$\ln \phi_{m|b} = \ln \frac{\Pr(K = m|\mathbf{x})}{\Pr(K = b|\mathbf{x})} = \mathbf{x}'\beta_{m|b} \qquad \text{for } m = 1 \textbf{ to } J, \qquad (3)$$

where b is the base category (in our case this will be category 1, the bottom quartile containing the the 25% of cities in the distribution with the lowest growth rates), $J = 4$ and $\mathbf{x}$ is the vector of the explanatory variables (the same variables as in the previous section), reflecting urban sprawl, human capital, productive structure or geographical situation[13]. We propose studying how these explanatory variables affect the probability of a city's being in one category (quartile) or another, focussing in particular on quartiles 1 and 4, representing those cities (25% each of the distribution) which grew least and most, respectively (bottom and top quartiles). For example, if the percentage of individuals with higher level education (some college or higher degree) increases. does the probability of the city's belonging to that 25% of cities with highest growth also increase?

[13] The MNLM makes the assumption known as independence of irrelevant alternatives (IIA). In this model: $\frac{\Pr(K = m|\mathbf{x})}{\Pr(K = n|\mathbf{x})} = e^{\mathbf{x}'(\beta_{m|b} - \beta_{n|b})}$, where the odds between each pair of alternatives do not depend on other available alternatives. Thus, adding or deleting alternatives does not affect the odds between the remaining alternatives. The assumption of independence follows from the initial assumptions that the disturbances are independent and homoscedastic. We have considered one of the commonest tests developed for testing the validity of the assumption, the Hausman test (Hausman and McFadden, 1998), and we cannot reject the null hypothesis in any of the two models (population and per capita income growth), that is, that the odds are independent of other alternatives, indicating that the MNLM is appropriate.

To deal with these questions we use odds ratios (also referred to as factor change coefficients). Holding other variables constant, the factor change in the odds of outcome m versus outcome n as x_i increases by δ equals:

$$\frac{\phi_{m|b}(\mathbf{x}, x_i + \delta)}{\phi_{n|b}(\mathbf{x}, x_i)} = e^{\beta_{i,m|n}\delta} . \qquad (4)$$

Thus, if the amount of change is $\delta = 1$, the odds ratio can be interpreted as follows: for a unit change in x_i, it is expected that the odds of m versus n change by a factor of $e^{\beta_{i,m|n}}$, holding all the other variables constant.

The estimated values of the β coefficients are shown in Tables 6 and 7 (1 is the base outcome). This model includes many coefficients, making it difficult to interpret the effects for all pairs of categories. To understand the effect of a variable, one needs to examine the coefficients for comparisons among all pairs of outcomes.

To simplify the analysis, odds-ratio plots have been developed, shown in Figures 5 and 6. An odds-ratio plot makes it easy to quickly see patterns in results for even a complex MNLM. In an odds-ratio plot, the independent variables are each presented on a separate row, and the horizontal axis indicates the relative magnitude of the β coefficients (see Tables 6 and 7) associated with each outcome. The numbers which appear (1, 2, 3 or 4) are the four possible outcomes, the categories (coinciding with the sample quartiles) which we previously constructed. The additive scale on the bottom axis measures the value of the $\beta_{i,m|n}$s. The multiplicative scale on the top axis measures the $e^{\beta_{i,m|n}}$s. The 1s are stacked on top of one another because the plot uses outcome 1 as its base category for graphing the coefficients.

These plots reveal a great deal of information (for more details, see Long and Freese, 2006). To begin, if a category is to the right of another category, it indicates that increases in the independent variable make the outcome to the right more likely. Also, the distance between each pair of categories indicates the magnitude of the effect. And when a line connects a pair of categories this indicates a lack of statistical significance for this particular coefficient, suggesting that these two outcomes are 'tied together'. We are especially interested in categories (quartiles) 1 (bottom quartile) and 4 (top quartile), corresponding to the tails of the distribution.

Figure 5 displays the results for the distribution of employment by sectors. Overall, we find support for hypothesis 1. In the income growth model all sectors possess a negative $\beta_{4|1}$ coefficient (Table 7), indicating a negative effect on the probability that the city's per capita income growth rate belongs to the 25% of cities with the highest growth rate, category 4 (top quartile). Services are among the sectors with the greatest coefficients. Focussing on the population growth model, only two sectors present a significant effect on category 4: the primary sector (agriculture, forestry, fishing, and mining) and professional services (see Table 6). The effect of agriculture, forestry, fishing, and mining activities is positive, as the most likely outcome is category 4 (top quartile). Higher employment in the primary sector (which could be consider as a proxy for the natural physical resources available to the city: cultivable land, access to the sea, etc.) means a higher probability that the growth rate of the city will be in the highest quartile. In contrast, the effect of professional services is negative, as the most likely outcome is category 1 (bottom quartile).

Figure 6 presents the odds ratio plots of median travel time, human capital variables, unemployment rate and weather variables. In principle, the bigger the city, the greater the median travel time borne by workers. However results point to category 4 (top quartile) in the population model as the most likely (in income model there is no significant effect in any category), which would indicate that indeed, where there is an increase in a unit of median travel time, the most likely outcome is that the city belongs to the 25% of cities with the highest growth, whether in per capita income or in population. As in the OLS model, the probable explanation for this counter-intuitive result is the existence of omitted variables (in this case, developable land)[14].

Figure 6 shows the opposite behaviour for the two human capital variables we introduced, both in population growth and in per capita income growth. Thus, results show that increases in the percentage of the population with the most education (some college or higher degree) have a positive impact on income growth, as the most likely outcome is that the city will end up in quartile 4; also in the population model, category (quartile) 4 is the most likely. On the other hand, the wider concept of human capital (high school graduate or higher degree) has almost no significant effect in either model.

These results coincide with those of other studies analysing the influence of education on city growth. Glaeser and Shapiro (2003) also find workers have a different impact depending on their education level[15] (high school or college). Simon and Nardinelli (2002) analyse the period 1900–1990 for the USA and conclude that the cities with higher average levels of human capital grew faster over the 20th century, and Glaeser and Saiz (2003) analyse the period 1970–2000 and show that this is due to skilled cities being more economically productive (than less skilled cities).

Figure 6 also shows that population growth depends negatively on the initial unemployment level, while the effect on income growth is not significant (as in the linear models). Thus, with an increase of 1% in the unemployment rate, the most likely outcome in population model is 1 (bottom quartile).

Regarding hypothesis 2, the temperature index has a negative effect on growth, as the most likely outcome is category 1 (bottom quartile) in both models, indicating that a higher index means a higher probability that the city will be among the 25% of cities with the lowest population or per capita income growth (although the coefficients are not significant—see Tables 6 and 7). The coefficients corresponding to annual precipitation are only significant for medium quartiles (categories 2 and 3). Therefore, the influence of weather seems weak.

However, location in some particular states affects growth. This second component of geography once we control for the weather is captured by the geographical dummies, which could be directly related to the geographical situation or, especially, the socio-economic environment. Focussing on category 4 (top quartile), Figure 7 presents a map showing the state-level dummies with the greatest significant effect on category 4, that is, when the $\beta_{i,4|1}$ coefficient corresponding to state-level dummy i is significant and the maximum or minimum value considering all categories. Thus, no significative effect in this map means that the state dummy is not significant, or that the effect on other categories is greater. We can identify five states where the

[14] The same omitted variable that makes it look like there is a positive relationship between X and Y in an OLS model will make it look like there is a relationship between X and the probability of Y being above a certain threshold in a logit model.

[15] In their sample of cities, the different effect is completely due to the impact of California.

highest population growth (top quartile) is the most likely outcome: Arizona, Georgia, Iowa, North Carolina and Wisconsin. In other cases the most likely outcome is the top quartile in per capita income growth: Louisiana and Massachusetts. Although in other states, the top quartile in per capita income growth is the least likely outcome (Michigan, Minnesota and Missouri). In some states, the highest population growth is the most likely outcome and the highest per capita income growth is the least likely outcome (Illinois, Indiana, Kansas and Ohio). Finally, location in Colorado or South Carolina has a positive effect on the probability that the growth rate of the city will be in the 25% of cities with the highest growth in both population and per capita income. It is notable that, in general, states where the highest growth in per capita income is the least outcome are located in the Rust (or manufacturing) Belt (Illinois, Michigan or Ohio), an area that has suffered a bad economic situation since the decline of industry in the 1970s, indicating that state-dummies are truly capturing differences in economic and productive structures.

6. Conclusions

This paper analyses the determinants of growth of American cities, understood as growth of the population or of per capita income, from 1990 to 2000. This empirical analysis uses data from all cities with more than 25,000 inhabitants in the year 2000 (1154 cities). The results show that, while a common convergence behaviour is observed in both population and per capita income growth, there are differences in the evolution of the distributions: population distribution remains almost unchanged, while per capita income distribution develops a great movement to the right.

We propose two hypotheses, related with the importance of services activities and geography on urban growth, and test them with different empirical tools: linear models and Multinomial Logit Models. Some urban characteristics included in the analysis confirm results from previous studies. Thus, we find a positive effect of education (although only the highest levels, some college or higher degree) on either population or income growth, or a negative effect of unemployment on population growth. Regarding our main hypotheses, we find support for hypothesis 1: both kinds of models reveal that some services (mainly professional services and public administration) are sectors with higher influence than manufacturing on urban growth.

And with regard to hypothesis 2, weather variables (physical geography) seem to have greater impact on income growth rather that on population growth. The influence of the second component of geography, the socio-economic environment, is greater. From the MNLM results we can identify several states with a significant effect; that is, location in those states affects the probability that the city‘s growth rate will be in the top quartiles with the highest growth in population or per capita income.

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Table 1.- Means and standard deviations, city variables in 1990

Variable	Mean	Stand. dev.
Population Growth (ln scale), 1990–2000	0.14	0.20
Per Capita Income Growth (ln scale), 1989–1999	0.38	0.10
Urban sprawl		
Land Area Growth (ln scale), 1990–2000	0.09	0.14
Population per Square Mile	3645.30	3397.94
Median Travel Time to Work (in minutes)	20.68	4.95
Human capital variables		
Percentage population 18 years and over: some college or higher degree	37.88	11.77
Percentage population 18 years and over: high school graduate (includes equivalency) or higher degree	58.57	9.67
Productive structure variables		
Unemployment rate	6.24	2.83
Percentage employed civilian population 16 years and over:		
Agriculture, forestry, fishing, and mining	1.94	2.62
Construction	5.62	1.99
Manufacturing (durable and nondurable goods)	17.44	7.56
Wholesale and Retail trade	22.51	3.02
Finance, insurance, and real estate	7.08	2.62
Educational, health, and other professional and related services	24.19	6.75
Public administration	4.72	3.39
Weather		
Temperature index	65.46	11.41
Annual precipitation (inches)	34.89	14.56

Sources: 1990 and 2000 Census, www.census.gov

Table 2.- City Population Growth: OLS results for the Model of Spatial Equilibrium

Variables	(1)	(2)	(3)
Urban sprawl			
Land Area Growth (ln scale)	0.403***	0.408***	0.376***
Population per Square Mile (ln scale)	-0.050***	-0.052***	-0.054***
Median Travel Time to Work (in minutes)	0.005***	0.005***	0.006***
Human capital variables			
Percentage population 18 years and over: Some college or higher degree	0.003***	0.003***	0.003***
Percentage population 18 years and over: High school graduate (includes equivalency) or higher degree	-0.001	-0.001	-0.002
Productive structure variables			
Unemployment rate	-0.011***	-0.011***	-0.007***
Percentage employed civilian population 16 years and over:			
Agriculture, forestry, fishing, and mining	0.007***	0.006***	0.010***
Construction	-0.007**	-0.009***	-0.003
Manufacturing (durable and nondurable goods)	-0.004***	-0.004***	-0.001
Wholesale and Retail trade	-0.010***	-0.009***	-0.006***
Finance, insurance, and real estate	-0.001	-0.001	0.002
Educational, health, and other professional and related services	-0.009***	-0.009***	-0.006***
Public administration	-0.007***	-0.008***	-0.004***
Weather			
Temperature index	-0.001***	-0.002***	0.001
Annual precipitation (inches)	0.000	0.001	0.000
Controls			
Initial Per Capita Income (ln scale) in 1989	-0.142***	-0.139***	-0.088***
City Population Growth Rate 1980–1990 (ln scale)	0.317***	0.318***	0.301***
Regions (Geographical dummy variables)	No	Yes	Yes
States (Geographical dummy variables)	No	No	Yes
Obervations	1154	1154	1154
R^2	0.636	0.642	0.702

***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level

Table 3.- City Per Capita Income Growth: OLS estimates of conditional β-convergence

Variables	(1)	(2)	(3)
Urban sprawl			
Land Area Growth (ln scale)	0.126***	0.107***	0.109***
Population per Square Mile (ln scale)	-0.044***	-0.038***	-0.040***
Median Travel Time to Work (in minutes)	0.001	0.001	0.001
Human capital variables			
Percentage population 18 years and over: Some college or higher degree	0.004***	0.003***	0.004***
Percentage population 18 years and over: High school graduate (includes equivalency) or higher degree	-0.001	0.000	-0.001
Productive structure variables			
Unemployment rate	-0.001	0.000	0.001
Percentage employed civilian population 16 years and over:			
Agriculture, forestry, fishing, and mining	-0.003**	-0.002*	-0.003*
Construction	-0.008***	-0.008***	-0.006***
Manufacturing (durable and nondurable goods)	-0.002***	-0.002***	-0.003***
Wholesale and Retail trade	-0.005***	-0.005***	-0.006***
Finance, insurance, and real estate	0.000	0.001	0.000
Educational, health, and other professional and related services	-0.005***	-0.004***	-0.005***
Public administration	-0.003***	-0.004***	-0.003***
Weather			
Temperature index	-0.002***	-0.003***	-0.002***
Annual precipitation (inches)	0.001**	0.001***	0.001*
Controls			
Initial Per Capita Income (ln scale) in 1989	-0.125***	-0.110***	-0.085***
City Population Growth Rate 1980–1990 (ln scale)	-0.035***	-0.026**	-0.040***
Regions (Geographical dummy variables)	No	Yes	Yes
States (Geographical dummy variables)	No	No	Yes
Obervations	1,154	1,154	1,154
R^2	0.279	0.294	0.374

***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level

Table 4.- City Per Capita Income Growth and Population Growth (ln scale): Sample quartiles

Percentile	Population Growth	Per capita income growth
25%	0.0188	0.3224
50%	0.0942	0.3843
75%	0.2072	0.4388

Source: 1990 and 2000 Census, www.census.gov

Table 5.- Cities by sample quartiles

		Per capita income growth quartiles			
		1	2	3	4
Population Growth quartiles	1	4.51%	8.93%	6.85%	4.68%
	2	7.80%	5.89%	6.07%	5.29%
	3	7.97%	5.55%	6.15%	5.37%
	4	4.77%	4.59%	5.89%	9.71%

Source: 1990 and 2000 Census, www.census.gov

Table 6.- City Population Growth: Multinomial Logit coefficients relative to Category (quartile) 1

	Categories (quartiles)		
Variables	2	3	4
Urban sprawl			
Population per Square Mile (ln scale)	-0.304	-0.461*	-1.666***
Median Travel Time to Work (in minutes)	0.084*	0.166***	0.183***
Human capital variables			
Percentage population 18 years and over: Some college or higher degree	0.123***	0.233***	0.161***
Percentage population 18 years and over: High school graduate (includes equivalency) or higher degree	-0.059	-0.133**	-0.042
Productive structure variables			
Unemployment rate	-0.175*	-0.242**	-0.264**
Percentage employed civilian population 16 years and over:			
Agriculture, forestry, fishing, and mining	-0.006	0.011	0.215**
Construction	0.148	0.279**	0.043
Manufacturing (durable and nondurable goods)	-0.033	-0.003	-0.010
Wholesale and Retail trade	-0.100	-0.075	-0.149
Finance, insurance, and real estate	-0.059	-0.069	0.035
Educational, health, and other professional and related services	-0.159***	-0.204***	-0.241***
Public administration	-0.061	-0.033	-0.081
Weather			
Temperature index	-0.027	-0.061	-0.012
Annual precipitation (inches)	-0.043*	-0.044*	-0.040

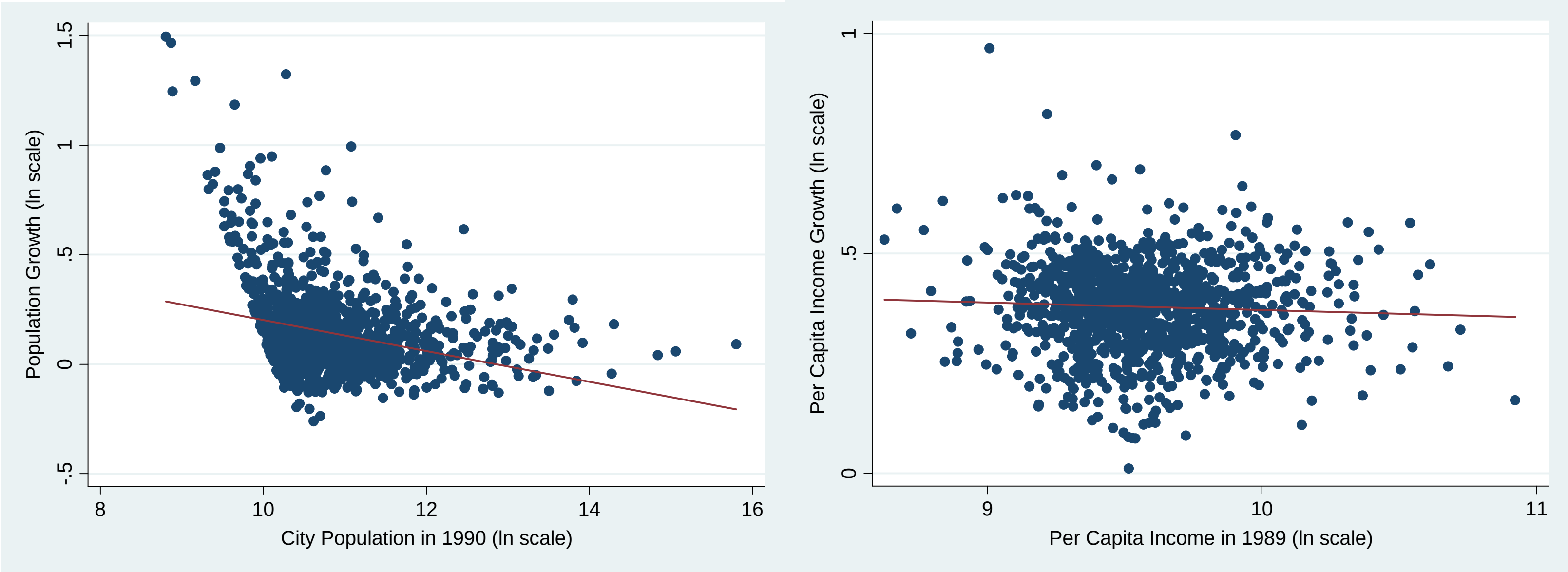
Note: Includes controls for: land area growth (ln scale), region and state dummies, initial per capita income (ln scale) in 1989, and city population growth rate 1980–1990 (ln scale). 1 is the base outcome. ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level

Table 7.- City Per Capita Income Growth: Multinomial Logit coefficients relative to Category (quartile) 1

	Categories (quartiles)		
Variables	2	3	4
Urban sprawl			
Population per Square Mile (ln scale)	-0.496**	-0.873***	-1.367***
Median Travel Time to Work (in minutes)	-0.054	0.046	0.045
Human capital variables			
Percentage population 18 years and over: Some college or higher degree	0.116***	0.107**	0.254***
Percentage population 18 years and over: High school graduate (includes equivalency) or higher degree	0.055	0.070*	-0.043
Productive structure variables			
Unemployment rate	0.042	0.160**	0.069
Percentage employed civilian population 16 years and over:			
Agriculture, forestry, fishing, and mining	0.012	-0.044	-0.138**
Construction	-0.063	-0.209**	-0.235***
Manufacturing (durable and nondurable goods)	-0.007	-0.048	-0.099***
Wholesale and Retail trade	-0.049	-0.058	-0.201***
Finance, insurance, and real estate	0.120	0.087	-0.035
Educational, health, and other professional and related services	-0.077*	-0.094**	-0.218***
Public administration	-0.023	-0.040	-0.136**
Weather			
Temperature index	-0.075**	-0.064*	-0.050
Annual precipitation (inches)	0.030*	0.039**	0.024

Note: Includes controls for: land area growth (ln scale), region and state dummies, initial per capita income (ln scale) in 1989, and city population growth rate 1980–1990 (ln scale). 1 is the base outcome. ***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level

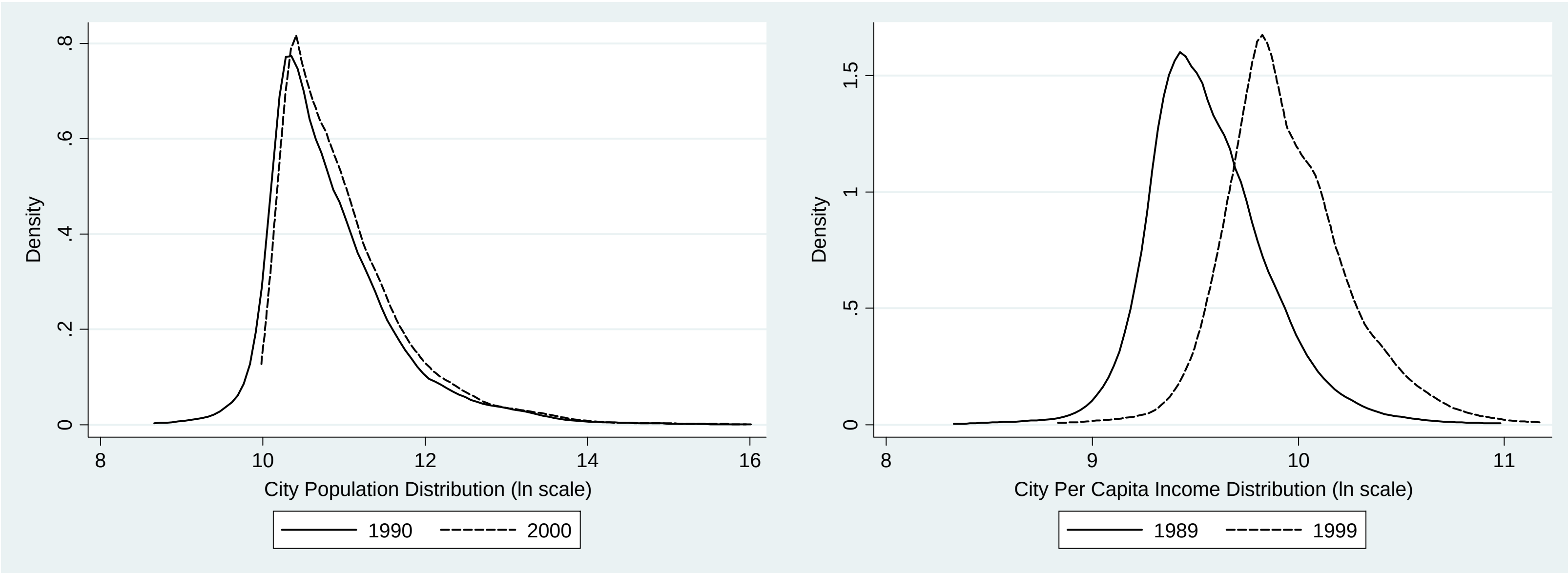
Figure 1.- Scatter Plots of City Growth (ln scale) against initial level



Note: Line fitted as $(\ln y_{it} - \ln y_{it-1}) = \alpha + \beta \ln y_{it-1}$.

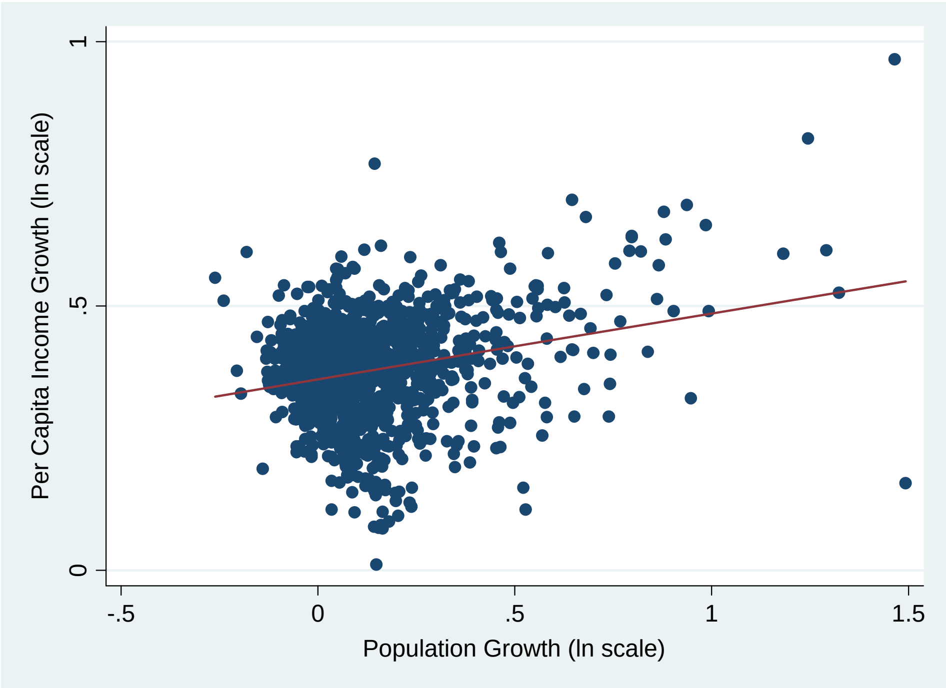
Source: 1990 and 2000 Census, www.census.gov

Figure 2.- Kernel density estimation (ln scale) of City Per Capita Income and City Population Distributions



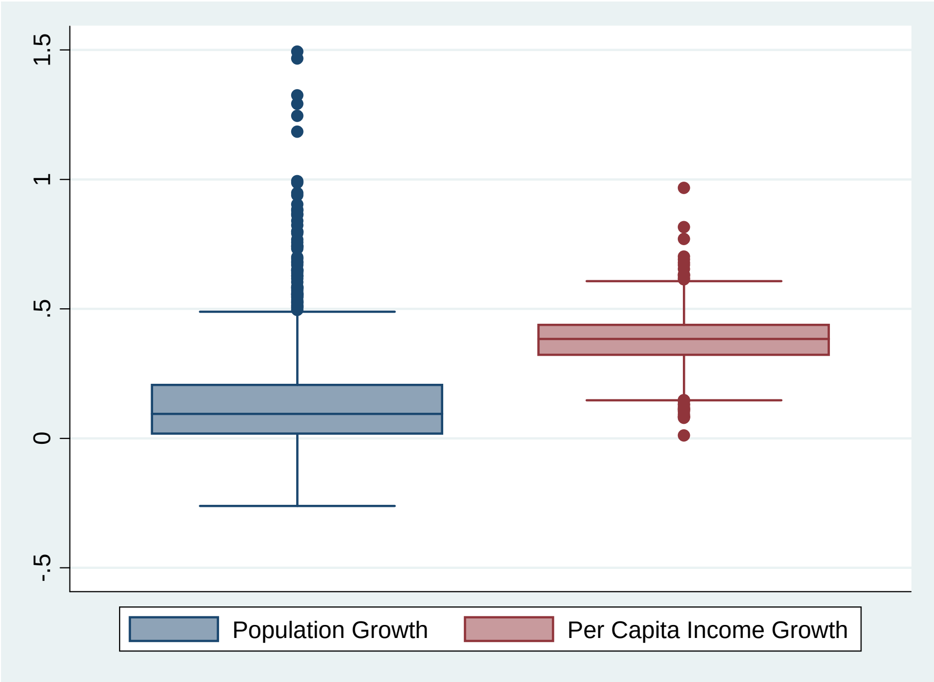
Source: 1990 and 2000 Census, www.census.gov

Figure 3.- Scatter Plot of City Per Capita Income Growth (ln scale) against City Population Growth (ln scale)



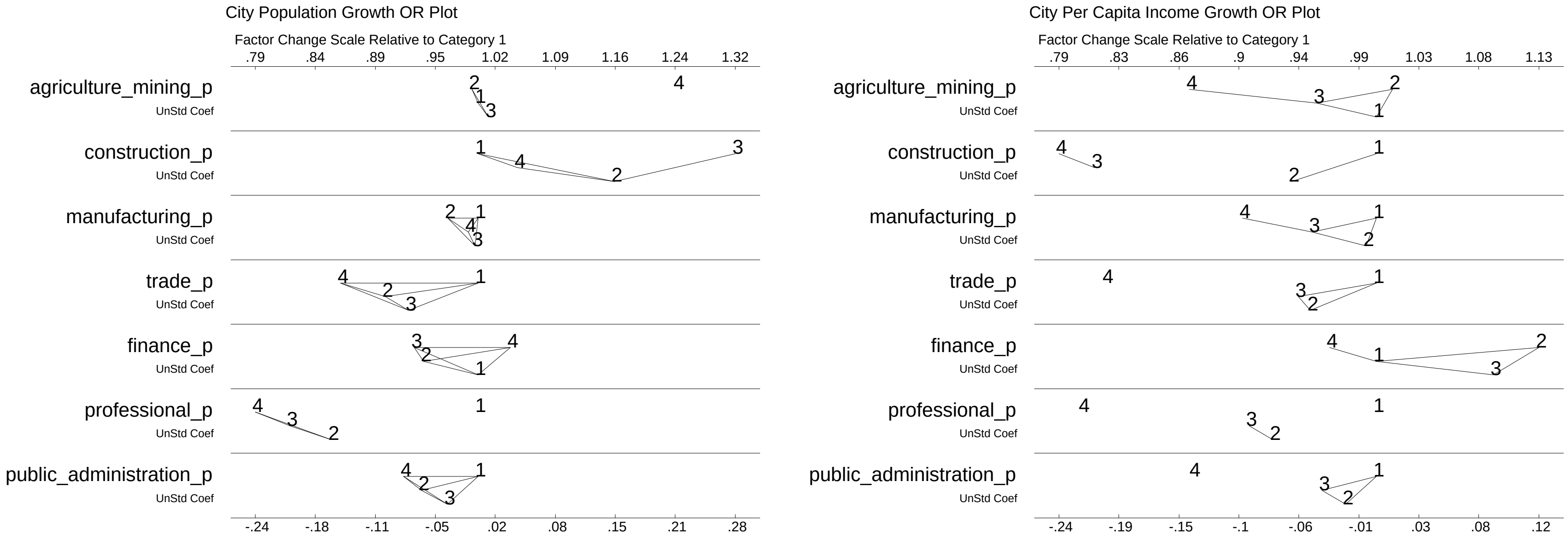
Source: 1990 and 2000 Census, www.census.gov

Figure 4.- Box Plots of City Per Capita Income Growth (ln scale) and City Population Growth (ln scale)



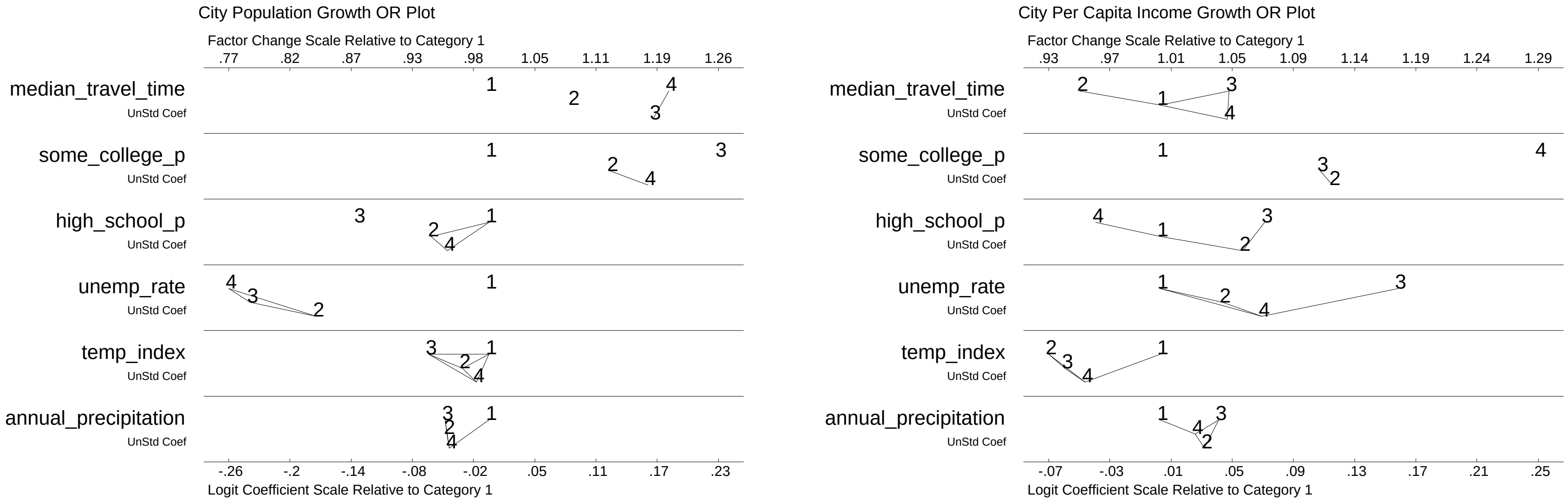
Source: 1990 and 2000 Census, www.census.gov

Figure 5.- Odds ratio plots of productive structure variables



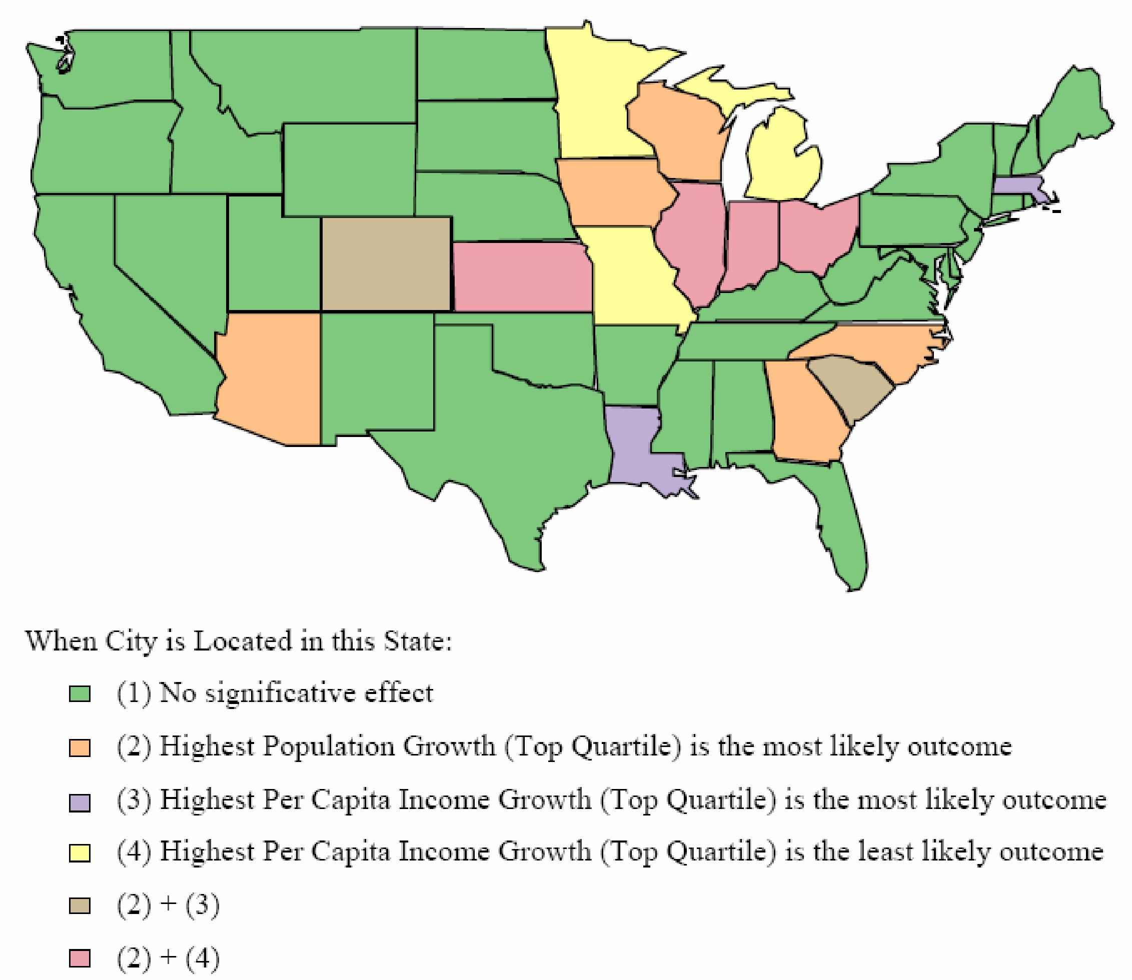
Note: Categories (Quartiles): 1 (bottom quartile, lowest growth rates), 2, 3 and 4 (top quartile, highest growth rates). Variables: Percentage employed civilian population 16 years and over: Agriculture_mining_p: ‘Agriculture, forestry, fishing, and mining’, Construction_p: ‘Construction’, Manufacturing_p: ‘Manufacturing (durable and nondurable goods)’, Trade_p: ‘Wholesale and Retail trade’, Finance_p: ‘Finance, insurance, and real estate’, Professional_p: ‘Educational, health, and other professional and related services’, Public_administration_p: ‘Public administration’.

Figure 6.- Odds ratio plots of median travel time, human capital variables, unemployment rate and weather variables



Note: Categories (Quartiles): 1 (bottom quartile, lowest growth rates), 2, 3 and 4 (top quartile, highest growth rates). Variables: Median_travel_time: ‘Workers 16 years and over who did not work at home: Median travel time to work (in minutes)’, Some_college_p: ‘Percentage population 18 years and over: Some college or higher degree’, High_school_p: ‘Percentage population 18 years and over: High school graduate (includes equivalency) or higher degree’, Unemp_rate: ‘Unemployment rate, based on unemployed persons 16 years and over’, Temp_index: ‘Temperature index’, Annual_precipitation: ‘Annual precipitation (inches)’.

Figure 7.- MNLM Results: Relationship between State-level dummies and Top Quartiles



Note: This map shows the state-level dummies with the greatest significant effect on category 4 (when the $\beta_{i,4|1}$ coefficient corresponding to state dummy i is significant and the maximum or minimum value considering all categories).