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Cities, Skills and Regional Change

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GLAESER E. L., PONZETTO G. A. M. and TOBIO K. Cities, skills and regional change, *Regional Studies*. One approach to urban areas emphasizes the existence of certain immutable relationships, such as Zipf's or Gibrat's law. An alternative view is that urban change reflects individual responses to changing tastes or technologies. This paper examines almost 200 years of regional change in the United States and finds that few, if any, growth relationships remain constant, including Gibrat's law. Education does a reasonable job of explaining urban resilience in recent decades, but it does not seem to predict county growth a century ago. After reviewing this evidence, a simple model of regional change is presented and estimated, where education increases the level of entrepreneurship. Human capital spillovers occur at the city level because skilled workers produce more product varieties and thereby increase labour demand. It is found that skills are associated with growth in productivity or entrepreneurship, not with growth in quality of life, at least outside of the West. It is also found that skills seem to have depressed housing supply growth in the West, but not in other regions, which supports the view that educated residents in that region have fought for tougher land-use controls. Evidence is also presented that skills have had a disproportionately large impact on unemployment during the current recession.

Microeconomics   Regional economics   Urban economics

GLAESER E. L., PONZETTO G. A. M. and TOBIO K. 城市、技术与区域变迁，*区域研究*。探究都市区域的其中一条途径便是强调一些不变关系的存在，例如齐普夫定律或吉尔伯特法则；但另类视角则认为城市变迁反映了个体对于品味或科技变革的响应。本论文检视美国近两百年来的区域变迁，发现仅有少数的成长关系持续不变，包括吉尔伯特法则。近数十年来，教育得以适切地解释都市的恢复力，但教育却似乎无法预测一百年前郡层级的成长。本研究检视此一证据后，提出并评量一个区域变迁的简易模型，其中教育提高了企业家精神的程度。人力资本在都市层级产生外溢，因为高技术的劳工生产更多的商品多样性，因而增加了劳动力需求。本研究发现，技术与生产力和企业家精神的增长有关，却无关乎生活质量的增长，至少在欧美地区以外的地方是如此。研究也发现，技术在欧美地区似乎抑制了房屋供给的增长，但此一情形却未发生于其他区域，而这也支持了聚居同区域的高等教育居民会一同致力于管制土地使用的观点。本文亦将呈现以下证据：技术对于目前经济衰退所造成的失业问题有着巨大的影响。

微观经济   区域经济   都市经济

GLAESER E. L., PONZETTO G. A. M. et TOBIO K. Les grandes villes, les compétences et l'évolution régionale, *Regional Studies*. L'une des méthodes d'aborder la question des zones urbaines met l'accent sur la présence de certains rapports immuables, tels la loi de Zipf ou bien la loi de Gibrat. Une autre thèse affirme que l'évolution urbaine reflète des réponses individuelles à la mutation des goûts ou des technologies. Cet article cherche à examiner presque 200 années d'évolution régionale aux Etats-Unis. Il s'avère que très peu des rapports de croissance restent constants, y compris la loi de Gibrat. L'éducation réussit dans une large mesure à expliquer la résilience urbaine pendant les dernières décennies, mais ne semble pas prédire la croissance au niveau des comtés il y a cent ans. Une fois examiné ces preuves, on présente et estime un modèle simple de l'évolution régionale où l'éducation développe l'esprit d'entreprise. Les retombées du capital humain ont lieu à l'échelle des villes parce que les travailleurs qualifiés font un éventail de produits plus large et, par la suite, augmente la demande de main-d'oeuvre. Il s'avère que les compétences sont en corrélation étroite avec la croissance de la productivité ou de l'esprit d'entreprise, mais ne le sont pas avec l'amélioration de la qualité de vie, du moins en dehors de l'Ouest. Il s'avère aussi que les compétences font fléchir la croissance de l'offre de logement dans l'Ouest, mais ne le font pas dans d'autres régions, ce qui tend à démontrer que les résidents diplômés de cette région se sont battus pour des mesures de contrôle des modes d'occupation des sols renforcées. On présente aussi des preuves qui laissent voir que les compétences ont eu un impact disproportionné sur le chômage pendant la récession actuelle.

Microéconomie   Économie régionale   Économie urbaine

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GLAESER E. L., PONZETTO G. A. M. und TOBIO K. Städte, Qualifikationen und regionale Veränderung, *Regional Studies*. Bei einem Ansatz zur Untersuchung urbaner Gebiete – z. B. beim Zipfschen oder Gibratschen Gesetz – wird die Existenz bestimmter unveränderlicher Beziehungen betont. Eine andere Ansicht lautet, dass sich in urbanen Veränderungen die individuellen Reaktionen auf veränderte Geschmäcke oder Techniken widerspiegeln. In diesem Beitrag untersuchen wir beinahe 200 Jahre regionaler Veränderungen in den USA und stellen fest, dass nur wenige Wachstumsbeziehungen (falls überhaupt welche) konstant bleiben, was auch für das Gibratsche Gesetz gilt. Die Bildung vermag die urbane Resilienz der letzten Jahrzehnte hinreichend zu erklären, doch vor einem Jahrhundert konnte sie nicht das Wachstum von Bezirken voraussagen. Nach einer Überprüfung dieser Belege wird ein einfaches Modell der regionalen Veränderung vorgestellt und geschätzt, bei dem die Bildung das Ausmaß des Unternehmertums erhöht. Die Übertragung von Humankapital findet auf Stadtebene statt, weil qualifizierte Arbeitnehmer mehr Produktvarietäten herstellen und damit die Nachfrage nach Arbeitskräften erhöhen. Wir stellen fest, dass Qualifikationen mit einem Wachstum der Produktivität oder des Unternehmertums einhergehen, aber zumindest außerhalb des Westens der USA nicht mit einer Zunahme der Lebensqualität. Ebenso stellen wir fest, dass sich die Qualifikationen im Westen – aber nicht in anderen Regionen – offenbar dämpfend auf das Wachstum des Wohnungsangebots ausgewirkt haben, was dafür spricht, dass gebildete Anwohner dieser Region für eine striktere Kontrolle der Landnutzung gekämpft haben. Außerdem stellen wir Belege dafür vor, dass sich die Qualifikationen während der momentanen Rezession unverhältnismäßig stark auf die Arbeitslosigkeit ausgewirkt haben.

Mikroökonomie Regionalwirtschaft Urbane Ökonomie

GLAESER E. L., PONZETTO G. A. M. y TOBIO K. Ciudades, habilidades y cambio regional, *Regional Studies*. Un enfoque sobre las áreas urbanas destaca la existencia de ciertas relaciones inmutables, tales como la Ley de Zipf o la Ley de Gibrat. Una perspectiva alternativa es que el cambio urbano refleja las respuestas individuales a los cambios en gustos o tecnologías. En este artículo analizamos casi 200 años de cambio regional en los Estados Unidos y constatamos que solamente pocas relaciones de crecimiento (si hay alguna) han sido constantes, incluyendo la Ley de Gibrat. La educación consigue explicar razonablemente la resiliencia urbana en los últimos decenios, pero no parece predecir el crecimiento de los condados de hace un siglo. Tras revisar esta evidencia, presentamos y calculamos un modelo simple de cambio regional en el que la educación aumenta el nivel de interés empresarial. Los desbordamientos de capital humano ocurren a nivel urbano porque los trabajadores cualificados producen más variedades de productos y, por consiguiente, aumentan la demanda laboral. Observamos que las habilidades están asociadas al crecimiento de la productividad o el interés empresarial, pero no al crecimiento de la calidad de vida, por lo menos fuera del oeste de los Estados Unidos. Asimismo observamos que al parecer las habilidades han hecho bajar el crecimiento del suministro de viviendas en el oeste, pero no en otras regiones, lo que respalda la opinión de que los residentes con estudios en esta región han luchado por unos controles más exigentes del uso de la tierra. También presentamos indicios de que las habilidades han tenido un impacto desproporcionado en el desempleo durante la recesión actual.

Microeconomía Economía regional Economía urbana

JEL classifications: D, R

INTRODUCTION

Are there universal laws of urban and regional population growth that hold over centuries, or do time-specific shifts in tastes and technology drive the shifts of population over space? Is urban change better understood with the tools of physics or a knowledge of history? This paper investigates patterns of population and income change over the long run in the older regions of the United States. Within this large land mass, there has been remarkable persistence in population levels across time. The logarithm of county population in the year 2000 rises almost perfectly one for one with the logarithm of population in 1860 and the correlation between the two variables is 66%.

Formal modelling of city growth has naturally tended to focus on patterns that are presumed to hold universally, such as Gibrat's law, which claims that population growth rates are independent of initial levels. Gibrat's law has received a great deal of recent interest because of its connection with Zipf's law, the claim being that the size distribution of cities in most countries is well approximated by a Pareto distribution (GABAIX, 1999, GABAIX and IOANNIDES, 2004; EECKHOUT, 2004).[1] This paper is not concerned with static laws of urban size, such as Zipf's law, but rather with the permanence of dynamic relationships.

The long-run persistence of county-level populations implies that Gibrat's law has very much held in the long run. But Gibrat's law does not hold reliably for county population changes at higher frequencies. Before 1860 and after 1970, less populous counties grew more quickly. During the intervening decades, when America industrialized and sectors concentrated to exploit returns to scale (KIM, 2006), population growth was regularly faster in more populated areas. One interpretation is that Gibrat's law is universal, but only over sufficiently long time periods. An equally plausible interpretation is that Gibrat's law holds in the long run because of the accidental balancing of centripetal forces, which dominated during the industrial era, and centrifugal forces, which have become more powerful in the age of the car and the truck; and that

– as a result – there is no reason to expect the law to hold in the future.

Geographic variables also wax and wane in importance. During recent decades, January temperature has been a reliable predictor of urban growth, and that was also true in the late nineteenth century; but it was not true either before 1860 or in the early decades of the twentieth century. The Great Lakes seem to have attracted population both in the early years of the American Republic and also during a second wave of growth in the first half of the twentieth century, which was associated with the expansion of industrial cities that formed around earlier commercial hubs. Population has moved away from these waterways since 1970, even within the eastern areas of the United States. These patterns seem to suggest waves of broad regional change that are associated with tectonic shifts in the economy, rather than time-invariant laws.

Even schooling has its limits as a predictor of growth. Since 1940, in the sample of counties, the share of a county's population with college degrees at the start of a decade predicts population growth in every subsequent decade except the 1970s. Even in the 1970s, schooling predicts growth among counties with more than 100 000 people. But this fact does not hold in the West even today, and it does not seem to hold during much of the nineteenth century. While SIMON and NARDINELLI (2002) documented a connection between skilled occupations and area growth since 1880, the present authors do not find much of a relationship between the share of the population with college degrees in 1940 and growth before 1900. Perhaps this just reflects the fact that one is forced to use an *ex-post* measure of education that may well be poorly correlated with skills in 1860 or 1880; but it seems as likely that the industrializing forces of the late nineteenth century just did not favour better educated areas.

The one persistent truth about population change in this group of counties is that growth strongly persists. With the exception of a single decade (the 1870s), the correlation between population growth in one decade and the lagged value of that variable is never less than 0.3 and typically closer to 0.5. Among counties with more than 50 000 people, the correlation between current and lagged population growth is never less than 0.4 in any decade. Over longer seventy-year time periods, however, faster growth in an early period is associated with lower subsequent growth. These facts are quite compatible with the view that growth is driven by epoch-specific forces, such as large-scale industrialization and the move to car-based living, that eventually dissipate.

This paper only has county income data since 1950, and as a result the authors have little ability to observe large historic shifts in this variable. In every decade except the 1980s there is a strong mean reversion in this variable; BARRO and SALA-I-MARTIN (1991) established mean reversion for state incomes going back to 1840. The connection between income growth and education or manufacturing has, however, varied from decade to decade. In the 1960s and 1970s, income growth was positively correlated with income growth during the previous decade, but that trend reversed after 1980. With the exception of mean reversion, universal laws about income growth seem no more common than universal laws about population growth.

One interpretation of the collection of facts assembled in the second section is that the eastern United States has experienced three distinct epochs. In the first sixty-odd years of the nineteenth century, the population spread out, especially towards colder areas with good soil quality and access to waterways. From the late nineteenth century until the 1950s, America industrialized and the population clustered more closely together, which set off a second growth spurt of the Great Lakes region. Over the past four decades, declining transport costs have led both to the spread of people across space, towards the Sun Belt, and the increasing success of skilled, entrepreneurial areas that thrive by producing new ideas. The early period of spatial concentration of US manufacturing at the beginning of the twentieth century and its dispersion in the last few decades are quite compatible with the work of DESMET and ROSSI-HANSBERG (2009a, 2009b, 2010), who suggested that innovative new industries cluster to benefit from knowledge spillovers while mature sectors spread out following technology diffusion.

After reviewing these stylized facts, the third section presents a model of human capital, entrepreneurship and urban reinvention. The model is meant to help one understand the strong connection between human capital and urban reinvention in the post-war period. The model suggests that the impact of skills on growth will differ depending on local conditions, and skills will be particularly valuable in places that are hit with adverse shocks. The model also suggests a decomposition that enables one to understand the channels through which human capital impacts on growth.

Skilled cities may grow because of faster productivity growth, perhaps due to greater entrepreneurship, as emphasized by the theory. They may also grow because of an expanding supply of housing, and GLAESER *et al.* (2006) found that human capital may predict increases in either the quantity or the price of housing, depending on the local regulatory environment. Finally, city growth responds to faster improvement in amenities, which skilled residents could induce through their demand as consumers and voters (SHAPIRO, 2006). The fourth section used data on population growth, income growth and changes in housing values to estimate the extent of the power of these different forces. It is found that the growth of skilled cities generally reflects growth in productivity rather than growth in amenities. The connection between growth and productivity seems strongest in the South and least strong in the West. The West is the only region where skills are associated with increases in the quality of life. It is also found that in the West more skilled areas have had less housing supply growth, which may reflect that tendency of skilled people to organize to block new construction. The paper also tries to separate out total productivity growth into growth in the number of employers and growth in the per-employer average productivity. It is found that skills are more strongly correlated with growth in per-employer average productivity. The fifth section turns to the connection between skills and urban resilience during the current recession. It looks at the strong negative connection between skills and unemployment and finds that this connection is larger than would be predicted solely on the basis of the cross-sectional relationship between education levels and unemployment rates. This fact is additional evidence for human capital spillovers at the city level, which may reflect the entrepreneurial tendencies of the more skilled. The sixth section concludes.

TEN STYLIZED FACTS ABOUT REGIONAL DECLINE AND RESILIENCE

This paper begins with a broad perspective on urban resilience and change in the older areas of the United States. The approach is non-standard. It follows economic historians such as KIM and MARGO (2004) and takes a very long perspective, going back, in some cases, to 1790. This longer perspective then forces one to focus on counties rather than on cities or metropolitan areas. County data are available for long time periods, and while it is possible to use modern metropolitan definitions to group those counties, the authors believe that such grouping introduces a considerable bias into the calculations. Since metropolitan area definitions are essentially modern, this paper would be using an outcome to define the sample, which introduces bias. Low-population areas in the nineteenth century would inevitably have to grow unusually quickly if they were to be populous enough to be counted as metropolitan areas in the twentieth century.

Also included are only counties in the eastern and central portions of the United States, to avoid having the results dominated by the continuing westward tilt of the US population. The western limit of the data is the 90th meridian (west), the location of Memphis, Tennessee; Mississippi can be thought of as the data's western border. Also excluded are those areas south of the 30th parallel, which excludes much of Florida and two counties in Louisiana, and those areas north of the 43rd parallel, which excludes some northern areas of New England and the Midwest. While data going back to the 1790 Census will be presented, the authors think of this area as essentially the settled part of the United States at the start of the Civil War, which allows the post-1860 patterns to be treated essentially as reflecting changes within a settled area of territory.

This section examines ten stylized facts about regional change using this sample of counties. These facts inform the later theoretical discussion and may be helpful in other discussions of urban change. In some cases these facts are quite similar to facts established using cities and metropolitan areas, but in other cases the county-level data display their own idiosyncrasies.

Fact 1: Population patterns have been remarkably persistent over long time periods

Perhaps the most striking fact about this sample of counties is the similarity of population patterns in 1860 and today. When the logarithm of population in 2000 is regressed on the logarithm of population in 1860, one finds:

$$\log(\text{Pop in 2000}) = \underset{(0.32)}{1.268} + \underset{(0.03)}{0.996} \cdot \log(\text{Pop in 1860}) \tag{1}$$

There are 1124 observations and $R^2 = 0.439$, which corresponds to a 66% correlation. Population in 2000 rises essentially one for one with population in 1860, as shown in Fig. 1. Some persistence is naturally to be expected because the housing stock of a city is durable (GLAESER and GYOURKO, 2005). But the finding implies furthermore that, over this long time horizon, Gibrat's law operates: the change in population is essentially unrelated to the initial population level.

If one restricts oneself to land even further east, using the 80th parallel as the boundary (about Erie, Pennsylvania), the following is estimated:

$$\log(\text{Pop in 2000}) = \underset{(0.58)}{-0.38} + \underset{(0.06)}{1.17} \cdot \log(\text{Pop in 1860}) \tag{2}$$

In this case there are only 306 observations, and R^2 rises to 0.57, which represents a 75% correlation between population in 1860 and the population in 2000 in this easternmost part of the United States. While urban dynamics in the United States often seem quite volatile, there is a great deal of permanence in this older region. In this sample there is a positive correlation between initial population levels and the rate of subsequent population growth, suggesting a tendency towards increased concentration.

Fact 2: Population growth persists over short periods but not over long periods

The permanence of population levels is accompanied by a remarkable permanence of population growth rates over shorter time periods. The first two columns of Table 1 show the correlation of population growth

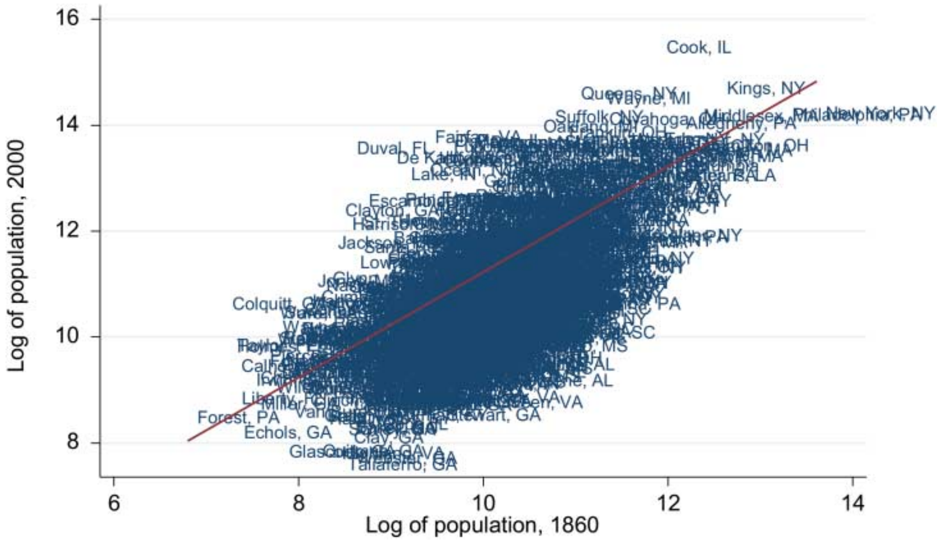

Fig. 1. *Stability of the population*
Source: County-level US Census data from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000

Table 1. *Population growth correlations*

Decade	(1) Correlation with lagged population change	(2) Correlation with lagged population change (50 000 or more)	(3) Correlation with initial log population	(4) Correlation with initial log population (50 000 or more)
1790s	.	.	–0.4681	–0.9505
1800s	0.3832	0.6462	–0.5625	0.1316
1810s	0.3256	0.4766	–0.5674	–0.0463
1820s	0.4423	0.5231	–0.5136	0.4178
1830s	0.4452	0.9261	–0.6616	0.2410
1840s	0.4634	0.8978	–0.5122	0.3922
1850s	0.4715	0.7661	–0.3190	–0.0392
1860s	0.3985	0.4631	0.0111	0.0065
1870s	–0.1228	0.4865	–0.3614	–0.0205
1880s	0.3978	0.4541	–0.1252	0.3323
1890s	0.4935	0.5382	–0.1181	0.3691
1900s	0.4149	0.6454	0.1754	0.2947
1910s	0.5027	0.5778	0.2747	0.0903
1920s	0.4760	0.4675	0.3381	0.1494
1930s	0.3005	0.4887	0.0415	–0.1585
1940s	0.4151	0.6752	0.3863	–0.0649
1950s	0.7397	0.7327	0.3985	0.0444
1960s	0.7225	0.8196	0.2922	0.0311
1970s	0.3821	0.4349	–0.2247	–0.4462
1980s	0.6410	0.7096	0.1062	–0.0693
1990s	0.7370	0.7863	–0.0197	–0.1570

Source: County-level data are from Inter-University Consortium for Political and Social Research (ICPSR) 2896: *Historical, Demographic, Economic, and Social Data: The United States, 1790–2000.*

rates, measured with the change in the logarithm of population, and the lagged value of that variable. The first column shows results for the entire sample. The second column shows results when the sample is restricted to include only those counties that have 50 000 people at the start of the lagged decade.

Column (1) shows that in every decade, except for the 1870s, there is a strong positive correlation between current and lagged growth rates. Between the 1800s and the 1860s, the correlation coefficients range from 0.32 to 0.47. Then during the aftermath of the Civil War there is a reversal, but starting in the 1880s, the pattern resumes again: between the 1880s and the 1940s, the correlation coefficients lie between 0.30 (the Great Depression decade) and 0.50 (the 1910s). During the post-war period, the correlations have been even higher, with correlation coefficients above 0.64 in all decades except for the somewhat unusual 1970s.

The pattern of persistence for more populous counties is even stronger. Over the entire period, the correlation coefficient never drops below 0.43. Except for the 1950s, the correlation coefficient is always higher for more populous counties than for smaller ones. The autocorrelation of growth rates for more populated counties was particularly high during the decades before the Civil War, when big cities were expanding rapidly in a more or less parallel path, and during more recent decades.

While short-term persistence is very much the norm for population growth rates, over longer periods growth rates can be negatively correlated. For the fifty-four counties that began with more than 50 000 people in 1860, an extra 10% growth between 1860 and 1930 was associated with a lower 2.5% growth rate between 1930 and 2000, as shown by Fig. 2. This negative correlation does not exist for the larger sample, but given that the persistence of decadal growth rates was even stronger among the counties with greater population levels the reversal is all the more striking. This negative relationship is the first indication of the changes in growth patterns over the 1860–2000 period. It suggests that different counties were growing during different epochs, and perhaps that fundamentally different forces were at work. The paper now turns to the relationship between initial population and later population growth, which is commonly called Gibrat's law.

Fact 3: Gibrat's law is often broken

In studies of the post-war growth of cities and metropolitan areas, population growth has typically been found to be essentially uncorrelated with initial population levels in both the United States and elsewhere (GLAESER *et al.*, 1995; EATON and ECKSTEIN, 1997; GLAESER and SHAPIRO, 2003). GABAIX (1999), EECKHOUT (2004), and CÓRDOBA (2008) used this regularity to explain the size distribution of cities. The long-run population persistence fact has already shown that Gibrat's law also seems to hold in the sample over sufficiently long time periods. In the entire sample, the correlation between change in log population between 1860 and 2000 is –0.0034 and the estimated coefficient in a regression where change in the logarithm of population is regressed on the initial logarithm of population is –0.0038, with a standard error of 0.033. There is also no correlation between the logarithm of population in 1950 and population change over the fifty years since then.

But Gibrat's law does not hold for many decades within the sample. Column (3) of Table 1 shows the correlation between the initial logarithm of population and the subsequent change in the logarithm of population over the subsequent decade. Column (4) shows the correlation only for more populous counties, those with at least 50 000 people at the start of the decade. Table 1 shows that Gibrat's law holds during some time periods, but certainly not uniformly.

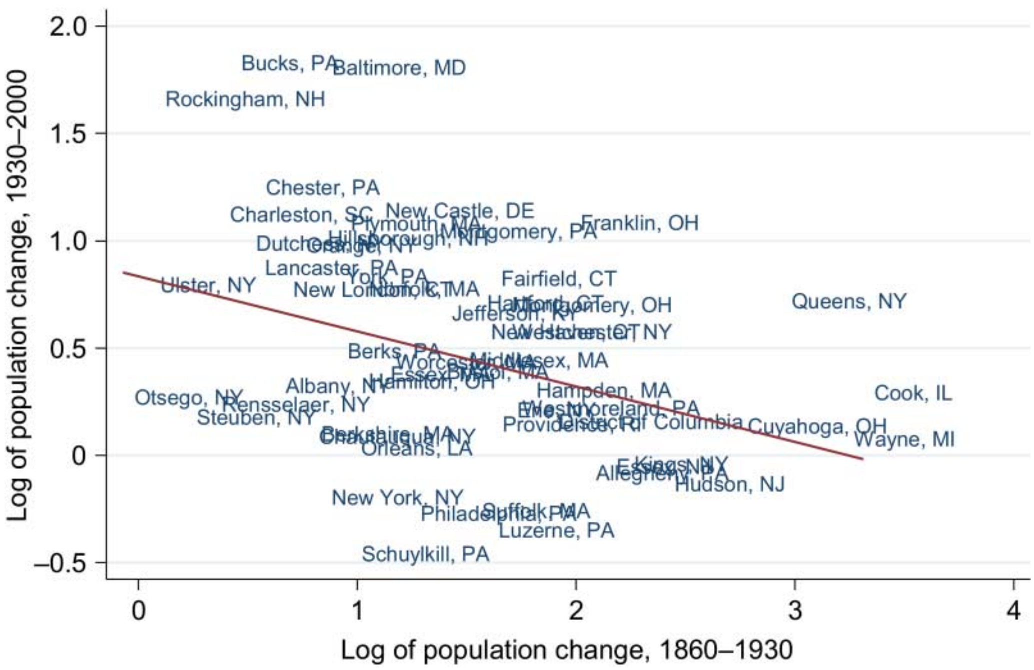

Fig. 2. Negative correlation of population changes

Note: The figure shows the fifty-four counties that had more than 50 000 people in 1860.

Source: County-level US Census data from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000

During the nineteenth century (with the exception of the 1860s), population growth is strongly negatively associated with initial population levels, especially in places that began with fewer people. This period is not marked by Gibrat's law at all – it is marked by mean reversion, as Americans spread out towards less populated counties. This process reflects improvements in transportation over this time period, and the great demand for newly accessible agricultural land.

While the entire sample is showing strong mean reversion, during the same period there is a positive, but usually insignificant, correlation between initial population levels and later growth in more populous counties. The pattern in this period is perhaps best understood as two separate processes that are going on simultaneously. Cities are getting bigger, as America grows, but empty farm areas are also gaining population.

This early period reflects the settlement of the region, and it can be considered anomalous and unrelated to patterns that should be expected to hold in a more mature area. The paper therefore focuses more on the twentieth century, when the eastern United States is more mature; but even then, Gibrat's law often fails to hold.

From the 1910s to the 1960s there was a long period where Gibrat's law, more or less, applies for more populated counties, but the larger sample shows faster population growth in places with higher initial levels of population. The process of centralized big city growth had become far weaker, but there was more growth in middle-population counties. This also reflects the relative decline of agriculture during those years and the fact that agriculture was overrepresented in the least dense counties.

Finally, from 1970 to 2000, the correlations between initial population and later growth are generally negative, especially in the most populous counties. This presumably reflects some of the impact of sprawl and the role that the automobile played in dispersing the American population.

Table 2. Geography correlation tables

Decade	(1) Correlation with longitude	(2) Correlation with proximity to the Great Lakes	(3) Correlation with January temperature
1790s	−0.2646	0.3746	−0.0008
1800s	−0.4368	0.4307	−0.2260
1810s	−0.3496	0.4473	−0.1891
1820s	−0.2857	0.3053	−0.1514
1830s	−0.3304	0.2631	−0.2676
1840s	−0.3414	0.1442	−0.2424
1850s	−0.3145	0.0703	−0.3466
1860s	−0.1495	0.1028	−0.3229
1870s	−0.0460	−0.1188	0.2575
1880s	−0.0256	−0.0336	0.1571
1890s	−0.1145	−0.0771	0.2273
1900s	0.1159	0.0153	0.1339
1910s	0.1448	0.1185	−0.0050
1920s	0.1733	0.1182	−0.0802
1930s	−0.0144	−0.0462	0.0379
1940s	0.2431	0.1665	−0.1300
1950s	0.2401	0.2075	−0.1843
1960s	0.1313	0.0915	−0.1062
1970s	−0.0435	−0.1630	0.2088
1980s	0.1974	−0.1107	0.2243
1990s	−0.0027	−0.1567	0.2702

Sources: County-level data are from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000. Geographical information is from ESRI GIS data.

Fact 4: The nineteenth century moved west; the twentieth century moved east

Just as Gibrat's law is hardly universal, there is also no universal pattern of horizontal movement within the region considered. During the nineteenth century, the norm was to move west, but that reversed itself during much of the twentieth century, within the restricted sample of counties. The paper focused on the eastern, central parts of the United States to reduce the impact of the enormous changes associated with the move to California and later to Florida. But that does not mean that there was not a westward push during much of nineteenth century. Table 2 shows the correlation between longitude and population growth by decade across the sample. Over the entire time period, there is no statistically significant correlation between population growth and longitude.

During every decade in the nineteenth century, growth was faster in the more western counties in the sample. This connection is strongest before the Civil War, when America is moving towards the Mississippi, but even as late as the 1890s, there is a weak negative relationship between longitude and population growth. The more interesting fact is that since 1900, there is a move back east, at least in this sample. In every decade, except for the 1930s, longitude positively predicts growth. One interpretation of this fact was that the gains from populating the Midwest declined substantially after 1900, perhaps because America had become a less agricultural nation. According to this hypothesis, the eastern counties grew more quickly because they were better connected with each other and more suitable for services and manufacturing, and the agricultural communities declined. Since the 1970s, the connection between population growth and longitude has essentially disappeared.

Fact 5: The Great Lakes region grew during two distinct periods

In the early nineteenth century, waterways were the lifeline of America's transportation network, and the Great Lakes were the key arteries for the network. The paper calculates the distance between the county centre and the centre of the nearest Great Lake.[2] It then defines proximity to the Great Lakes as the maximum of 200 minus the distance to the Great Lake centroid or zero.[3]

The second column of Table 2 shows the correlation between population growth and this measure of proximity to these large central bodies of water. Between 1790 and 1870, the correlation is uniformly positive, ranging from 0.07 during the 1850s to 0.44 during the 1810s. The early nineteenth century was the period when the Great Lakes had the strongest impact on population growth, which is not surprising since there were few other workable forms of internal transportation in the pre-rail era.

Between 1870 and 1910, the correlation between proximity to the Great Lakes and growth is generally negative and quite weak. It turns out that this negative correlation is explained by the positive relationship between proximity to the Great Lakes and population levels in 1870 (correlation coefficient = 0.28). When one controls for population in 1870, there is no negative correlation between proximity to the Great Lakes and population growth between 1870 and 1900. Still, the absence of a positive relationship can be seen as an indication that the growing rail network had made access to waterways far less critical during the latter years of the nineteenth century.

Between 1910 and 1960, there is again a positive correlation between proximity to the Great Lakes and growth. Fig. 3 shows the 0.33 correlation for counties within 200 miles of the Great Lakes. During this era of industrial growth and declining agricultural populations, factories grew in cities, like Detroit, that had once been centres of water-borne commerce. In some cases, the waterways were still important conduits for inputs and outputs. In other cases, industry located along the Great Lakes because this is where population masses were already located – about 44% of the positive correlation disappears when one controls for population in 1910.

After this second surge of Great Lakes population growth, the region declined after 1970. Many explanations have been given for the decline of the Rust Belt, such as high union wages and an anti-business political environment (HOLMES, 1998), a lack of innovation in places with large plants and little industrial diversity, and the increasing desire to locate in sunnier climates. The model below formalizes how technological progress has reduced the importance of logistical advantage conferred by the Great Lakes, thereby inducing a population shift towards regions with greater consumption amenities (GLAESER *et al.*, 2001).

Fact 6: The Sun Belt rose both after 1870 and after 1970

The third column in Table 2 shows the correlation between population growth and January temperature between 1790 and today. In every decade from the 1790s to the 1860s, colder places show faster growth, as the North was gaining population relative to the South. Several factors explain this phenomenon. Many Northern areas had better farmland and they had a denser network of waterways. Industrialization came first to the North. Some illnesses, like malaria, were more prevalent in the South. For every extra 1°C of January temperature, population growth fell by 0.038 log points between 1810 and 1860, and by

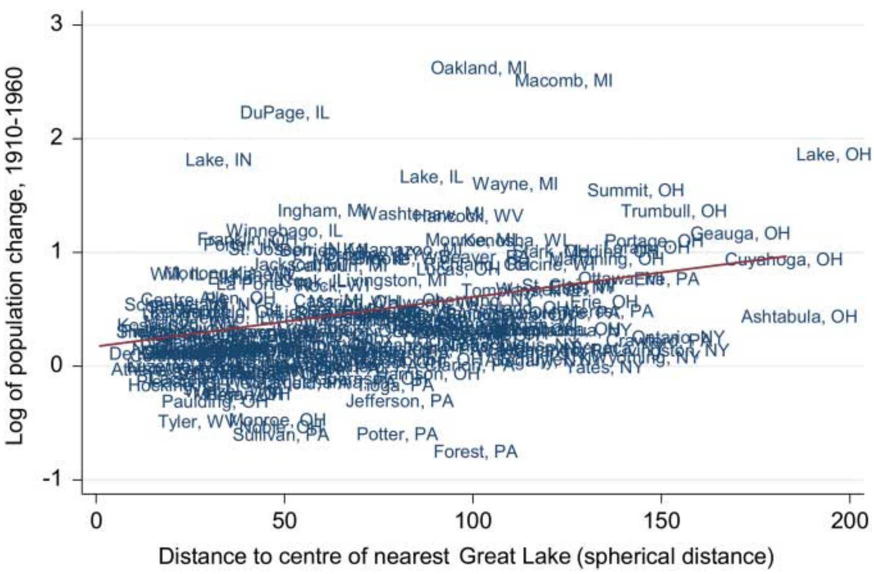

Fig. 3. Population growth and the proximity to the Great Lakes
Note: The figure shows the counties that are within 200 miles of a Great Lake.
Source: County-level US Census data from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000

1860, the correlation between county population levels and January temperature was –0.41.

After the Civil War, the relationship between temperature and population growth reversed itself. In every decade from the 1870s to the 1900s, population growth was positively associated with January temperature. Every extra 1°C of January temperature was associated with 0.01 log points of growth between 1880 and 1910.[4] The effect of January temperature is strongest in less dense areas and the effect disappears in more populous counties. This may reflect higher fertility among the poorer and less educated Southern population (STECKEL, 1978). Increasing rail densities in the South may also have made farming in more remote areas more attractive.

The relationship between January temperature and population growth then disappears between 1910 and 1970. The correlation is weak, and if anything negative. Moreover, it is largely explained by the positive correlation between initial population levels and later growth: controlling for initial population, the effect of January temperature on growth during the entire 1910–1970 period is indistinguishable from zero. The coefficients become significantly positive once the sample is restricted to counties with more than 50 000 people in 1910, consistent with previous evidence on city growth (GLAESER and TOBIO, 2008). Before 1970, people were moving to warmer cities, but not to warmer rural areas.

The three decades since have seen a remarkable rise of the Sun Belt. From 1970 to 2000 warmth is a strong positive predictor of population growth for all counties, and an extra 10°C of January temperature is associated with an extra 0.1 log points of population growth.

Table 3 shows the impact of initial population, January temperature, proximity to the Great Lakes and longitude in multivariate regressions for six different thirty-year periods.[5] Differences across columns remind one that all variables had different impacts in different epochs, and that regional growth can only be understood by bringing in outside information about changing features of the US economy.

In the antebellum era, the US population was spreading out: proximity to the Great Lakes had a positive impact on growth, while longitude, January temperature and especially initial population had a negative impact. The overall explanatory power of these variables drops significantly for the late nineteenth century. Warmer areas grew more quickly, although the undercounting of the Southern population in the 1870 Census means that this coefficient should be cautiously interpreted. January temperature also had a positive effect on population growth from 1900 to 1930, but so did proximity to the East Coast and to the Great Lakes. Places with more initial population grew more quickly, reflecting the growth of big cities during those decades. Results for 1940–1970 are quite similar, except that January temperature is no longer significant. After 1970,

Table 3. Population growth regressions

	Change in population					
	(1)	(2)	(3)	(4)	(5)	(6)
	1800–1830	1830–1860	1870–1900	1900–1930	1940–1970	1970–2000
Average January temperature	–0.025	–0.033	0.008	0.007	–0.002	0.009
	(0.003)**	(0.003)**	(0.001)**	(0.001)**	(0.002)	(0.001)**
Distance to the centre of the nearest Great Lake	0.008	0.004	0.001	0.001	0.002	–0.001
	(0.001)**	(0.001)**	(0.000)*	(0.000)**	(0.000)**	(0.000)
Longitude	–0.038	–0.005	–0.000	0.011	0.017	0.008
	(0.005)**	(0.005)	(0.002)	(0.002)**	(0.003)**	(0.002)**
Log of population, 1800	–0.255					
	(0.025)**					
Log of population, 1830		–0.551				
		(0.021)**				
Log of population, 1870			–0.126			
			(0.014)**			
Log of population, 1900				0.125		
				(0.013)**		
Log of population, 1940					0.103	
					(0.012)**	
Log of population, 1970						–0.021
						(0.008)**
Constant	0.628	6.320	1.379	–0.407	0.523	0.872
	(0.57)	(0.505)**	(0.268)**	(0.263)	(0.28)	(0.213)**
Number of observations	368	788	1210	1276	1324	1338
R^2	0.63	0.60	0.14	0.11	0.13	0.09

Note: Standard errors are given in parentheses. *Significant at 5%; **significant at 1%.

Sources: County-level data are from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000. Geographical information is from ESRI GIS data.

Table 4. Income growth correlations

Decade	(1) Correlation with January temperature	(2) Correlation with lagged income	(3) Correlation with lagged income growth	(4) Correlation with share of manufacturing in 1950
1950s	0.4023	−0.5692		−0.1215
1960s	0.4807	−0.7732	0.2888	−0.4119
1970s	0.3107	−0.6857	0.3303	−0.4911
1980s	0.1842	0.0904	−0.2839	0.0860
1990s	0.0700	−0.3492	−0.1966	−0.2710

Source: County-level data are from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000.

January temperature becomes the most powerful predictor of county-level growth. Population moves east rather than west. Initial population is negatively associated with growth, which presumably reflects the growth of sprawl. Proximity to the Great Lakes has a slight negative impact on county-level population growth.

For the post-war period there are also income data that can help one make more sense of the growth of the South during this period. Table 4 shows the correlation of county median incomes and other variables.[6] The correlation between income growth and January temperature is highest in the 1950s and 1960s, when the connection between January temperature and population growth is weakest. During this era the Sun Belt was getting much more prosperous, but it was not attracting a disproportionate number of migrants. After 1970, the connection between January temperature and income drops considerably, though the correlation between population growth and January temperature rises. One explanation for this phenomenon, given by Glaeser and Tobio (2008), is that over the last thirty years, sunshine and housing supply have gone together. The South seems to be considerably more permissive towards new construction, which may well explain why three of the fastest growing American metropolitan areas since 2000 are in states of the old Confederacy (Atlanta, Dallas and Houston).

Fact 7: Income mean reverts

One explanation for Gibrat's law is that areas receive productivity shocks that are proportional to current productivity (Eeckhout, 2004). But that interpretation is difficult to square with the well-known convergence of regional income levels found by Barro and Sala-i-Martin (1991) and others. In the data sample, median incomes also mean revert. There are data on median income levels starting in 1950, and the second column of Table 4 shows the correlation between the decadal change in the logarithm of this variable and the logarithm of the variable.

Table 4 shows that during every decade except the 1980s, income growth was substantially lower in places that started with higher income levels. Overall, if median income was 0.1 log points higher in 1950, it grew by 0.066 log points less from 1950 to 2000, as Fig. 4 shows. Income in 1950 can explain 72% of the variation in income since then. While population levels persist, income levels generally do not.

Income convergence does seem to have fallen off after 1980, most notably during the 1980s and among larger cities. In the whole sample, as income in 1980 rises by 0.1 log points, income growth from 1980 to 2000 falls by 0.0049 log points. But the relationship is instead positive for counties that began with more

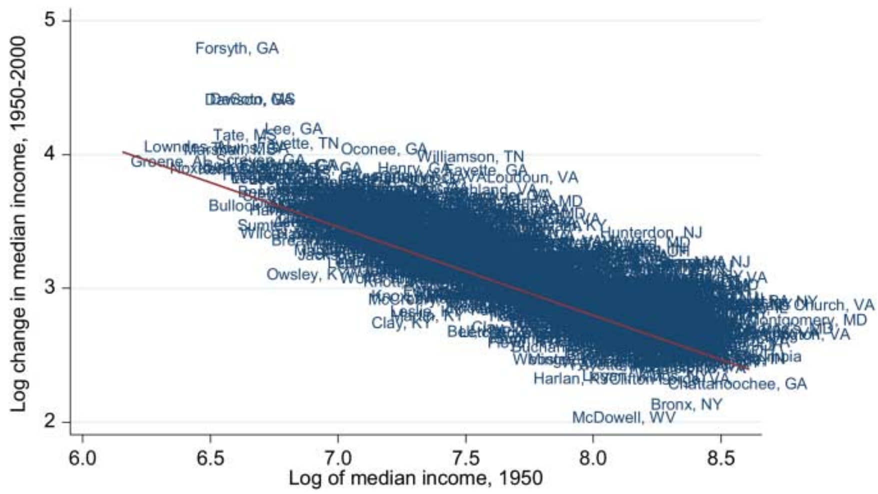

Fig. 4. Convergence of median incomes

than 50 000 people. This weakening of income convergence may be due to an increase in the returns to skill.

There is a positive correlation between population growth and initial income levels which may explain some of the income convergence. Between 1950 and 1980, an extra 0.1 log points of initial income was associated with a reduction in income growth of 0.06 log points and an increase in population growth of 0.03 log points. But given conventional estimates of labour demand elasticity (BORJAS, 2003), this population growth can only explain about one-fifth of income convergence. Other explanations for income convergence are that technology has spread over space, and capital mobility and the changing composition of the labour force. The last explanation, however, is troubled by the fact that the share of the population with college degrees has increased more quickly in places that had higher incomes in 1950; on average a 0.1 log point increase in 1950 incomes is associated with a 0.007% increase in the share of the adult population with college degrees.

Since 1980, higher income growth in one decade predicts lower income growth over the next ten years. This can be reconciled with the strong positive persistence of population growth if a steady flow of new people is pushing wages down in some areas.

Fact 8: Manufacturing predicts the decline of cities but not the decline of counties

Many papers have noted the negative correlation between concentration in manufacturing and subsequent urban growth (GLAESER *et al.*, 1995). This correlation does not appear in the county data. The share of the county's employment that is in manufacturing in 1950 is used as the measure of the concentration of the county in manufacturing at the start of the post-war era.

Fig. 5 shows that as the share of a county's workers in manufacturing in 1950 rises by 10%, subsequent population growth rises by 0.07 log points. The effect grows stronger if one controls for initial population, January temperature and proximity to the Great Lakes. It gets slightly weaker if one controls for initial income, because manufacturing counties had higher wages.

This positive correlation does not hold for the more populous counties, which presumably explains why city and metropolitan-area data show a negative connection between manufacturing and growth. If the sample is restricted to counties with more than 100 000 people in 1950, the correlation becomes negative. Manufacturing left cities, and cities that were highly concentrated in manufacturing declined.

At the county level, an initial concentration in manufacturing does not seem to have had such a negative impact. It does predict income decline in every decade except the 1980s: the last column in Table 4 shows that a 10% rise in the share of manufacturing in 1950 is associated with a 0.114 log point fall in median incomes between 1950 and 2000. However, once one controls for initial income, manufacturing is positively associated with income growth as well as population growth.

Again, the impact of manufacturing on income growth is more strongly negative in more populous counties. This reinforces the view that manufacturing has proven to be far worse for densely populated areas than for those with fewer people. Big factories seem a better match for moderate density levels (GLAESER and KOHLHASE, 2004).

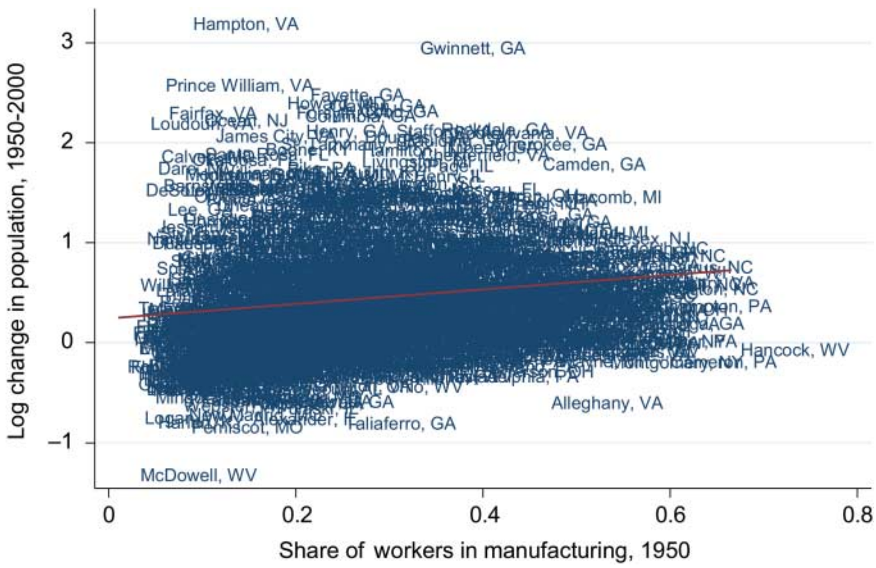

Fig. 5. Population growth and share in manufacturing, 1950
Source: County-level US Census data from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000

Fact 9: Education predicts post-war growth

A series of papers have also shown the connection between education and the success of cities (Rauch, 1993; Glaeser *et al.*, 1995; Simon and Nardinelli, 2002; Glaeser and Saiz, 2004; Shapiro, 2006). The present authors now ask whether this correlation also holds at the county level. Table 5 shows the correlation between the share of the adult population with college degrees and subsequent income and population growth. This is possible during every decade except 1960, and for that year the college attainment rates in 1950 are used instead.

The first column of Table 5 shows that college attainment and population growth have a strong positive correlation in the sample. In the long run, as the share of the population with college degrees increases by 10% in 1940, population growth between 1940 and 2000 increases by 0.13 log points. Over shorter periods, the positive effect is strongest in the 1950s and 1960s, and it holds in every decade but the 1970s, when there is a negative correlation that becomes insignificant when one controls for the logarithm of 1970 population.

The second column of Table 5 shows results for income growth. Across the entire sample, there is a negative relationship between initial education and subsequent income growth. This is certainly not true across cities or metropolitan areas. Across counties, the effect is primarily due to mean reversion in median incomes. Controlling for initial log income, the estimated coefficients for the initial share of the population with college degrees are always positive, and they are statistically significant for the 1950s (0.89), the 1960s (0.55, using college attainment in 1950), and the 1980s (0.9). More educated places seem to be growing both in population and income, once one accounts for the tendency of incomes to revert to the mean.

Glaeser and Resseger (2010) presented evidence suggesting that skills have more impact in larger cities. In theory, urban density is more valuable when it connects people who have more to teach one another. The last two columns of Table 5 focus on those counties that begin the decade with at least 100 000 people. Column (3) shows the population growth correlations, which are uniformly positive, but not always larger than those observed in the entire sample. Column (4) shows that the correlation between income growth and education is always more positive for more populous counties than for the entire sample. In the 1950s and 1960s, when skills were negatively associated with income growth in the entire sample, skills were positively associated with income growth in more populous counties. These results support the view that there is a complementarity between skills and density.

Table 6 presents two regressions looking at the entire 1950–2000 period. In the first regression, income growth is the dependent variable. In the second regression, population growth is the dependent variable. Included as controls are January temperature, longitude and distance to the Great Lakes. The logarithms of initial education and population are controlled for. The share of employment in manufacturing, the share of the population with college degrees, and an interaction between the logarithm of the 1950 population and the share of the population with college degrees are also included. The initial population has been normalized by subtracting the mean of that variable in this sample; this enables one to glean the impact of education for the mean city with the coefficient in the regression.

Initial income strongly predicts subsequent income declines and significant population increases. Initial population is negatively associated with both income and population growth. Proximity to the East Coast, longitude and manufacturing are positively correlated with both income and population growth. Proximity to the Great Lakes has no impact on population growth, but a negative correlation with income growth.

Education has a positive effect on both income and population growth. At the average initial population level, as the share of adults with college degrees in 1950 increases by 3% (about 1 SD (standard deviation)), subsequent population growth increases by slightly more than 0.12 log points (about 12%) and income growth rises by around 7%. These effects are statistically significant and economically meaningful.

Table 5. Education correlations

Decade	(1) Population correlation with lagged BA share	(2) Income correlation with lagged BA share	(3) Population correlation with lagged BA share (100 000 or more)	(4) Income correlation with lagged BA share (100 000 or more)
1940s	0.5904		0.3332	
1950s	0.4820	–0.2517	0.3634	0.0291
1960s	0.3758	–0.3864	0.3460	0.1586
1970s	–0.0961	–0.3690	0.1122	–0.0391
1980s	0.3194	0.3564	0.3908	0.4739
1990s	0.1269	–0.2334	0.2396	–0.1017

Note: BA, bachelor's degree.
Source: County-level data are from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000.

Table 6. Income and population growth regressions, 1950–2000

	Income growth	Population growth
Share of workers in manufacturing, 1950	0.3025	0.5597
	(0.05)	(0.1369)
Log of population, 1950	–0.0868	–0.2817
	(0.0139)	(0.0381)
Mean January temperature	–0.0003	0.0198
	(0.0008)	(0.0022)
Longitude	0.0048	0.0107
	(0.0012)	(0.0032)
Distance to the centre of the nearest Great Lake	–0.0009	–0.0007
	(0.0002)	(0.0006)
Share with a bachelor degree, 1950	2.5141	4.3104
	(0.3098)	(0.8479)
Log of population/bachelor degree interaction, 1950	1.1749	2.7005
	(0.2127)	(0.5822)
Log of median income, 1950	–0.7392	0.4600
	(0.0221)	(0.0605)
Constant	8.8912	–3.2321
	(0.2083)	(0.57)
Number of observations	1328	1328
R^2	0.7476	0.1833

Sources: County-level data are from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000. Geographical information is from ESRI GIS data.

The effects of education on income and population growth are stronger for counties with higher initial levels of population. As the level of population increases by 1 log point (slightly less than 1 SD), the impact of education on population growth increases by 54% and the impact of education on income growth increases by 36%. Skills do seem, over the fifty-year period, to have had a particularly strong positive effect on income and population growth for areas that initially had higher levels of population.

While it is clear that skills matter during the post-war period, it is less clear whether skills were as important before the Second World War. The authors are limited by an absence of good education data during this earlier period, which is why SIMON and NARDINELLI (2002) focused on the presence of skilled occupations in 1900. Yet, because it seems worthwhile to know whether skilled places also grew in the nineteenth century, Table 7 shows the correlation between the share of the population with college degrees in 1940 and growth over the entire 1790–2000 period. There are at least two major problems with this procedure. First, skill levels change, and a place that is skilled in 1940 may well not have been skilled in 1840. One is only moderately reassured by the 0.75 correlation between the share of the population with college degrees in 1940 and the share of the adult population with college degrees in 2000. Second, it is possible that skilled people came disproportionately to quickly growing areas. Indeed, there is a strong positive correlation (0.61) in the sample between population growth between 1940 and 2000 and the growth in the share of the population with college degrees over the same period.

Despite these caveats, Table 7 shows the correlations over the long time period. The first column includes all the counties; the second column shows results only for those counties with more than 50 000 people at the start of the decade. Table 7 shows a strong positive correlation between skills in 1940 and growth in population for most of the twentieth century. In the nineteenth century, education was largely uncorrelated with growth across the entire sample. Among more populous counties, the correlation is generally positive after 1820. One interpretation of these differences is that there was a complementarity between cities and skills even in the nineteenth century. A second interpretation is that skills in 1940 are a reasonable proxy for skills in the nineteenth century among more populous counties, but not for sparsely populated areas that presumably changed more over the century.

Those different interpretations yield different conclusions about the long-run correlation between skills and population growth. If the latter interpretation is correct, and the correlation disappears because skills in 1940 do not correlate with nineteenth-century skills, then the skills–growth correlation may be the one relationship that holds virtually over the entire sample. If, however, the former interpretation is correct, then the relationship between skills and growth is, like everything else that has been looked at, a phenomenon that holds only during certain eras.

MORETTI (2004) and BERRY and GLAESER (2005) reported a positive correlation between initial levels of education and education growth over the post-war period. The present paper confirms this powerful fact with the cross-county data. It looks at the relationship between change in the share of population with college degrees between 1940 and 2000 and the share of the population with college degrees in 1940. Over the entire sample, the following relationship can be estimated:

$$\begin{aligned}&\text{Change in share with BAs } 1940-2000\\ &\quad= \underset{(0.003)}{0.048} + \underset{(0.088)}{2.66} \cdot \text{Share with BAs in } 1940\end{aligned} \qquad (3)$$

Standard errors are given in parentheses. There are 1326 observations; and $R^2 = 0.4$. As the share with college degrees in 1940 increases by 2%, growth in the share of college degrees increases by 5.32%. Fig. 6 illustrates this relationship.[7] The only decade in which there is no positive correlation between initial schooling and subsequent growth in schooling is the 1940s. Afterwards, schooling uniformly predicts

Table 7. Education and firm size correlations with population growth

Decade	(1) Correlation with a share of BAs in 1940	(2) Correlation with a share of BAs in 1940 (50 000 or more)	(3) Correlation with average estimated size in 1977	(4) Correlation with average estimated size in 1977 (50 000 or more)
1790s	0.0105	–0.3090	0.1152	0.2688
1800s	–0.1012	0.3758	0.0627	0.7698
1810s	–0.0960	–0.2574	0.0142	0.3910
1820s	–0.0543	0.3583	0.1338	0.7404
1830s	–0.0102	0.5014	0.0930	0.7733
1840s	–0.0080	0.3810	0.1130	0.5929
1850s	0.0208	0.1145	0.0651	0.0149
1860s	0.1457	0.0671	0.0779	0.2524
1870s	–0.1386	–0.0157	0.0134	0.2407
1880s	0.0079	0.1089	0.1676	0.3557
1890s	–0.1269	0.0522	0.0751	0.2893
1900s	0.1711	0.2133	0.2220	0.2529
1910s	0.2265	0.1866	0.3172	0.3638
1920s	0.4162	0.3581	0.3476	0.2414
1930s	0.2304	0.3216	0.1594	0.0225
1940s	0.5904	0.5613	0.3336	0.1356
1950s	0.4953	0.3619	0.2273	0.0286
1960s	0.3830	0.3298	0.1259	–0.0974
1970s	–0.1614	–0.1199	–0.1786	–0.3530
1980s	0.1129	0.0806	–0.0862	–0.3212
1990s	–0.0878	–0.1116	–0.1715	–0.2893

Note: BA, bachelor's degree.
Source: County-level data are from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000.

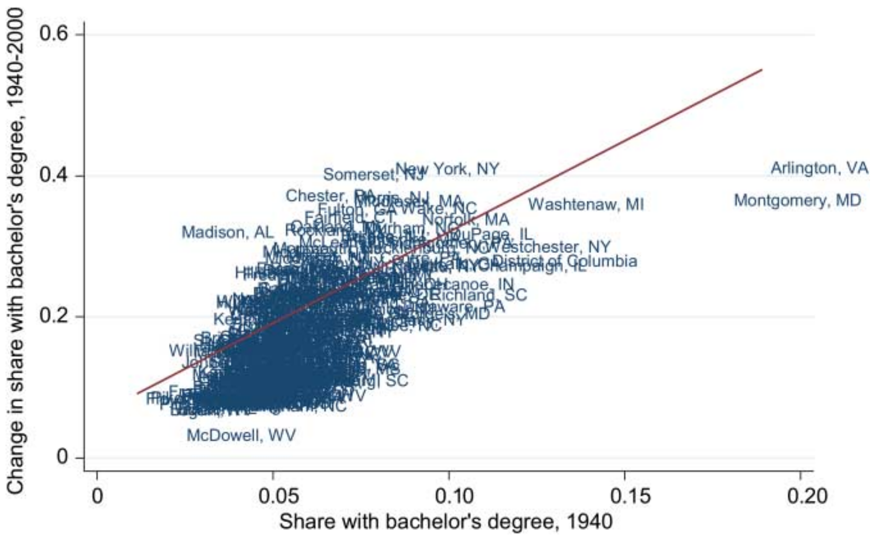

Fig. 6. Growth in the share of the population with a bachelor's degree
Note: The figure shows the counties that had more than 50 000 people in 1940.
Source: County-level US Census data from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000

schooling growth. In the 1970s, 1980s and 1990s, the correlation coefficients between initial schooling and subsequent increases in the share with college degrees are 0.57, 0.66 and 0.54, respectively. One of the reasons why initially skilled places have done so well is quite possibly that they have attracted more skilled people over time.

Fact 10: Firm size is strongly correlated with employment and income growth after 1980

GLAESER *et al.* (1992) found a strong negative correlation between average firm size and subsequent growth across large industrial groups within metropolitan areas. GLAESER *et al.* (2010) showed that smaller firm size predicts growth both across and within metropolitan areas. The last fact is that firm size is correlated with population and income growth across the sample of counties.

Firm size is typically measured by looking at the ratio of the number of establishments to the number of employees within a metropolitan area or industrial cluster. In the case, the 1977 County Business Patterns data are used and the average number of employees per establishment in each county in the sample is calculated. The variable ranges from 2.9 to 35, with a sample mean of 12.74. There is a strong positive correlation between county population and average establishment size.

Table 8 shows four growth regressions that include average establishment size. The first two look at population growth between 1980 and 2000. Columns (3) and (4) show results on growth in median income over the same two decades. Columns (1) and (3) look at the entire sample. Columns (2) and (4) look only at those counties that had at least 50 000 people in 1980. In all cases, the standing controls including the logarithms of initial income and population, the share of the labour force in manufacturing, the geographic controls and the initial share of the population with a college degree are included. The effect of these variables is unchanged from the previous regressions.

Regressions 1 and 2 both show the strong negative correlation between average establishment size and subsequent population growth. As average establishment size rises by four workers (approximately 1 SD), subsequent population growth declines by 0.06 log points across the entire sample. The effect is somewhat larger for more populous counties, where the decline is around 10 percentage points.

Regressions 3 and 4 show the strong negative connection between average establishment size and income growth. As average establishment size increases by four, income growth declines by 0.045 log points across the entire sample, and by 0.06 log points in the sample of more populous counties. These effects are comparable in magnitude with the education effect on income growth and even stronger statistically.

While larger establishment sizes do seem to predict less growth of income and population, it is less clear how to interpret these facts. GLAESER *et al.* (1992) interpreted the positive connection between small firm size and later growth as evidence on the value of competition. MIRACKY (1995) observed the same phenomenon and associated it with the product life cycle. While this remains one plausible interpretation, the fact that these connections occur within very finely detailed industry groups, and controlling for average establishment age, speaks against this interpretation. GLAESER *et al.* (2010) suggested that these connections suggest the value of local entrepreneurship. The authors prefer this latter interpretation, which will fit closely with the following model, but it is certainly acknowledged that other interpretations are possible. The authors also recognize that entrepreneurship has received multiple definitions

Table 8. Income and population growth regressions, 1980–2000

	Log change in population, 1980–2000		Log change in median income, 1980–2000	
	(1)	(2)	(3)	(4)
Decade	Full sample	Counties with 50 000 or more	Full sample	Counties with 50 000 or more
Share of workers in manufacturing, 1980	0.338	0.600	0.390	0.434
	(0.063)**	(0.117)**	(0.031)**	(0.052)**
Log of population, 1980	–0.017	–0.039	0.001	0.008
	(0.007)*	(0.013)**	(0.003)	(0.006)
Share with a bachelor's degree, 1980	0.493	0.830	0.966	0.846
	(0.145)**	(0.188)**	(0.071)**	(0.084)**
Distance to the centre of the nearest Great Lake	0.000	0.000	0.000	0.000
	(0.000)*	(0.000)**	(0.000)**	(0.000)**
Average establishment size, 1977	–0.016	–0.022	–0.011	–0.012
	(0.002)**	(0.003)**	(0.001)**	(0.001)**
Log of median income, 1980	0.519	0.646	–0.065	0.062
	(0.039)**	(0.071)**	(0.019)**	(0.032)
Longitude	0.005	0.001	0.006	0.007
	(0.002)**	(0.002)	(0.001)**	(0.001)**
Mean January temperature	0.010	0.009	–0.003	–0.004
	(0.002)**	(0.002)**	(0.001)**	(0.001)**
Constant	–4.629	–6.027	1.982	0.737
	(0.382)**	(0.663)**	(0.187)**	(0.297)*
Number of observations	1336	444	1336	444
R^2	0.28	0.45	0.31	0.52

Note: Standard errors are given in parentheses. *Significant at 5%; **significant at 1%.

Sources: County-level data are from ICPSR 2896 – Historical, Demographic, Economic, and Social Data: The United States, 1790–2000. Geographical information is from ESRI GIS data. Average establishment size in 1977 is from county business patterns.

and has proven difficult to measure empirically. The ultimate focus is on entrepreneurs as the drivers of change, innovation and productivity growth (AUDRETSCH, 1995). In practice, such entrepreneurial activity has been commonly proxied by business ownership rates and by the creation of new firms, while small firms have been increasingly recognized as key contributors to innovation (AUDRETSCH, 2003).

The last two columns of Table 7 also look at the correlation between firm size and growth during early decades. Average establishment size in 1977 is used an *ex-post* measure that raises all the concerns about using schooling in 1940 to proxy for education in the nineteenth century. In this case, the negative relationship between firm size in 1977 and growth is not present during earlier decades. Either the small firm size effect is specific to the past thirty years, or small firm size in 1977 does not capture small firm size during earlier years. Certainly, when GLAESER *et al.* (1992) looked at firm size in 1957, they found a negative correlation with subsequent growth.

THEORETICAL FRAMEWORK

This section now presents a model of regional change, skills and resilience. The model provides a framework that will enable one to understand better the reasons why skilled areas have grown more quickly over the past sixty years. In principle, it is possible that skilled places could have been growing more quickly because of improvements in productivity, amenities or housing supply. A formal framework is needed to help separate these competing explanations. The model will also deliver some intuition as to why skills have been so important in the older areas of the United States that seems to have been hit by adverse shocks after the Second World War.

Individual utility is defined over consumption of land, denoted L, and a constant elasticity of substitution (CES) aggregate of measure G of differentiated manufactured goods, each denoted $c(\nu)$. Thus:

$$U = \theta_i \left[\int_0^G c(\nu)^{\frac{\sigma-1}{\sigma}} \mathrm{d}\nu \right]^{\frac{\mu\sigma}{\sigma-1}} L^{1-\mu} \tag{4}$$

where $\theta_i > 0$ is a quality-of-life multiplier associated with the exogenous amenities of city i.

Each entrepreneur manufactures a differentiated variety employing labour according to the linear production function:

$$x(\nu) = a_i n(\nu) \tag{5}$$

where $x(\nu)$ is the output of firm ν; $n(\nu)$ is its workforce; and a_i is the productivity of entrepreneurs in city i. Appendix A derives the optimal pricing and hiring decisions of monopolistically competitive manufacturers.

City i is endowed with an exogenous number of entrepreneurs, denoted E_i. With an endogenous workforce of N_i full-time workers, its equilibrium wage is:

$$w_i = \frac{\sigma - 1}{\sigma} \left(\mu Y a_i^{\sigma-1} \frac{E_i}{N_i} \right)^{\frac{1}{\sigma}} \tag{6}$$

having normalized to unity the price index for the composite manufactured good.

City i has a fixed quantity of land, denoted by $\bar{L}_i$, which is owned by developers who reside in the city itself. Given the utility function (4), workers, entrepreneurs and developers all choose to spend a fraction $1 - \mu$ of their income on the consumption of land. Hence, equilibrium in the real-estate market implies that the price of land in city i is:

$$r_i = \frac{1-\mu}{\mu \bar{L}_i} \left[\mu Y E_i (a_i N_i)^{\sigma-1} \right]^{\frac{1}{\sigma}} \tag{7}$$

In an open-city model in which workers are fully mobile, their utility needs to be equalized across locations. Spatial equilibrium then requires:

$$\theta_i w_i r_i^{\mu-1} = \theta_j w_j r_j^{\mu-1} \text{ for all } i,\ j \tag{8}$$

A continuum of cities is considered, each of which is arbitrarily small compared with the aggregate economy. Then, letting:

$$N = \int N_j \mathrm{d}j$$

denote the aggregate size of the workforce, for each city i the equilibrium workforce is:

$$\log N_i = \kappa_N + \frac{\sigma \log\theta_i + \mu(\sigma - 1)\log a_i + \mu \log E_i + (1-\mu)\sigma \log \bar{L}_i}{\mu + \sigma - \mu\sigma} \tag{9}$$

where the constant κ_N is independent of idiosyncratic shocks affecting the city. Likewise, for given constants κ_w and κ_r equilibrium wages are:

$$\log w_i = \kappa_w + \frac{(1-\mu)\left[(\sigma-1)\log a_i + \log E_i - \log \bar{L}_i\right] - \log\theta_i}{\mu + \sigma - \mu\sigma} \tag{10}$$

and equilibrium rents:

$$\log r_i = \kappa_r + \frac{(\sigma - 1)(\log\theta_i + \log a_i) + \log E_i - \log \bar{L}_i}{\mu + \sigma - \mu\sigma} \tag{11}$$

The three constants κ_N, κ_w and κ_r are defined exactly in Appendix A.

A disaggregation of city-specific productivity into separate components for manufacturing and logistical efficiency enables the model to provide a simple account of the role of transport costs in the pattern of US regional dynamics during the latter part of the twentieth century. Specifically, let productivity in city i at time t be:

$$a_{i,t} = A_{i,t}\exp\left(-\frac{\Gamma_i}{T_t}\right) \tag{12}$$

In this decomposition, $A_{i,t}$ captures the productive efficiency achieved at time t by entrepreneurs in city i, measured by output per worker in their firms. However, delivering goods to the final consumer involves transportation and distribution costs such that for every x units shipped from a plant in city i, only $x\exp(-\Gamma_i/T_t)$ reach the final consumer, according to the conventional specification of 'iceberg' transport costs. The time-invariant city-specific parameter $\Gamma_i > 0$ is a measure of each city's natural logistical advantages, resulting from geographic characteristics such as access to waterways. The time-varying common parameter T_t measures the ability of transportation technology to overcome natural obstacles. The following result is then obtained.

Proposition 1. Advances in transportation technology reduce the share of the cross-city variance of population, income, and housing prices that is explained by heterogeneity in natural logistical advantages:

$$\frac{\partial^2 \mathrm{Var}(\log \Xi_{i,t})}{\partial T_t \partial \mathrm{Var}(\Gamma_i)} < 0 = \frac{\partial^2 \mathrm{Var}(\log \Xi_{i,t})}{\partial T_t \partial \mathrm{Var}(\theta_{i,t})} = \frac{\partial^2 \mathrm{Var}(\log \Xi_{i,t})}{\partial T_t \partial \mathrm{Var}(A_{i,t})} = \frac{\partial^2 \mathrm{Var}(\log \Xi_{i,t})}{\partial T_t \partial \mathrm{Var}(E_{i,t})} = \frac{\partial^2 \mathrm{Var}(\log \Xi_{i,t})}{\partial T_t \partial \mathrm{Var}(\bar{L}_{i,t})}$$

for all:

$$\Xi_{i,t} \in \{N_{i,t}, w_{i,t}, r_{i,t}\}$$

The stylized Fact 5 emphasized that the rise of the Great Lakes region was due to the crucial importance of proximity to the waterways through which most domestic trade used to flow. Over time, technological progress was a substitute for a favourable location: as transportation technology improved (an increase in T_t), natural harbours and geographic accessibility (Γ_i) came to matter less for regional success. Heterogeneity in amenities ($\theta_{i,t}$), housing supply ($\bar{L}_{i,t}$) and entrepreneurial achievement ($A_{i,t}$ and $E_{i,t}$) then acquired proportionally greater importance, leading to the rise of the Sun Belt (Fact 6) and the enduring success of cities and regions with the highest levels of human capital (Fact 9).

Through equations (9) to (11), the model provides the basis for the empirical work in the fourth section. It is assumed that for each city i and time t the values of $\theta_{i,t}$, $a_{i,t}$, $E_{i,t}$ and $\bar{L}_{i,t}$ evolve according to the dynamics:

$$\theta_{i,t+k} = \theta_{i,t}\exp\left(k\beta^{\theta}\cdot \mathbf{X}^i + \varepsilon^{\theta}_{i,t+k}\right) \tag{13}$$

$$a_{i,t+k} = a_{i,t}\exp\left(k\beta^{a}\cdot \mathbf{X}^i + \varepsilon^{a}_{i,t+k}\right) \tag{14}$$

$$E_{i,t+k} = E_{i,t}\exp\left(k\beta^{E}\cdot \mathbf{X}^i + \varepsilon^{E}_{i,t+k}\right) \tag{15}$$

$$\bar{L}_{i,t+k} = \bar{L}_{i,t}\exp\left(k\beta^{\bar{L}}\cdot \mathbf{X}^i + \varepsilon^{\bar{L}}_{i,t+k}\right) \tag{16}$$

The parameter vectors β^{θ}, β^{a}, β^{E} and $\beta^{\bar{L}}$ connect time-invariant city characteristics, denoted by $\mathbf{X}^i$, with growth in θ, a, E and $\bar{L}$, respectively. The terms $\varepsilon^{\theta}_{i,t+k}$, $\varepsilon^{a}_{i,t+k}$ $\varepsilon^{E}_{i,t+k}$, and $\varepsilon^{\bar{L}}_{i,t+k}$ are stochastic errors.

For any set of variables $\mathbf{X}^i$, one can then write:

$$\log N_{i,t+1} - \log N_{i,t} = \frac{\sigma\beta^{\theta} + \mu(\sigma-1)\beta^{a} + \mu\beta^{E} + (1-\mu)\sigma\beta^{\bar{L}}}{\mu+\sigma-\mu\sigma}\cdot \mathbf{X}^i + \varepsilon^{N}_{i,t} \tag{17}$$

$$\log w_{i,t+1} - \log w_{i,t} = \frac{(1-\mu)\left[(\sigma-1)\beta^{a} + \beta^{E} - \beta^{\bar{L}}\right] - \beta^{\theta}}{\mu+\sigma-\mu\sigma}\cdot \mathbf{X}^i + \varepsilon^{w}_{i,t} \tag{18}$$

where $N_{i,t}$ and $w_{i,t}$ are the number of workers and the wage level in city i at time t; and $\varepsilon^{N}_{i,t}$ and $\varepsilon^{w}_{i,t}$ are error terms.

A similar first difference for housing costs could be performed, but the data on property (real estate) typically involve home prices, which are a stock of value rather than a flow. The stock value of land in the model at time t, denoted $V_{i,t}$, can be interpreted as the discounted value of the flow of future land rents or future flow costs:

$$\begin{aligned} V_{i,t} &= E\left(\int_{k=0}^{\infty} e^{-\rho k} r_{i,t+k}\,\mathrm{d}k\right) \\ &= r_{i,t}E\left(\int_{k=0}^{\infty} e^{(g_r-\rho)k+\varepsilon^{r}_{t+k}}\,\mathrm{d}k\right) \end{aligned} \tag{19}$$

where:

$$g_r \equiv \frac{(\sigma-1)\left(\beta^\theta+\beta^a\right)+\beta^E-\beta^{\bar{L}}}{\mu+\sigma-\mu\sigma}\cdot\mathbf{X}^i \tag{20}$$

is the time-invariant expected growth rate of future rents; and ε^r_{t+k} the relative error term. For a time-invariant error distribution:

$$\log V_{i,t+1}-\log V_{i,t}=\log r_{i,t+1}-\log r_{i,t}$$
$$=\frac{(\sigma-1)\left(\beta^\theta+\beta^a\right)+\beta^E-\beta^{\bar{L}}}{\mu+\sigma-\mu\sigma}\cdot\mathbf{X}^i+\varepsilon^V_{i,t} \tag{21}$$

If then one has estimated coefficients for a variable, such as schooling, in population, income and housing-value growth regressions of B_{Pop}, B_{Inc} and B_{Val}, respectively, then by combining these estimated coefficients it is possible to uncover the underlying connections between a variable and growth in amenities, land availability, and entrepreneurship. Algebra yields the effect on residential amenities:

$$\beta^\theta_s=-B_{\text{Inc}}+\left(1-\mu\right)B_{\text{Val}} \tag{22}$$

on the supply of real estate:

$$\beta^{\bar{L}}_s=B_{\text{Pop}}+B_{\text{Inc}}-B_{\text{Val}} \tag{23}$$

and on productivity-increasing entrepreneurship:

$$\tilde{\beta}^E_s\equiv(\sigma-1)\beta^a_s+\beta^E_s=B_{\text{Pop}}+\sigma B_{\text{Inc}} \tag{24}$$

The last coefficient captures both the extensive margin of entrepreneurship, which corresponds to the creation of more numerous firms, and its intensive margin, namely the creation of more efficient firms. The two components can be disentangled through their different impact on average firm size, measured by employment per firm $n_i = N_i/E_i$, which evolves as:

$$\log n_{i,t+1}-\log n_{i,t}=$$
$$\frac{\sigma\beta^\theta+\mu(\sigma-1)\beta^\tau+\left(1-\mu\right)\sigma\left(\beta^{\bar{L}}-\beta^E\right)}{\mu+\sigma-\mu\sigma}\cdot \tag{25}$$
$$\mathbf{X}^i+\varepsilon^n_{i,t}$$

If an additional average firm size growth regression yields an estimated coefficient of B_{Siz}, it can be inferred that the effect on the intensive margin is:

$$\beta^a_s=\frac{\sigma B_{\text{Inc}}+B_{\text{Siz}}}{\sigma-1} \tag{26}$$

and the effect on the extensive margin is:

$$\beta^E_s=B_{\text{Pop}}-B_{\text{Siz}} \tag{27}$$

Endogenous entrepreneurship and responses to shocks

While the previous equations will serve to frame the empirical work in the fourth section, this section now focuses on the connection between skills, entrepreneurship and regional resilience. An adverse regional shock can be understood as a reduction Δ_i in the exogenous stock of entrepreneurs $\bar{E}_i$, due to death or technological obsolescence or migration, so only $\bar{E}_i-\Delta_i$ entrepreneurs remain. The ability of a region to respond to such a shock will depend on the production of new ideas. To address this, entrepreneurship is endogenize, and it is assumed that all workers are endowed with one unit of time that they can spend either working or engaging in entrepreneurial activity. The time cost of trying to become an entrepreneur is a fixed quantity t. If the worker becomes an entrepreneur, she has an individual-specific probability η of being successful. The value of an entrepreneurial attempt is thus $\eta\pi_i+(1-t)w_i$.

It is assumed that there is a distribution of η in the population such that the share of agents with probability of success no greater than η equals η^α for $\alpha\in(0,1)$.[8] Given this assumption, suppose that city i has a number M_i of potential entrepreneurs. All those with probabilities of success greater than $\bar{\eta}_i$ attempt entrepreneurship, while those with probability of success below $\bar{\eta}_i$ spend all their time as employees. Then the total number of entrepreneurs equals:

$$E_i=\bar{E}_i-\Delta_i+\frac{\alpha}{1+\alpha}\left(1-\bar{\eta}_i^{1+\alpha}\right)M_i \tag{28}$$

while the labour supply is:

$$N_i=\left[1-t\left(1-\bar{\eta}_i^\alpha\right)\right]M_i \tag{29}$$

These in turn determine wages w_i and firm profits π_i, as detailed in Appendix A. It is privately optimal for an agent to attempt entrepreneurship if and only if his probability of success is $\eta\pi_i\geq tw_i$. Thus, an equilibrium is given by:

$$\bar{\eta}_i=1\text{ if }M_i\leq(\sigma-1)t\left(\bar{E}_i-\Delta_i\right) \tag{30}$$

and if instead:

$$M_i>(\sigma-1)t\left(\bar{E}_i-\Delta_i\right)$$

by:

$$\bar{\eta}_i\in[0,1]\quad\text{such that}$$
$$\bar{\eta}_i=\frac{(\sigma-1)t}{1-t\left(1-\bar{\eta}_i^\alpha\right)}\left[\frac{\bar{E}_i-\Delta_i}{M_i}+\frac{\alpha}{1+\alpha}\left(1-\bar{\eta}_i^{1+\alpha}\right)\right] \tag{31}$$

which is uniquely defined since the right-hand-side is a monotone decreasing function of $\bar{\eta}_i$.

In particular, if $t = 1$, so people are either would-be entrepreneurs or employees, then the following result holds for a closed city with an exogenous number $\bar{M}_i$ of agents choosing between employment and entrepreneurship.

Proposition 2. In a closed city, both wages and the number of employers fall in response to a negative shock ($\partial \log w_i/\partial\Delta_i < 0$ and $\partial \log E_i/\partial\Delta_i < 0$), but their proportional decline is smaller in magnitude if the endogenous supply of entrepreneurs is more elastic ($\partial^2 \log w_i/(\partial\alpha\partial\Delta_i) \geq 0$ and $\partial^2 \log E_i/(\partial\alpha\partial\Delta_i) \geq 0$).

Proposition 2 delivers the connection between urban resilience and entrepreneurship in a closed-city framework. As older employers either go bankrupt or leave the city, this causes incomes in the city to decline. This negative shock can be offset by entrepreneurship, as a decline in wages causes entrepreneurship to become relatively more attractive. If the supply of entrepreneurship is more elastic, which is captured by a higher value of the parameter α, then there is a stronger entrepreneurial response to urban decline and the impact of a negative shock on incomes becomes less severe.

The closed-city model also allows one to shed light on the observed correlation between urban resilience and cross-city differences in average firm size.

Proposition 3. Consider a set of closed cities with identical size, $M_i = \bar{M}$ for all i. Both wages and the number of employers fall in response to a negative shock ($\partial \log w_i/\partial\Delta_i < 0$ and $\partial \log E_i/\partial\Delta_i < 0$), but their proportional decline is smaller in magnitude in cities with a lower initial average firm size ($\partial^2 \log w_i/(\partial\Delta_i\partial n_i) < 0$ and $\partial^2 \log E_i/(\partial\Delta_i\partial n_i) < 0$).

Keeping city size constant, higher firm density and smaller average firm size are the indication of greater entrepreneurship. When a negative shock hits, some firms are forced to shut down by exogenous forces such as the obsolescence of their product or the death of an entrepreneur. Although cushioned by the entry of new entrepreneurs, this blow implies a fall in the number of employers and in the local wage level. Intuitively, the crisis is more severe in cities that did not have a diversified set of firms to begin with, because those cities are reliant on a few large employers and thus suffer disproportionately from the disappearance of any single firm.

To extend the analysis to the open-city model, it is assumed that $t = 0$, so there is no time cost to entrepreneurship. In this case, everyone tries to be an entrepreneur, which means that $\bar{\eta} = 0$. In a closed city, it would remains true that $\partial w_i/\partial\Delta_i < 0$ and $\partial^2 \log w_i/(\partial\alpha\partial\Delta_i) > 0$, so a greater endogenous supply of entrepreneurs offsets the negative effects of an exogenous shock to the number of employers. When the city is open, it is assumed that people choose their location before the realization of their individual entrepreneurial ability η. Spatial equilibrium then requires $\theta_i y_i r_i^{\mu-1} = \bar{U}$ for all i, where $y_i \equiv w_i + \pi_i\alpha/(1+\alpha)$ denotes expected earnings. With a continuum of atomistic cities, the following result holds. = 1

Proposition 4. Expected earnings, the total number of employers, and the price of land decrease in the exogenous negative shock to the endowment of employers ($\partial y_i/\partial\Delta_i < 0$, $\partial E_i/\partial\Delta_i < 0$, and $\partial r_i/\partial\Delta_i < 0$) and increase in the endogenous supply of entrepreneurs ($\partial y_i/\partial\alpha > 0$, $\partial E_i/\partial\alpha > 0$ and $\partial r_i/\partial\alpha > 0$). The labour supply and city population ($\Lambda_i \equiv \bar{E}_i - \Delta_i + N_i$) increase in the endogenous rate of entrepreneurship ($\partial\Lambda_i/\partial\alpha = \partial N_i/\partial\alpha > 0$). If the endogenous supply of entrepreneurs is sufficiently elastic, population decreases with an exogenous negative shock to the endowment of employers ($\alpha \geq 1/(\sigma - 1) \Rightarrow \partial\Lambda_i/\partial\Delta_i < 0$).

In the limit case $\mu = 1$, the labour supply and city population both decrease with an exogenous negative shock to the endowment of employers ($\partial\Lambda_i/\partial\Delta_i < \partial N_i/\partial\Delta_i < 0$). Moreover, a greater endogenous supply of entrepreneurship mutes the proportional impact of a negative endowment shock on expected earnings, the total number of employers and city population ($d^2 \log y_i/(d\alpha d\Delta_i) > 0$, $d^2 \log E_i/(d\alpha d\Delta_i) > 0$ and $d^2 \log \Lambda_i/(d\alpha d\Delta_i) > 0$).

Proposition 4 makes the point that entrepreneurship can substitute for a decline in an area's core industries in a way that keeps population, earnings and real-estate values up. A higher rate of exodus for older industries will cause a city to lose both population and income, but that can be offset if the city also has a higher rate of new entrepreneurship.

What factors are likely to make entrepreneurship more common? One possibility is skilled workers have a comparative advantage at producing new ideas. To capture this intuition, it is assumed that there are two types of workers. Less skilled workers have one unit of human capital and have a value of $\alpha/(1+\alpha)$ equal to $\underline{\alpha}$. The assumption that skilled workers are more likely to be successful entrepreneurs is supported by the evidence given by GLAESER (2009). More skilled workers have $1 + H$ units of human capital, where $H > 0$, and have a value of $\alpha/(1+\alpha)$ equal to $\bar{\alpha}$. It is assumed that the high and low human capital workers are perfect substitutes in production and that the share of high human capital workers in city i is fixed at h_i (this is a closed-city model). In this case, the total number of employers is:

$$E_i = \bar{E}_i - \Delta_i + [h_i\bar{\alpha} + (1 - h_i)\underline{\alpha}]N_i \tag{32}$$

and the following result obtains.

Proposition 5. If $H\,\bar{E}_i/N_i + (1+H)\underline{\alpha} > \bar{\alpha} > (1+H)\underline{\alpha}$, then there exists a value $\bar{\Delta}_i \in (0, \bar{E}_i)$ of the exogenous negative shock for which changes in human capital have no impact on the wages earned by each type of worker ($\Delta_i = \bar{\Delta}_i \Leftrightarrow \partial w_i/\partial h_i = 0$). If Δ_i is above that value wages rise with the share of skilled workers ($\Delta_i > \bar{\Delta}_i \Leftrightarrow \partial w_i/\partial h_i > 0$), and if Δ_i is below that value wages decline with the share of skilled workers ($\Delta_i < \bar{\Delta}_i \Leftrightarrow \partial w_i/\partial h_i < 0$).

If $\bar{\alpha} \geq H\bar{E}_i/N_i + (1+H)\underline{\alpha}$, then wages for both classes of workers rise with the share of skilled workers ($\partial w_i/\partial h_i \geq 0$ for all $\Delta_i \in [0, \bar{E}_i]$), and if $\bar{\alpha} \leq (1+H)\underline{\alpha}$ wages for both classes of workers fall with the share of the population that is skilled ($\partial w_i/\partial h_i \leq 0$ for all $\Delta_i \in [0, \bar{E}_i]$).

Proposition 5 illustrates one way in which human–capital externalities might work. There are always two effects of having more skilled workers on earnings. More skilled workers can depress earnings because they are more productive and therefore lower the marginal product of labour when the number of employers is held fixed. But more skilled workers also increase the number of employers, and this causes wages to rise. If $\bar{\alpha}$ is higher than:

$$H\bar{E}_i/N_i + (1+H)\underline{\alpha}$$

so skilled workers have a real comparative advantage at innovation, then wages will always rise with the share of skilled workers. This is one way in which human capital externalities might operate.

The proposition also illustrates the connection between adverse shocks and the value of having more skilled workers in the city. When there is more adverse economic shock that destroys the stock of old employers, then it is more likely that skilled workers will increase wages for everyone. When the shock is less severe, then skilled workers are less likely to improve everyone's welfare.

Proposition 5 examines the potential impact that skills can have on urban wages and success in the face of a downturn. The human capital needed to innovate might also result from experience in management, especially of smaller firms. This will not be formally modelled, but note that the human capital needed to develop new firms may come from working in smaller, more entrepreneurial ventures. This would then be another reason why smaller firms are a source of urban resilience.

WHY DO EDUCATED CITIES GROW?

This section now turns to the primary statistical exercise of this paper: an examination of the link between education and metropolitan growth. Since the section is focusing entirely on this later period, it switches from counties to metropolitan areas to be in line with past research. It also uses data from the entire United States. It follows the work of SHAPIRO (2006) and GLAESER and SAIZ (2004) and attempts to assess the reasons why skilled cities might grow more quickly. It differs from these earlier studies in two primary ways. First, it estimates all the results for different regions. This enables one to estimate whether human capital has different effects in declining areas (for example, the Midwest) and growing areas. Second, it uses the methodology described in the third section, which enables one to assess whether human capital is increasing population growth because of increasing productivity (or entrepreneurship), amenities or housing supply.

One set of regressions focus on metropolitan area level regressions, where the basic method is to regress:

$$\log \frac{Y_{2000}}{Y_{1970}} = B_Y \cdot \text{Schooling}_{1970} + \text{Other Controls} \quad (33)$$

In this case, Y denotes one of three outcome variables: population, median income and self-reported housing values. Focus here is only on the long difference between 1970 and 2000. The second approach is to use individual data and estimate:

$$\log Y_t = \text{MSA Dummies} + \text{Individual Controls} + B_Y \cdot \text{Schooling}_{1970} \cdot I_{2000} \quad (34)$$

where Y in this case indicates either labour-market earnings or self-reported housing values. Data for 1970 and 2000 are pooled together. In the case of the earnings regressions, individual controls include individual schooling, age and race. In the case of the housing value regressions, individual controls include structural characteristics such as the number of bedrooms and bathrooms. In both cases, the coefficients on these characteristics are allowed to change by year and an indicator variable is included that takes on a value of 1 if the year is 2000.

The primary focus is on the coefficient B_Y which multiplies the interaction between the share of the adult population with college degrees in 1970 and the year 2000. Essentially, this coefficient is assessing the extent to which housing values and incomes increased in more educated places. This specification is preferred to the raw income growth or housing value growth regressions because these regressions can control for differences in the returns to various individual characteristics.

One novelty of the work here is that it estimates the impact of education separately by regions. To do this, B_Y is interacted with four region dummies, and thereby the impact of schooling on population, income and housing value growth is allowed to differ by region. These different regional parameter estimates will then imply different estimates of the underlying parameters found using the formulas of the last section.

Table 9 shows the results for metropolitan area-level regressions. In all regressions, the initial values of the

Table 9. Metropolitan area level regressions

	Log change in population, 1970–2000		Log change in median income in 2000 US$, 1970–2000		Log change in median housing value in 2000 US$, 1970–2000		Log change in population average firm size, 1970–2000	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log of population, 1970	–0.007	–0.007	0.003	0.003	0.056	0.057	–0.026	–0.027
	(0.019)	(0.019)	(0.006)	(0.006)	(0.013)**	(0.013)**	(0.013)*	(0.013)*
Log of median income in 2000 US$, 1970	–0.769	–0.841	–0.391	–0.403	–0.297	–0.328	–0.650	–0.643
	(0.191)**	(0.191)**	(0.061)**	(0.062)**	(0.133)*	(0.135)*	(0.131)**	(0.135)**
Log of median housing value in 2000 US$, 1970	0.273	0.272	0.173	0.174	–0.008	0.004	0.046	0.028
	(0.117)*	(0.115)*	(0.037)**	(0.038)**	(0.081)	(0.082)	(0.080)	(0.082)
South dummy	0.146	–0.133	0.030	0.015	0.028	0.012	–0.114	–0.163
	(0.054)**	(0.122)	(0.017)	(0.040)	(0.038)	(0.087)	(0.037)**	(0.087)
East dummy	–0.054	–0.077	–0.010	–0.039	0.054	0.041	–0.164	–0.282
	(0.057)	(0.158)	(0.018)	(0.052)	(0.040)	(0.112)	(0.039)**	(0.112)*
West dummy	0.384	0.632	–0.044	–0.145	0.299	0.052	0.012	0.084
	(0.051)**	(0.135)**	(0.016)**	(0.044)**	(0.035)**	(0.096)	(0.035)	(0.096)
College completion among the population aged twenty-five years or above, 1970	1.528		0.797		0.802		0.800	
	(0.445)**		(0.142)**		(0.310)*		(0.307)**	
South dummy * per cent BA, 1970		3.840		0.673		0.405		1.188
		(0.772)**		(0.252)**		(0.548)		(0.548)*
East dummy * per cent BA, 1970		1.498		0.839		0.424		1.859
		(1.310)		(0.428)		(0.929)		(0.929)*
West dummy * per cent BA, 1970		–0.573		1.364		2.257		0.211
		(0.812)		(0.265)**		(0.576)**		(0.576)
Midwest dummy * per cent BA, 1970		1.314		0.583		0.363		0.731
		(0.597)*		(0.195)**		(0.424)		(0.424)
Constant	5.264	6.074	2.275	2.407	2.801	3.040	6.741	6.888
	(1.576)**	(1.595)**	(0.504)**	(0.521)**	(1.100)*	(1.132)**	(1.086)**	(1.132)**
Number of observations	257	257	257	257	257	257	257	257
R^2	0.427	0.466	0.379	0.396	0.339	0.362	0.313	0.321

Note: BA, bachelor's degree. Standard errors are given in parentheses. *Significant at 5%, **significant at 1%.
Source: Metropolitan Statistical Area data and County Business Patterns from the US Census.

logarithm of population, median income and housing values are included. Also included are three region dummies (the Midwest is the omitted category). The first regression shows the overall impact of education in this sample. As the share of the adult population with college degrees increased by 5% in 1970, predicted growth between 1970 and 2000 increases by about 8%.

The other coefficients in the regression are generally unsurprising. Growth was faster in the South and the West. Gibrat's law holds and population is unrelated to population growth. Places with higher housing values actually grew faster, perhaps because their expensiveness reflected a higher level of local amenities. Places with higher incomes grew more slowly, perhaps reflecting the movement away from high-wage, manufacturing metropolitan areas.

The second regression allows the impact of education in 1970 to differ by region. The strongest effect appears in the South, where a 5% increase in the share of adults with college degrees in 1970 is associated with 19% faster population growth. The second largest coefficient appears in the Northeast. In that region, the coefficient is about the national average, even though it is not statistically significant. The coefficient is slightly smaller in the Midwest, where a 5 percentage point increase in the share of adults with college degrees in 1970 is associated with a 6.5 percentage point predicted increase in population between 1970 and 2000. In this case, however, the coefficient is statistically significant. In the West, the impact of education on population growth is negative and insignificant.

The third regression looks at median growth in income. Income mean reverts, but increases in high housing value areas, perhaps suggesting that wealthier people are moving to higher-amenity areas. Incomes rose by less in the West; the other region dummies are statistically insignificant. There is a strong positive effect of initial education levels, which reflects in part the returns to skill and the tendency of skilled people to move to already skilled areas. As the share of the population with college degrees in 1970 increased by 5%, median incomes increase by 4% more since then.

The fourth regression estimates different initial education by region. Education has a positive effect on income growth in all four regions. The biggest impact is in the West, where income growth increases by 0.07 log points as the share of the population with college degrees in 1970 increases by 5 percentage points. The smallest impact of education on income growth is in the Midwest, where the coefficient is less than half of that found in the West.

The fifth and sixth regressions turn to appreciation in median housing values. Housing values rose by more in more populous metropolitan areas. Prices increased somewhat less in initially higher-income areas, perhaps reflecting the mean reversion of income levels. Prices, however, did not themselves mean revert. The West had much more price appreciation than the other three regions. As the share of the population with college degrees in 1970 increased by 5 percentage points, housing values increased by about 4% more.

The sixth regression allows the impact of college education on housing-value growth to differ by region. In this case, a big positive effect in the West is found, and far smaller effects in all other regions. In the West, prices rose by more than 10% more as the share of the population with college degrees in 1970 increased by 5 percentage points. In the other regions, the impact of education is statistically insignificant and less than one-fifth of its impact in the West. It is notable that the region where education had its weakest impact on population growth is the area where it had its largest impact on housing-value growth. This difference shows the value of examining the impact of education by region.

The seventh and eight regressions examine the connection between education and average firm size. In the model, the number of firms per worker reflects the number of entrepreneurs in the area. If education is associated with a greater increase in population than in average firm size, then it is also associated with an increase in the number of firms, which is interpreted as an increase in the amount of entrepreneurship. In the seventh regression, a coefficient of 0.8 on college graduation rates across the whole sample is estimated. This coefficient is substantially lower than the population growth coefficient, so this suggests, at least according to the logic of the model, that the number of entrepreneurs is growing more quickly in more educated areas.

In the eighth regression, the coefficient on education is allowed to differ by region. The strongest effect is in the East; the weakest in the West. In both the East and the West, the coefficient on education is higher in the average firm size regression than in the population growth regression. The very strong coefficient on average firm size in the East appears to be driven by two types of metropolitan areas. There are some less educated metropolitan areas where firm size is dramatically decreasing, presumably because large plants are all closing. There are also some well-educated metropolitan areas, including Boston, where firm size is increasing dramatically, perhaps because of the dominance of certain big-firm industries, such as healthcare. In the West, more educated areas seem also to be moving into larger, rather than smaller, firm industries.

Table 10 turns to wages and housing values using individual-level data. It looks at annual earnings and restricts the sample to prime-age males (aged between twenty-five and fifty-five years), who work at least thirty hours a week and over forty weeks per year. These restrictions are meant to limit issues associated with being out of the labour force. Individual human-capital characteristics are controlled for, including years of experience and education, and the impact of these variables to differ by area is allowed for. As such, these coefficients can be understood as the impact of skills on area income growth correcting for the movement of skilled people across places and the rise in the returns to skill. All regressions also control for the initial levels of income, population and housing values, just like the metropolitan area-level regressions. There are also metropolitan statistical area (MSA) dummies in each regression, controlling for the permanent income differences between places.

The first regression shows a raw coefficient of 0.557, which implies that as the share of college graduates in a metropolitan area in 1970 increases by 5 percentage points, earnings rise by 0.028 log points more over the next thirty years. Comparing this coefficient with the coefficient on education (0.8) in regression 3 in Table 10 suggests that almost one-third of the metropolitan-area coefficient is explained by the rise in returns to skill at the individual level and increased sorting across metropolitan areas. The second regression adds in industry dummies, and the coefficient drops to 0.442.

The third regression compares the impact of education at the area level with education at the industry level in 1970. In this case, the MSA dummies are allowed to differ by year, so these effects should be understood as across industries but within metropolitan area. The cross-industry effect of education on income growth is also positive, but it is much weaker than the effect at the metropolitan area level.

Regressions 4 and 5 look at the impact of the initial education level in the MSA–Industry. It calculates the share of workers in that metropolitan area in that industry in 1970 with college degrees. It then controls for MSA–Year dummies and industry fixed-effects in regression 4. It is found that more skilled sectors are seeing faster wage growth. Regression 5 shows that this effect does not withstand allowing the industry effects, nationwide, to vary by year.

Regression 6 essentially duplicates regression 1 of Table 10 allowing the coefficient on education to differ by region. In this case, however, unlike the metropolitan area-level tables, it is found that there are few significant regional differences. The coefficient is slightly higher in the Northeast, but the effects are generally quite similar and close to the national effect.

Table 10. *Individual-level regressions*

	Log of real wage in 2000 US$					Log of real housing value in 2000 US$	
	(1)	(2)	(3)	(4)	(5)	(7)	(8)
Percentage of the population aged twenty-five years or over with a BA (1970), MSA, * year 2000 dummy	0.557 (0.195)**	0.472 (0.121)**				3.339 (1.278)**	
Percentage of the population aged twenty-five years or over with a BA (1970), Industry, * year 2000 dummy			0.089 (0.016)**				
Percentage of the population aged twenty-five years or over with a BA (1970), Industry–MSA, * year 2000 dummy				0.028 (0.008)**	0.002 (0.009)		
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects detail	MSAs	MSAs and Industry	MSA–Year and Industry	MSA–Year and Industry	MSA–Year and Industry–Year	MSAs	MSAs
Percentage of the population aged twenty-five years or over with a BA (1970), MSA, * year 2000 dummy * Northeast dummy							1.649 (0.738)*
Percentage of the population aged twenty-five years or over with a BA (1970), MSA, * year 2000 dummy * Midwest dummy							0.435 (0.690)
Percentage of the population aged twenty-five years or over with a BA (1970), MSA, * year 2000 dummy * South dummy							1.246 (0.632)*
Percentage of the population aged twenty-five years or over with a BA (1970), MSA, * year 2000 dummy * West dummy							3.734 (0.664)**
Constant	10.400 (0.017)**	7.254 (0.286)**	7.952 (0.307)**	7.426 (0.313)**	8.783 (0.344)**	10.843 (0.063)**	10.853 (0.062)**
Number of observations	402 490	402 490	377 891	364 266	364 266	426 295	426 295
R^2	0.33	0.38	0.38	0.38	0.39	0.36	0.36

Notes: BA, bachelor's degree; MSA, metropolitan statistical area.

(1) Robust standard errors are given in parentheses. Standard errors are clustered by MSA, Industry and Year (1)–(5) or MSA–Year (6)–(8).

(2) Wage regressions data are only for males aged twenty-five to fifty-five years, who are in the labour force, who worked thirty-five or more hours per week and forty or more weeks per year, and who earned over a certain salary (equal or more than if they had worked half-time at minimum wage).

(3) Individual-level data (wages, housing prices and controls) are from Integrated Public Use Microdata Series (IPUMS).

(4) MSA-level data (baPct1970 in MSA, population, log of real housing value, and log of real income) are from aggregate-level Census data.

(5) Wage regressions include controls for individual education, age and race, as well as the interaction of those variables with a dummy variable for year 2000. Housing regressions include housing quality controls as well as the interaction of those variables with a dummy variable for year 2000.

(6) Industry and Industry–MSA BA shares are calculated using IPUMS data.

(7) Includes controls for initial (1970) values for population, median income and median housing value interacted with a year 2000 dummy.

Regressions 7 and 8 estimate housing price appreciation using individual-level housing data and controlling for individual housing characteristics. Regression 7 shows the overall national coefficient of 3.3. Regression 8 estimates different effects by region, and again shows that housing price appreciation has gone up faster in the West.

Table 11 then shows the estimated coefficients, using the formulas in the third section:

$$\beta_j^{\theta} = -B_{\text{Inc}} + (1-\mu)B_{\text{Val}}$$

$$\beta_j^{\bar{L}} = B_{\text{Pop}} + B_{\text{Inc}} - B_{\text{Val}}$$

$$\tilde{\beta}_j^{E} = B_{\text{Pop}} + \sigma B_{\text{Inc}}$$

It also uses the firm size effect to separate the impact of education on 'productivity':

$$\beta_j^{a} = (\sigma B_{\text{Inc}} + B_{\text{Siz}})/(\sigma - 1)$$

from the impact of education on 'entrepreneurship':

$$\beta_j^{E} = B_{\text{Pop}} - B_{\text{Siz}}$$

These enable one to combine these coefficients and assess whether education is acting on housing supply, productivity or amenities. To implement these equations a value of 0.7 for μ is used, which is compatible with housing representing 30% of consumption. For σ, a value of 4 is used, which corresponds to an average mark-up of 33%. JAIMOVICH and FLOETOTTO (2008) presented some support for this calibration, which only impacts on the estimated connection between skills and productivity growth.

The first five columns show results for the country and each region using only the metropolitan area-level coefficients. Columns (6) to (10) of Table 11 show results using the metropolitan area estimates for population growth and the area-level estimates for income and housing price growth. The estimates show standard errors estimated by bootstrap. However, the authors believe that these standard errors substantially overstate the actual precision of these estimates, since they take into account only the error involved in the estimated parameters, not the possibility that the assumed parameters, and indeed the model itself, are at best noisy approximations of reality.

The first column shows a positive connection between productivity growth and skills everywhere. The national coefficient is about 5, meaning that as the share of the population with college degrees increase by 5%, the growth in the number of entrepreneurs over the next thirty years increases by 25%. The coefficient is somewhat higher in the South and somewhat lower in the West, but these differences are not statistically significant. Using these national metropolitan-area coefficients, it is found that the impact of education on the growth of productivity, or entrepreneurship, is reasonably homogeneous across regions.

The second column shows results for amenity growth. In every region the coefficient is negative, suggesting that amenities have been shrinking rather than growing in skilled areas. This comes naturally out of the model because real wages have, according to the formulation, been shrinking in skilled places. Again, with the metropolitan area-level coefficients, the impact of skills on amenities is fairly similar across regions. However, if housing were a larger share of consumption or if housing prices were actually proxying for the growth of all prices, then the real wage effect would be zero and hence the implied connection between skills and amenity growth would be zero as well.

The third column looks at the growth of housing supply. Overall, skills have been associated with increases in housing supply, but there are very substantial regional differences. In the South, there is an

Table 11. Estimated coefficients

	MSA-level coefficients					Individual-level coefficients				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Nation	4.716	–0.556	1.523	1.329	0.729	3.757	0.444	–1.253	1.009	0.729
	(0.853)	(0.111)	(0.517)	(0.249)	(0.573)	(0.282)	(0.061)	(0.085)	(0.096)	(0.573)
East	4.855	–0.712	1.913	1.739	–0.361	4.65	–0.293	0.638	1.728	–0.361
	(2.551)	(0.333)	(1.312)	(0.701)	(1.212)	(0.409)	(0.116)	(0.166)	(0.136)	(1.212)
Midwest	3.647	–0.475	1.534	1.022	0.582	3.711	–0.469	1.478	1.092	0.582
	(1.027)	(0.143)	(0.462)	(0.317)	(0.747)	(0.337)	(0.079)	(0.095)	(0.112)	(0.747)
South	6.531	–0.551	4.108	1.293	2.652	6.366	–0.258	3.225	1.276	2.652
	(1.702)	(0.207)	(0.956)	(0.461)	(0.811)	(0.304)	(0.075)	(0.091)	(0.099)	(0.811)
West	4.883	–0.687	–1.466	1.889	–0.784	1.785	0.531	–3.717	0.91	–0.784
	(1.846)	(0.215)	(1.114)	(0.531)	(1.220)	(0.341)	(0.099)	(0.135)	(0.117)	(1.220)

Notes: Metropolitan statistical area (MSA)-level coefficients are from Table 9. Individual-level coefficients are from Table 10. Values used were $\sigma = 4$ and $\mu = 0.7$. See the third section for formulas.

extremely strong implied relationship between skills and housing supply growth. In the West, the implied relationship is negative. These differences reflect the very different relationship between skills and population growth in the South and in the West. It is thought that in a richer model with a better developed construction sector, these effects would appear as a movement along a supply curve rather than an actual shift in the supply of housing, and that the differences between West and South could be explained, at least in part, by very different housing supply elasticities (as found by SAIZ, 2010).

Columns (4) and (5) decompose the overall productivity effect into an effect associated with rising values of firm-level productivity (a_j, column 4) and rising levels of entrepreneurship (E_j, column 5). Column (1) is equal to three times column (4) plus column (5):

$$\tilde{\beta}_j^E = (\sigma - 1)\beta_j^a + \beta_j^E$$

In the first row, it is found that education is significantly associated with increases in firm-level productivity and insignificantly associated with increases in entrepreneurship. Overall, the firm-level productivity coefficient is responsibility for 84% of the connection between education and total productivity.

The next rows show that in both the East and the West, an insignificant negative connection is found between area education and the entrepreneurship measure. In these areas, education has a strong and quite similar positive correlation with firm-level productivity. In the Midwest and the South, there is more of a positive correlation between area education and entrepreneurship growth, and the connection is statistically significant in the South.

Columns (6) to (10) show results using individual-level regressions for housing and income. In column (6), the skills coefficient on entrepreneurship growth is smaller, reflecting the fact that the connection between skills and income growth is lower in the individual-level regressions. The authors believe that these estimates are more defensible. As in column (1), the connection between skills and entrepreneurship seems strongest in the South and weakest in the West. In this case, the gulf in estimated coefficients is much larger and statistically significant. Understanding this regional gap seems like an important topic for future research.

Column (7) shows the connection between skills and amenity growth. Overall, the estimated coefficient is positive, but it is negative in three out of four regions. Only in the West are skills positively associated with implied amenity growth, meaning that only in the West are skills associated with declines in real wages. In the other regions, skills are associated with rising real wages, which implies a decline in amenities. As discussed above, this implication is not taken all that seriously, because it is quite sensitive to assumptions about the connection between housing prices and the overall price level. Moreover, if unobserved skill levels are rising in skilled metropolitan areas, then the rise in real wages, and hence the implied decline in amenity levels, would also be somewhat illusory. The authors are more confident about the difference between regions – the rise in the value of amenities in skilled areas in the West – than about the overall sign in the rest of the nation.

Column (8) shows the land growth effects, which are positive everywhere but in the West. Just as in column (6), the West is the one region where skills seem associated with a decline in housing availability. In this case, the effect seems to be quite strong, statistically and economically; and indeed, the West is so powerful that it makes the estimated national coefficient negative. Housing supply has grown very little in skilled areas in the West, perhaps because educated Westerners have been particularly effective in pushing for limits on new construction.

Columns (9) and (10) show results when overall productivity is broken into firm-level productivity and the number of entrepreneurs. The basic patterns are quite similar to the MSA-level coefficients. Overall, the impact of education on both variables is positive, but the effect is only statistically significant for the firm-level productivity variable, which accounts for the lion's share of the overall productivity effect of education. In the East and West, the estimated coefficient of entrepreneurs on area-level education is negative, but not statistically significant. In the South, the coefficient is strongly positive.

Overall, this exercise leads to four main conclusions. First, the impact of education on productivity seems to be quite clear everywhere. Second, the growth of skilled places has far more to do with rising productivity than with amenity growth outside of the West, and indeed, amenity levels may have been declining in skilled areas. This conclusion echoes the findings of SHAPIRO (2006) and GLAESER and SAIZ (2004). Third, skills seem to depress housing supply growth in the American West, and that is a substantial difference with other regions. This negative connection could reflect the ability and taste of skilled people for organizing to oppose new construction. Fourth, the connection between education and overall productivity growth does not, outside of the South, primarily reflect a connection between education and an increase in the number of entrepreneurs.

EDUCATION AND UNEMPLOYMENT IN THE GREAT RECESSION

The previous section focused on the role that education played in mediating cities' ability to respond to the great shocks of the mid-twentieth century, but there has also

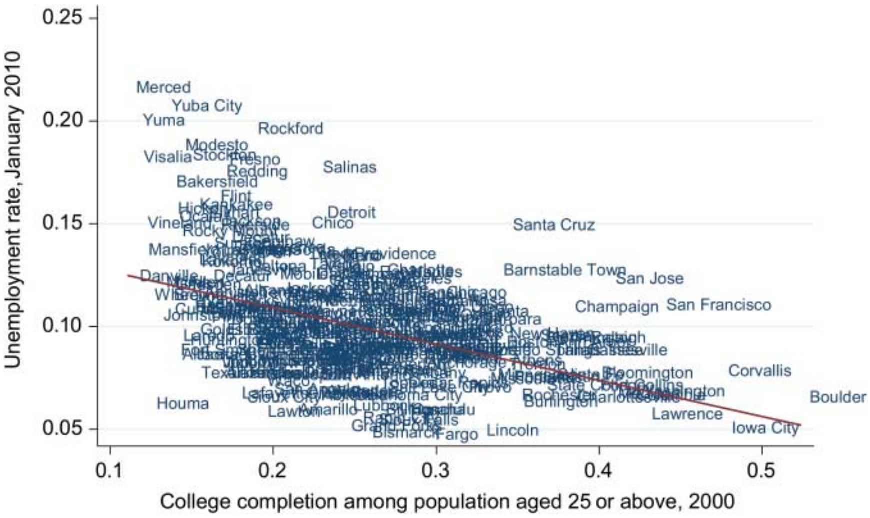

Fig. 7. Unemployment in January 2010 and education in 2000
Source: Metropolitan Statistical Area level data from the US Census

been a more recent crisis. According to the National Bureau of Economic Research (NBER), a recession began in December 2007. Unemployment then rose significantly in 2008 and 2009, rising above 10% in October 2009. But while the recession impacted on all of America, it did not hit every place equally. In February 2010, the unemployment rate was over 20% in Merced, California, and over 15% in Detroit, Michigan. At the same time, the unemployment rate in Minneapolis, Minnesota, was 7.7% and in Boulder, Colorado, only 6.5% (US DEPARTMENT OF LABOR, BUREAU OF LABOR STATISTICS, 2010).

Just as education predicted the ability of older, colder cities to survive the mid-twentieth-century shocks, skills also predict the ability of cities today to weather the storm. Fig. 7 shows the –0.44 correlation between the share of adults with a college degree in a metropolitan area and the unemployment rate in that area as of January 2010.

Although educational attainment is negatively correlated with unemployment at the individual level, the city-level correlation is too high to be entirely due to composition effects. A predicted unemployment rate based on the breakdown of city population by education level is constructed:

$$\text{Predicted unemployment} = \sum_{\text{Groups}} \text{Share}^{\text{MSA}}_{\text{Group}} \cdot U^{\text{USA}}_{\text{Group}} \tag{35}$$

where $\text{Share}^{\text{MSA}}_{\text{Group}}$ is the share of the adult labour force in each group in each metropolitan area in 2000 (the latest date available with reliable data); and $U^{\text{USA}}_{\text{Group}}$ is the national unemployment rate for the group, which was 5.1% for those with college degrees, 17.6% for high school dropouts and 10.25% for the remainder.

Fig. 8 shows the 0.48 correlation between actual unemployment and the predicted unemployment measure. The key finding is that the slope of the regression line is 1.78: as predicted unemployment falls by 5%, actual unemployment declines by almost 8%. Education accounts for a greater decline in city unemployment than the national relationship between education and unemployment would imply. This provides another piece of evidence suggesting the existence of human capital spillovers.

Many interpretations of this fact are possible. It might be a coincidence that unemployment rates were unusually low in highly educated areas. People who live in educated areas could be more skilled than their years of schooling suggest. This in turn might reflect sorting, but also human capital spillovers that enhance unobserved skill levels (GLAESER, 1999). The model in the third section emphasized that skilled workers are both employers and employees. Hence, the strong negative effect of education on unemployment may reflect the ability of more skilled entrepreneurs to find opportunity in a downturn. Of course, this explanation is now merely a hypothesis and further work will be needed to determine if it is correct.

CONCLUSION

The regional history of the eastern United States is best understood not through a set of immutable laws, but as a progression of different eras during which local attributes waxed and waned in importance. Few if any growth patterns hold over the entire 150-year period: many relationships, such as Gibrat's law, hold during some periods, but not in others. During some periods growth is faster in more

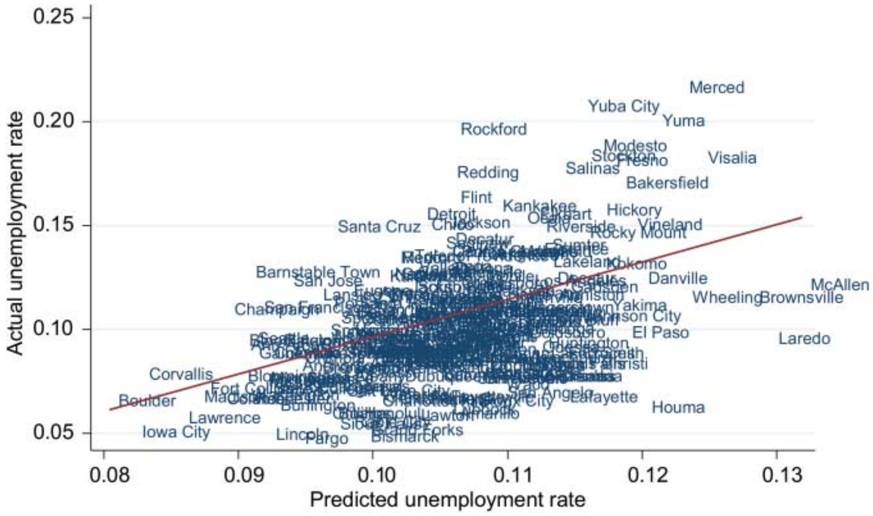

Fig. 8. Actual unemployment and unemployment predicated by education
Source: Metropolitan Statistical Area level data from the US Census, and Actual Unemployment Rate from the US Department of Labor, Bureau of Labor Statistics

populous places, and during others the population moves to more sparsely populated areas. Warmth positively predicts growth during the late nineteenth and twentieth centuries, but not during the early parts of the two centuries.

To the authors these findings support the view that regional and urban change is best understood not as the application of time-invariant growth processes, but rather as a set of responses by people and firms to large-scale technological change. These responses are quite amenable to formal modelling, but only to formal models that respect the changing nature of transportation and other technologies. The nineteenth century was primarily agricultural, and the spread west reflected the value of gaining access to highly productive agricultural land. The Great Lakes were a magnet because they lowered otherwise prohibitive transport costs. During the late nineteenth century, America became increasingly industrial and the population moved to places that began the era with more population. Cities, such as Detroit and Chicago, that had formed as hubs for transporting the wealth of American agriculture, became centres for producing manufactured goods such as cars.

Finally, during the post-war era, transportation costs fell still further and the population de-concentrated. The Great Lakes declined and people moved to the Sun Belt. The older areas that were best placed to reinvent themselves had a heavy concentration of skills and a disproportionate number of small firms, which may be a proxy for the level of entrepreneurial human capital. Industry no longer created a strong reason for concentration in populated counties, but it was increasingly valuable to be around skilled people. The model formally addressed reinvention in skilled areas.

When the channels through which skills affect growth are examined, it is found that growth in labour demand was significantly higher in more skilled areas, at least outside of the West. But in the West, skilled areas appear to have experienced faster amenity growth, perhaps because skilled people located in areas that were inherently more attractive. Skills were positively correlated with housing supply growth in the Midwest and South, but strongly negatively associated with housing supply growth in the West.

It was also examined whether skills impact on labour demand primarily by increasing the number of entrepreneurs, as measured by the number of establishments in an area, or by increasing average firm level productivity. It was found that education positively predicts growth in the number of establishments, but that this effect is relatively modest. The bulk of the connection between skills and labour demand appears to reflect a positive link between skills and average firm productivity.

America has experienced dramatic changes over the past two centuries, and population change does not appear to follow any form of strict rule. There has been a great deal of population persistence in the eastern United States, but population change has followed different patterns at different times. Over the past thirty years, skills and small firms have been strongly correlated with growth, but that may not always be the case.

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APPENDIX A

Setup of the model

The utility function (4) implies the demand function for each manufactured variety:

$$q(\nu) = \mu Y P^{\sigma-1} p(\nu)^{-\sigma} \tag{A1}$$

where Y is nominal aggregate income in the whole economy; and:

$$P \equiv \left[\int_0^G p(\nu)^{1-\sigma} \, \mathrm{d}\nu \right]^{1/(1-\sigma)} \tag{A2}$$

is the manufacturing price index, which can be set equal to 1 by a choice of numeraire. If the wage in city i is w_i, the price charged by the monopolistically competitive producer of each good ν manufactured in city i equals:

$$p(\nu) = \frac{\sigma}{\sigma - 1} \frac{w_i}{a_i} \tag{A3}$$

and labour demand from each manufacturer equals:

$$n(\nu) = \left(\frac{\sigma - 1}{\sigma} \right)^{\sigma} \mu Y a_i^{\sigma-1} w_i^{-\sigma} \tag{A4}$$

With E_i producer labour demand in city i equals:

$$N_i = \left(\frac{\sigma - 1}{\sigma} \right)^{\sigma} \mu Y E_i a_i^{\sigma-1} w_i^{-\sigma} \tag{A5}$$

which yields the equilibrium wage (6) for a given labour supply N_i. The profits earned by each entrepreneur are then:

$$\pi_i = \frac{1}{\sigma} \left[\mu Y \left(a_i \frac{N_i}{E_i} \right)^{\sigma-1} \right]^{\frac{1}{\sigma}} \tag{A6}$$

The spatial equilibrium condition (8) can be rewritten as:

$$\frac{1}{N_i} \left[\theta_i^{\sigma} a_i^{\mu(\sigma-1)} E_i^{\mu} \bar{L}_i^{(1-\mu)\sigma} \right]^{\frac{1}{\mu+\sigma-\mu\sigma}} = \frac{1}{N_j} \left[\theta_j^{\sigma} a_j^{\mu(\sigma-1)} E_j^{\mu} \bar{L}_j^{(1-\mu)\sigma} \right]^{\frac{1}{\mu+\sigma-\mu\sigma}} \text{ for all } i, \ j \tag{A7}$$

which implies equation (9) for:

$$\kappa_N \equiv \log N - \log \int \left[\theta_j^{\sigma} a_j^{\mu(\sigma-1)} E_j^{\mu} \bar{L}_j^{(1-\mu)\sigma} \right]^{\frac{1}{\mu+\sigma-\mu\sigma}} \mathrm{d}j \tag{A8}$$

Aggregate income is:

$$Y = \frac{1}{\psi\mu} \left\{ \int \left[E_j \left(a_j N_j \right)^{\sigma-1} \right]^{\frac{1}{\sigma}} \mathrm{d}j \right\}^{\frac{\sigma}{\sigma-1}} = \frac{N}{\psi\mu} \frac{\left\{ \int \left[\left(\theta_j a_j \right)^{\sigma-1} E_j \bar{L}_j^{(1-\mu)(\sigma-1)} \right]^{\frac{1}{\mu+\sigma-\mu\sigma}} \mathrm{d}j \right\}^{\frac{\sigma}{\sigma-1}}}{\int \left[\theta_j^{\sigma} a_j^{\mu(\sigma-1)} E_j^{\mu} \bar{L}_j^{(1-\mu)\sigma} \right]^{\frac{1}{\mu+\sigma-\mu\sigma}} \mathrm{d}j} \tag{A9}$$

so equation (10) holds for:

$$\kappa_w \equiv \log \frac{\sigma - 1}{\sigma} - \log \psi + \frac{1}{\sigma - 1} \log \int \left[\left(\theta_j a_j \right)^{\sigma-1} E_j \bar{L}_j^{(1-\mu)(\sigma-1)} \right]^{\frac{1}{\mu+\sigma-\mu\sigma}} \mathrm{d}j \tag{A10}$$

and equation (11) for:

$$\kappa_r \equiv \log\frac{1-\mu}{\mu} - \log\frac{\sigma-1}{\sigma} + \kappa_N + \kappa_w \tag{A11}$$

Proof of Proposition 1

Equations (9) to (11) yield:

$$\frac{\partial \mathrm{Var}\left(\log N_{i,t}\right)}{\partial \mathrm{Var}(\Gamma_i)} = \left[\frac{\mu(\sigma-1)}{\left(\mu+\sigma-\mu\sigma\right)T_t}\right]^2 \tag{A12}$$

so:

$$\frac{\partial^2 \mathrm{Var}\left(\log N_{i,t}\right)}{\partial T_t \partial \mathrm{Var}(\Gamma_i)} = -\frac{2}{T_t^3}\left[\frac{\mu(\sigma-1)}{\mu+\sigma-\mu\sigma}\right]^2 < 0, \tag{A13}$$

$$\frac{\partial \mathrm{Var}\left(\log w_{i,t}\right)}{\partial \mathrm{Var}(\Gamma_i)} = \left[\frac{\left(1-\mu\right)(\sigma-1)}{\left(\mu+\sigma-\mu\sigma\right)T_t}\right]^2 \tag{A14}$$

so:

$$\frac{\partial^2 \mathrm{Var}\left(\log w_{i,t}\right)}{\partial T_t \partial \mathrm{Var}(\Gamma_i)} = -\frac{2}{T_t^3}\left[\frac{\left(1-\mu\right)(\sigma-1)}{\mu+\sigma-\mu\sigma}\right]^2 < 0 \tag{A15}$$

and

$$\frac{\partial \mathrm{Var}\left(\log r_{i,t}\right)}{\partial \mathrm{Var}(\Gamma_i)} = \left[\frac{\sigma-1}{\left(\mu+\sigma-\mu\sigma\right)T_t}\right]^2 \tag{A16}$$

so:

$$\frac{\partial^2 \mathrm{Var}\left(\log r_{i,t}\right)}{\partial T_t \partial \mathrm{Var}(\Gamma_i)} = -\frac{2}{T_t^3}\left(\frac{\sigma-1}{\mu+\sigma-\mu\sigma}\right)^2 < 0 \tag{A17}$$

while for all:

$$\Xi_{i,t} \in \left\{N_{i,t}, w_{i,t}, r_{i,t}\right\}$$

it means:

$$\frac{\partial^2 \mathrm{Var}\left(\log \Xi_{i,t}\right)}{\partial T_t \partial \mathrm{Var}\left(\theta_{i,t}\right)} = \frac{\partial^2 \mathrm{Var}\left(\log \Xi_{i,t}\right)}{\partial T_t \partial \mathrm{Var}\left(A_{i,t}\right)} = \frac{\partial^2 \mathrm{Var}\left(\log \Xi_{i,t}\right)}{\partial T_t \partial \mathrm{Var}\left(E_{i,t}\right)} = \frac{\partial^2 \mathrm{Var}\left(\log \Xi_{i,t}\right)}{\partial T_t \partial \mathrm{Var}\left(\bar{L}_{i,t}\right)} = 0 \tag{A18}$$

Proof of Proposition 2

Equation (28) and (29) imply that the market-clearing wage is:

$$w_i = \frac{\sigma-1}{\sigma}\left\{\mu Y \frac{a_i^{\sigma-1}}{1-t\left(1-\bar{\eta}_i^{\alpha}\right)}\left[\frac{\bar{E}_i-\Delta_i}{M_i} + \frac{\alpha}{1+\alpha}\left(1-\bar{\eta}_i^{1+\alpha}\right)\right]\right\}^{\frac{1}{\sigma}} \tag{A19}$$

and the profits of each successful entrepreneur are:

$$\pi_i = \frac{1}{\sigma}(\mu Y)^{\frac{1}{\sigma}} \left\{ \frac{1}{a_i\left[1 - t\left(1 - \bar{\eta}_i^{\alpha}\right)\right]} \left[\frac{\bar{E}_i - \Delta_i}{M_i} + \frac{\alpha}{1+\alpha}\left(1 - \bar{\eta}_i^{1+\alpha}\right) \right] \right\}^{\frac{1-\sigma}{\sigma}} \tag{A20}$$

In particular if $t = 1$, so people are either would-be entrepreneurs or employees, then:

$$\bar{\eta}_i = \begin{cases} 1 & \text{if } M_i \le (\sigma - 1)\left(\bar{E}_i - \Delta_i\right) \\ \left\{ \frac{\sigma - 1}{1 + \alpha\sigma} \left[(1+\alpha)\frac{\bar{E}_i - \Delta_i}{M_i} + \alpha \right] \right\}^{\frac{1}{1+\alpha}} & \text{if } M_i \ge (\sigma - 1)\left(\bar{E}_i - \Delta_i\right) \end{cases} \tag{A21}$$

the total number of employers is:

$$E_i = \begin{cases} \bar{E}_i - \Delta_i & \text{if } M_i \le (\sigma - 1)\left(\bar{E}_i - \Delta_i\right) \\ \frac{(1+\alpha)\left(\bar{E}_i - \Delta_i\right) + \alpha M_i}{1 + \alpha\sigma} & \text{if } M_i \ge (\sigma - 1)\left(\bar{E}_i - \Delta_i\right) \end{cases} \tag{A22}$$

and wages are:

$$w_i = \begin{cases} \frac{\sigma - 1}{\sigma}\left[\mu Y \left(\frac{\tau_i}{\psi}\right)^{\sigma-1} \frac{\bar{E}_i - \Delta_i}{M_i} \right]^{\frac{1}{\sigma}} & \text{if } M_i \le (\sigma - 1)\left(\bar{E}_i - \Delta_i\right) \\ \frac{\sigma - 1}{\sigma}\left\{ \mu Y \left(\frac{\tau_i}{\psi}\right)^{\sigma-1} \left[\frac{\alpha + (1+\alpha)\left(\bar{E}_i - \Delta_i\right)/M_i}{(1+\alpha\sigma)(\sigma - 1)^{\alpha}} \right]^{\frac{1}{1+\alpha}} \right\}^{\frac{1}{\sigma}} & \text{if } M_i \ge (\sigma - 1)\left(\bar{E}_i - \Delta_i\right) \end{cases} \tag{A23}$$

The response of wages to a negative shock is:

$$\frac{\partial \log w_i}{\partial \Delta_i} = \left\{ \begin{array}{ll} -\left[\sigma\left(\bar{E}_i - \Delta_i\right)\right]^{-1} & \text{if } \Delta_i < \bar{E}_i - \frac{M_i}{\sigma - 1} \\ -\left\{\sigma\left[\alpha M_i + (1+\alpha)\left(\bar{E}_i - \Delta_i\right)\right]\right\}^{-1} & \text{if } \Delta_i > \bar{E}_i - \frac{M_i}{\sigma - 1} \end{array} \right\} < 0 \tag{A24}$$

such that:

$$\frac{\partial^2 \log w_i}{\partial \alpha \partial \Delta_i} = \left\{ \begin{array}{ll} 0 & \text{if } \Delta_i < \bar{E}_i - \frac{M_i}{\sigma - 1} \\ \frac{M_i + \bar{E}_i - \Delta_i}{\sigma\left[\alpha M_i + (1+\alpha)\left(\bar{E}_i - \Delta_i\right)\right]^2} & \text{if } \Delta_i > \bar{E}_i - \frac{M_i}{\sigma - 1} \end{array} \right\} \ge 0 \tag{A25}$$

with a convex kink at:

$$\Delta_i = \bar{E}_i - M_i/(\sigma - 1)$$

The number of entrepreneurs reacts according to:

$$\frac{\partial \log E_i}{\partial \Delta_i} = \left\{ \begin{array}{ll} -\left(\bar{E}_i - \Delta_i\right)^{-1} & \text{if } \delta_i < \bar{E}_i - \frac{M_i}{\sigma - 1} \\ -\left(\bar{E}_i - \Delta_i + \frac{\alpha}{1+\alpha} M_i\right)^{-1} & \text{if } \Delta_i > \bar{E}_i - \frac{M_i}{\sigma - 1} \end{array} \right\} < 0 \tag{A26}$$

such that:

$$\frac{\partial^2 \log E_i}{\partial\alpha\partial\Delta_i} = \begin{Bmatrix} 0 & \text{if} \quad \Delta_i < \bar{E}_i - \dfrac{M_i}{\sigma-1} \\ M_i\left[(1+\alpha)\left(\bar{E}_i-\Delta_i\right)+\alpha M_i\right]^{-2} & \text{if} \quad \Delta_i > \bar{E}_i - \dfrac{M_i}{\sigma-1} \end{Bmatrix} \geq 0 \tag{A27}$$

with a convex kink at:

$$\Delta_i = \bar{E}_i - M_i/(\sigma-1)$$

Proof of Proposition 3

Average firm size is:

$$n_i = \begin{cases} \dfrac{\bar{M}}{\bar{E}_i-\Delta_i} & \text{if} \quad \Delta_i \leq \bar{E}_i - \dfrac{\bar{M}}{\sigma-1} \\ \left[\dfrac{(1+\alpha\sigma)(\sigma-1)^{\alpha}}{\alpha+(1+\alpha)\left(\bar{E}_i-\Delta_i\right)/\bar{M}}\right]^{\frac{1}{1+\alpha}} & \text{if} \quad \Delta_i \geq \bar{E}_i - \dfrac{\bar{M}}{\sigma-1}, \end{cases} \tag{A28}$$

such that:

$$\frac{\partial n_i}{\partial\left(\bar{E}_i-\Delta_i\right)} = \begin{cases} -\bar{M}\left(\bar{E}_i-\Delta_i\right)^{-2} & \text{if} \quad \Delta_i \leq \bar{E}_i - \dfrac{\bar{M}}{\sigma-1} \\ -\dfrac{\left[(1+\alpha\sigma)(\sigma-1)^{\alpha}\right]^{\frac{1}{1+\alpha}}}{\bar{M}}\left[\alpha-(1+\alpha)\dfrac{\bar{E}_i-\Delta_i}{\bar{M}}\right]^{-\frac{2+\alpha}{1+\alpha}} & \text{if} \quad \Delta_i \geq \bar{E}_i - \dfrac{\bar{M}}{\sigma-1} \end{cases} < 0 \tag{A29}$$

The response of wages to a negative shock has:

$$\frac{\partial^2 \log w_i}{\partial\Delta_i\partial\left(\bar{E}_i-\Delta_i\right)} = \begin{Bmatrix} \dfrac{1}{\sigma}\left(\bar{E}_i-\Delta_i\right)^{-2} & \text{if} \quad \Delta_i < \bar{E}_i - \dfrac{\bar{M}}{\sigma-1} \\ \dfrac{1+\alpha}{\sigma}\left[\alpha\bar{M}+(1+\alpha)\left(\bar{E}_i-\Delta_i\right)\right]^{-2} & \text{if} \quad \Delta_i > \bar{E}_i - \dfrac{\bar{M}}{\sigma-1} \end{Bmatrix} > 0 \tag{A30}$$

which implies:

$$\frac{\partial^2 \log w_i}{\partial\Delta_i\partial n_i} = \begin{Bmatrix} -\dfrac{1}{\sigma\bar{M}} & \text{if} \quad \Delta_i < \bar{E}_i - \dfrac{\bar{M}}{\sigma-1} \\ -\dfrac{1+\alpha}{(1+\alpha\sigma)\sigma(\sigma-1)^{\alpha}}\dfrac{n_i^{\alpha}}{\bar{M}} & \text{if} \quad \Delta_i > \bar{E}_i - \dfrac{\bar{M}}{\sigma-1} \end{Bmatrix} < 0 \tag{A31}$$

The number of entrepreneurs reacts according to:

$$\frac{\partial^2 \log E_i}{\partial\Delta_i\partial\left(\bar{E}_i-\Delta_i\right)} = \begin{Bmatrix} \left(\bar{E}_i-\Delta_i\right)^{-2} & \text{if} \quad \Delta_i < \bar{E}_i - \dfrac{\bar{M}}{\sigma-1} \\ \left(\bar{E}_i-\Delta_i+\dfrac{\alpha}{1+\alpha}\bar{M}\right)^{-2} & \text{if} \quad \Delta_i > \bar{E}_i - \dfrac{\bar{M}}{\sigma-1} \end{Bmatrix} > 0 \tag{A32}$$

which implies:

$$\frac{\partial^2 \log E_i}{\partial \Delta_i \partial n_i} = \left\{ \begin{array}{cc} -\dfrac{1}{\bar{M}} & \text{if} \quad \Delta_i < \bar{E}_i - \dfrac{\bar{M}}{\sigma - 1} \\ -\dfrac{(1+\alpha)^2}{(1+\alpha\sigma)\sigma(\sigma-1)^\alpha} \dfrac{n_i^\alpha}{\bar{M}} & \text{if} \quad \Delta_i > \bar{E}_i - \dfrac{\bar{M}}{\sigma - 1} \end{array} \right\} < 0 \tag{A33}$$

Proof of Proposition 4

For $t = 0$, the total number of employers equals:

$$E_i = \bar{E}_i - \Delta_i + \frac{\alpha}{1+\alpha} N_i \tag{A34}$$

wages are:

$$w_i = \frac{\sigma - 1}{\sigma} \left[\mu Y a_i^{\sigma-1} \left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha} \right) \right]^{\frac{1}{\sigma}} \tag{A35}$$

and the profits of a successful entrepreneur are:

$$\pi_i = \frac{1}{\sigma} \left[\mu Y a_i^{\sigma-1} \left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha} \right)^{1-\sigma} \right]^{\frac{1}{\sigma}} \tag{A36}$$

so expected earnings equal:

$$y_i \equiv w_i + \frac{\alpha}{1+\alpha} \pi_i = \left(\frac{\sigma - 1}{\sigma} \frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha} \right) \left[\mu Y a_i^{\sigma-1} \left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha} \right)^{1-\sigma} \right]^{\frac{1}{\sigma}} \tag{A37}$$

with:

$$\frac{\partial \log y_i}{\partial \left[\left(\bar{E}_i - \Delta_i \right) / N_i \right]} = \frac{\sigma - 1}{\sigma^2} \frac{\bar{E}_i - \Delta_i}{N_i} \left[\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha} \right) \left(\frac{\sigma - 1}{\sigma} \frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha} \right) \right]^{-1} > 0 \tag{A38}$$

so that:

$$\partial \log y_i / \partial N_i < 0, \ \partial \log y_i / \partial \bar{E}_i > 0, \qquad \text{and}$$

$$\partial \log y_i / \partial \Delta_i < 0$$

while:

$$\frac{\partial \log y_i}{\partial \alpha} = \frac{1}{(1+\alpha)^2 \sigma} \left(\frac{2\sigma - 1}{\sigma} \frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha} \right) \cdot \left[\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha} \right) \left(\frac{\sigma - 1}{\sigma} \frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha} \right) \right]^{-1} > 0 \tag{A39}$$

The price of land is:

$$r_i = \left(1 - \mu \right) \left[Y \left(\frac{a_i}{\mu} \right)^{\sigma - 1} \left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha} \right) \right]^{\frac{1}{\sigma}} \frac{N_i}{\bar{L}_i} \tag{A40}$$

with:

$$\frac{\partial \log r_i}{\partial N_i} = \frac{1}{N_i}\left(\frac{\sigma - 1}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)^{-1} > 0 \tag{A41}$$

$$\frac{\partial \log r_i}{\partial\left(\bar{E}_i - \Delta_i\right)} = \frac{1}{\sigma N_i}\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)^{-1} > 0 \tag{A42}$$

so that:

$$\partial \log r_i / \partial \bar{E}_i > 0, \qquad \text{and}$$

$$\partial \log r_i / \partial \Delta_i < 0$$

while:

$$\frac{\partial \log r_i}{\partial \alpha} = \frac{1}{(1+\alpha)^2\,\sigma}\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)^{-1} > 0 \tag{A43}$$

The spatial equilibrium requirement:

$$\theta_i \gamma_i r_i^{\mu - 1} = \bar{U}$$

can be written as:

$$\theta_i a_i^{\mu\frac{\sigma-1}{\sigma}}\left(\frac{\bar{L}_i}{N_i}\right)^{1-\mu}\left(\frac{\sigma - 1}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)^{\frac{\mu-\sigma}{\sigma}} = \left(1-\mu\right)^{1-\mu}\mu^{\frac{\mu\sigma - \mu - \sigma}{\sigma}}Y^{-\frac{\mu}{\sigma}}\bar{U} \tag{A44}$$

With a continuum of cities, changes in a single atomistic city i do not affect the aggregate variables on the right-hand side, so the effects of changes in α and $\bar{E}_i - \Delta_i$ on the equilibrium workforce N_i can be taken from the constancy of:

$$\Omega \equiv \left(1-\mu\right)\log N_i + \frac{\sigma - \mu}{\sigma}\log\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right) - \log\left(\frac{\sigma - 1}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right) \tag{A45}$$

such that:

$$\begin{aligned}\frac{\partial \Omega}{\partial N_i} = &\frac{1}{N_i}\left[\frac{\sigma - 1}{\sigma^2}\left(\frac{\bar{E}_i - \Delta_i}{N_i}\right)^2 + \left(1-\mu\right)\left(\frac{\sigma - 1}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)^2\right] \\ &\cdot\left[\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)\left(\frac{\sigma - 1}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)\right]^{-1} > 0,\end{aligned} \tag{A46}$$

$$\frac{\partial \Omega}{\partial \alpha} = -\frac{1}{(1+\alpha)^2}\left[\frac{\sigma - \mu + \mu\sigma}{\sigma^2}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha\mu}{(1+\alpha)\sigma}\right]\cdot\left[\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)\left(\frac{\sigma - 1}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)\right]^{-1} < 0 \tag{A47}$$

and

$$\frac{\partial \Omega}{\partial\left(\bar{E}_i - \Delta_i\right)} = \frac{1}{\sigma N_i}\left[\frac{\alpha\left(1-\mu\right)}{1+\alpha} - \frac{\mu(\sigma - 1)}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i}\right]\cdot\left[\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)\left(\frac{\sigma - 1}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)\right]^{-1} \tag{A48}$$

which switches from positive to negative as μ ranges in (0,1).

The exogenous endowment of entrepreneurs has an ambiguous impact on the labour supply:

$$\frac{\partial N_i}{\partial(\bar{E}_i - \Delta_i)} = \frac{1}{\sigma}\left[\frac{\mu(\sigma-1)}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} - \frac{\alpha(1-\mu)}{1+\alpha}\right] \cdot \left[\frac{\sigma-1}{\sigma^2}\left(\frac{\bar{E}_i - \Delta_i}{N_i}\right)^2 + (1-\mu)\left(\frac{\sigma-1}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)^2\right]^{-1} \tag{A49}$$

such that:

$$\begin{aligned} &\partial^2 N_i/\left[\partial\mu\left(\bar{E}_i - \Delta_i\right)\right] > 0 \qquad \text{for all } \mu \in (0,1) \qquad \text{and} \\ &-\frac{\alpha}{1+\alpha}\frac{1}{\sigma}\left[\frac{\sigma-1}{\sigma^2}\left(\frac{\bar{E}_i - \Delta_i}{N_i}\right)^2 + \left(\frac{\sigma-1}{\sigma}\ \frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)^2\right]^{-1} \\ &\leq \frac{\partial N_i}{\partial\left(\bar{E}_i - \Delta_i\right)} \leq \frac{N_i}{\bar{E}_i - \Delta_i}. \end{aligned} \tag{A50}$$

Taking into account the endogenous response of the workforce, expected earnings are decreasing in Δ_i:

$$\frac{d\log y_i}{d\left(\bar{E}_i - \Delta_i\right)} = \frac{\partial \log y_i}{\partial\left(\bar{E}_i - \Delta_i\right)} + \frac{\partial \log y_i}{\partial N_i}\frac{\partial N_i}{\partial\left(\bar{E}_i - \Delta_i\right)} \geq \frac{\partial \log y_i}{\partial\left(\bar{E}_i - \Delta_i\right)} + \frac{\partial \log y_i}{\partial N_i}\frac{N_i}{\bar{E}_i - \Delta_i} = 0 \tag{A51}$$

and so are the total number of employers:

$$\frac{dE_i}{d\left(\bar{E}_i - \Delta_i\right)} = 1 + \frac{\alpha}{1+\alpha}\frac{\partial N_i}{\partial\left(\bar{E}_i - \Delta_i\right)} \geq \frac{\sigma-1}{\sigma}\left(\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)^2\left[\frac{\sigma-1}{\sigma^2}\left(\frac{\bar{E}_i - \Delta_i}{N_i}\right)^2 + \left(\frac{\sigma-1}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)^2\right]^{-1} > 0 \tag{A52}$$

and the price of land:

$$\frac{d\log r_i}{d\left(\bar{E}_i - \Delta_i\right)} = \frac{\partial \log r_i}{\partial\left(\bar{E}_i - \Delta_i\right)} + \frac{\partial \log r_i}{\partial N_i}\frac{\partial N_i}{\partial\left(\bar{E}_i - \Delta_i\right)} \geq \frac{\sigma-1}{\sigma^2}\frac{\bar{E}_i - \Delta_i}{N_i^2}\left[\frac{\sigma-1}{\sigma^2}\left(\frac{\bar{E}_i - \Delta_i}{N_i}\right)^2 + \left(\frac{\sigma-1}{\sigma}\frac{\bar{E}_i - \Delta_i}{N_i} + \frac{\alpha}{1+\alpha}\right)^2\right]^{-1} > 0 \tag{A53}$$

City population equals:

$$\Lambda_i \equiv \bar{E}_i - \Delta_i + N_i$$

which is increasing in $\bar{E}_i - \Delta_i$ if, but not only if:

$$\sigma \geq \frac{1+\alpha}{\alpha} \geq 2 \Leftrightarrow \alpha \geq \frac{1}{\sigma - 1} \tag{A54}$$

The elasticity of endogenous entrepreneurship α increases the labour supply:

$$\frac{\partial N_i}{\partial \alpha} = -\frac{\partial\Omega/\partial\alpha}{\partial\Omega/\partial N_i} > 0 \tag{A55}$$

and therefore population, as well as the total number of employers:

$$\frac{dE_i}{d\alpha} = \frac{N_i}{(1+\alpha)^2} + \frac{\alpha}{1+\alpha}\frac{\partial N_i}{\partial\alpha} > 0 \tag{A56}$$

land prices:

$$\frac{d\log r_i}{d\alpha} = \frac{\partial \log r_i}{\partial \alpha} + \frac{\partial \log r_i}{\partial N_i}\frac{\partial N_i}{\partial \alpha} > 0 \tag{A57}$$

and expected earnings:

$$\frac{d\log y_i}{d\alpha} = \frac{\partial \log y_i}{\partial \alpha} + \frac{\partial \log y_i}{\partial N_i}\frac{\partial N_i}{\partial \alpha} > 0 \tag{A58}$$

which can be verified with tedious but straightforward algebra.

Proof of Proposition 5

The wage per effective unit of human capital equals:

$$w_i = \frac{\sigma - 1}{\sigma}\left\{\frac{\mu Y a_i^{\sigma-1}}{1 + h_i H}\left[\frac{\bar{E}_i - \Delta_i}{N_i} + h_i\bar{\alpha} + (1 - h_i)\underline{\alpha}\right]\right\}^{\frac{1}{\sigma}} \tag{A59}$$

such that:

$$\frac{\partial \log w_i}{\partial h_i} = \frac{1}{\sigma}\left[\bar{\alpha} - (1 + H)\underline{\alpha} - H\frac{\bar{E}_i - \Delta_i}{N_i}\right]\left\{(1 + h_i H)\left[\frac{\bar{E}_i - \Delta_i}{N_i} + h_i\bar{\alpha} + (1 - h_i)\underline{\alpha}\right]\right\}^{-1} \tag{A60}$$

Thus:

$$\bar{\alpha} \geq (1 + H)\underline{\alpha} + H\frac{\bar{E}_i}{N_i} \Rightarrow \frac{\partial \log\ w_i}{\partial h_i} \geq 0 \text{ for all } \Delta_i \in \left[0, \bar{E}_i\right] \tag{A61}$$

and

$$\bar{\alpha} \leq (1 + H)\underline{\alpha} \Rightarrow \frac{\partial \log\ w_i}{\partial h_i} \leq 0 \text{ for all } \Delta_i \in \left[0, \bar{E}_i\right] \tag{A62}$$

while if:

$$H\,\bar{E}_i\,/N_i + (1 + H)\underline{\alpha} > \bar{\alpha} > (1 + H)\underline{\alpha}$$

then:

$$\frac{\partial \log w_i}{\partial h_i} = 0 \Leftrightarrow \Delta_i = \bar{E}_i - \frac{\bar{\alpha} - (1 + H)\underline{\alpha}}{H}N_i \equiv \bar{\Delta}_i \tag{A63}$$

and wages are increasing in h_i for $\Delta_i > \bar{\Delta}_i$ and decreasing in h_i for $\Delta_i < \bar{\Delta}_i$.

NOTES

1. Another strand of the literature has expanded the standard theory of endogenous growth to incorporate urban dynamics and reconcile increasing returns at the local level with constant returns and a balanced growth path for the aggregate economy (EATON and ECKSTEIN, 1997; BLACK and HENDERSON, 1999; DURANTON, 2006, 2007; ROSSI-HANSBERG and WRIGHT, 2007).
2. ESRI Data and Maps 9.3 were used for the calculation.
3. Unadjusted distance to the Great Lakes is strongly correlated with latitude and with temperature (–0.89). Using a truncated measure, one can better distinguish proximity to the Great Lakes from coldness.
4. The 1870 Census is potentially problematic because of an undercount in the South (FARLEY, 2008).
5. The 1860s are skipped, which are unusual because of the Civil War; as are the 1930s, which are unusual because of the Great Depression.
6. This income measure does nothing to control for the human capital composition of the population.
7. To make the graph less cluttered, only counties with at least 50 000 people in 1940 are displayed.
8. In other words, $1/\eta$ has a Pareto distribution with a minimum of 1 and shape parameter α.

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