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Did the Death of Distance Hurt Detroit and Help New York?*

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Abstract

One of the great attractions of cities is that urban proximity speeds the flow of ideas. Improvements in communications technology could erode this advantage and allow people and firms to decentralize. On the other hand, if cities have an edge in producing new ideas, then communication technology may strengthen the demand for cities by increasing the returns to innovation. Improvements in communication technology can increase the returns to innovation by allowing new ideas to be used in more geographic locales. This paper presents a model that illustrates these two rival effects that communication technology will have on cities. We then present some evidence suggesting that the model can help us to understand why the past 35 years have been kind to some cities, like New York and Boston, and devastating to others, like Cleveland and Detroit.

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1 Introduction

Thirty years ago, every major Northeastern and Midwestern city looked troubled. America had 20 cities with more than 450,000 people in 1950. Every one of them lost population between 1950 and 1980, except for Los Angeles, Houston and Seattle. The primary source of economic decline for these places was a decline of manufacturing, which first suburbanized, as in the case of Henry Ford's River Rouge Plant, and then left metropolitan areas altogether. Improvements in information technology had made it quite easy for corporate leaders, who often remained in the older cities, to manage production in cheaper locales.

But since 1980 a number of older cities, which had been declining, started once again to grow both in population and often more strikingly in incomes. Places like New York, San Francisco, Boston and Minneapolis have all thrived since the 1970s, generally in idea-intensive industries, like finance, professional services and new technology. Urban density that once served to connect manufacturers with railroads and boats now serves to facilitate contact of smart people in idea-producing sectors. The idea-producing advantages of geographic concentration are not a new phenomenon. After all, Alfred Marshall wrote in 1890 that in dense agglomerations "the mysteries of the trade become no mystery, but are, as it were, in the air." However, these idea-producing advantages appear to be more and more critical to the success of older, high density cities.

This paper advances the hypothesis that improvements in communication technology can explain both the decline of Detroit and the reinvigoration of Manhattan. While we present some suggestive evidence, the main contribution of this paper is a model that illustrates how reductions in the costs of communication can cause manufacturing cities to decline and innovative cities to grow. In the model individuals choose between three activities: (1) innovating, which creates more types of intermediate products, (2) manufacturing those intermediate goods, and (3) producing in a traditional sector which we think of as agriculture. Firms can also choose whether to locate in a city or in the hinterland, where the difference between the two areas is the availability of land and the ease of communication.

We assume that the traditional sector needs land the most and suffers the least from poor communication, while the innovative sector needs land the least and loses the most from communication difficulties. Since the city has a comparative advantage in speeding communication and limited, and hence expensive, land, the traditional sector locates entirely in the hinterland, while the innovative sector locates entirely in the city. The manufacturing sector is generally split between the city and the hinterland. These predictions of the model roughly describe modern America where high human capital industries tend to the best centralized within metropolitan areas, manufacturing is in medium density areas and natural resource-based industries are generally non-urban (Glaeser and Kahn, 2001).

All individuals have the same level of productivity in the manufacturing or traditional sectors, but we assume that there is heterogeneous ability to innovate. As a result, the most able people end up in the innovative sector. Heterogeneity of ability determines decreasing returns to the size of the innovative sector, and it also predicts that the economy will become more unequal if it becomes more innovative.

The model allows us to consider the impact of improvements in information technology. We model these improvements as a reduction in the costs of communication for people working in the hinterland in the manufacturing and innovative sectors. However, as long as the innovative sector stays entirely in the city, the communication costs parameter that matters is the cost associated with manfacturing intermediate goods in the hinterland. In our view, this comparative static is meant to reflect the increasing ability of corporate leaders or idea producers, who remain in urban areas, to communicate with far-flung production facilities.

When communication costs fall, manufacturing firms leave the city, which causes a decline in urban income and property values. The economy as a whole is getting more productive as the the city's advantage in production is disappearing. This effect is meant to capture the decline in erstwhile manufacturing powerhouses like Cleveland and Detroit.

But the decline in communication costs also has two other impacts which are more benign for the city. Most importantly, reducing these communication costs increases the returns for innovation. Since the city has a comparative advantage in producing new ideas, this effect increases incomes in the urban area. The exodus of manufacturing and the decline in the costs of urban land also increases the total size of the innovative sector in the city, which in turn further bolsters urban success through the increasing returns to new idea production that are a key element in models like ours (e.g. Grossman and Helpman, 1991, Romer, 1990).

As communication costs decline and the size of the innovative sector increases, within-city inequality increases. This increase in inequality does not represent a welfare loss, for improvements in communication technology improve the real wages for all workers even though nominal wages for workers in the city decline. City population will rise as city manufacturing declines, because the innovative sector is less land intensive than the manufacturing sector.

As long as manufacturing is the industry on the margin between the city and the hinterland, then decreasing the information costs of locating in the hinterland will reduce city propert values. However, once all manufacturing has left the city, then further decreases in communication costs impact the city mainly by increasing the returns to innovation by reducing the costs of production. In this case, further improvement in information technology cause urban land values to rise. We think of the first model as capturing cities like New York and Boston in the 1970s, when the exodus of manufacturing caused property values to plummet, while the extension reflects these cities in more recent years, when booming innovative sectors have been associated with rising real-estate costs.

We also extend the model to consider a second city. In this case, we explicitly model the urban advantage as reflecting human capital spillovers (as in Fujita and Thisse, 2003). With this assumption, the innovative sector completely clusters in one of the two cities. Manufacturing locates in both of the cities. In this case, an improvement in communication technology will cause the more innovative city to increase its population and income relative to the manufacturing city. When manufacturing completely leaves the first city, then further improvements in information technology will also cause a growing gap in property values between the two places. This model is meant to show how improvements in information technology can strengthen idea-oriented cities and hurt production-oriented cities.

After discussing the model, we turn to a little suggestive evidence. First, we document the connection between urban success and specialization in innovation, measured, as the model suggests, by employment in primarily non-governmental occupations that are high education. Specialization in these high-education, and presumably more innovative sectors, is positively correlated with income growth between 1980 and 2000 and with employment growth over the same time period in the Northeast and Midwest. We also find that successful places increased their specialization in these activities, just as the model suggests.

Second, we turn to the model's predictions about urban inequality. We find that inequality within cities rose more in cities that had faster income growth and in cities with more initial specialization in skilled occupations initially. These effects are, however, modest.

2 Urban Diversity and Improvements in Information Technology

Before proceeding to the model, we first review four facts that motivate the model: (1) the past forty years have seen spectacular improvements in information technology, (2) those improvements have made separation between idea-producers and manufacturers increasingly common, (3) there has been a remarkable heterogeneity in the growth of both income and population among many older cities since 1980, and (4) while all of the older cities suffered a significant decline in manufacturing jobs, the successful older cities have increasingly specialized in idea-intensive sectors.

The first fact—that there have been substantial improvements in information technology since 1975—has at least two separate sources. First, there has been a proliferation of new technologies that facilitate communication across space. Among the communication technologies that were not generally available in 1975 but are commonplace today are fax machines, cellular phones, e-mail, the internet, wi-fi, and personal digital assistants. Many of these technologies, like cellular phones, existed before 1975, but they only became widely affordable after that date.

Increased competition in key communication sectors, like telephones, air travel and cargo shipping, has also improved the ability to exchange information over long distances. For example, in 1973, Federal Express began challenging the U.S. Postal Service in providing speedy delivery of packages. In 1982, as part of a settlement of an anti-trust case, ATT divested its local exchanges. After this divestment there was a considerable increase in long-distance phone companies, such as MCI and Sprint, that made long-distance communication cheaper. In the late 1970s, the airline industry was also deregulated, which increased competition and reduced prices in that sector.

These improvements in information technologies have been accompanied by an "increasing separation of the management and production facilities of individual firms" (Duranton and Puga, 2005). Duranton and Puga (2005) connect this separation to the increasing specialization of cities on the basis of function (i.e. management or production) rather than industrial sector. Kim (1999) is among the empirical sources cited by those authors, and he found that the share of manufacturing workers in the U.S. working in multi-unit firms increased from 51 percent in 1937 to 73 percent in 1977. There is also an increase in the number of corporate headquarters that are separate from their production facilities (Kim, 1999), which is also seen in the work of Henderson and Ono (2007). The rise in multinational firms, which has been extensively document and discussed (Markusen, 1995), represents a particularly extreme example of increasing geographic distance between firm leadership and production.

Our third motivating fact concerns the heterogeneity in urban success within the U.S. over the last forty years. Population and income give us two alternative measures of urban growth and Figure 1 shows the path of population for six major metropolitan areas. Since 1970, San Francisco has grown by more than 17 percent. Chicago has grown by 13 percent, whilee Detroit has lost more than 20 percent of its population. San Francisco and New York have both gained slightly. New York and Boston lost population in the 1970s, but have gained since then. Over the third decade, the population of New York increased by two percent while the population of Boston rose by eight percent. Cleveland has steadily lost population.

There has also been substantial divergence in income levels across metropolitan areas. Figure 2 shows the time path of earnings per worker in the largest county of each of these metropolitan areas. Since County Business Patterns is the natural source of firm-level data, this pushes us to look at the counties that surround the areas' economic centers. The earnings of New York and San Francisco soar over this time period. Wayne County (Detroit) begins with the highest payroll per worker and declines over the time period, starting out quite prosperous but losing substantially relative to the other two areas. In 1977, Wayne's payroll per worker was slightly higher than that of New York and today it is less than 60 percent of income in New York.

Figure 3 shows the distribution of log of median family income across metropolitan areas in 1980 and 2000. As the figure shows, the variance of incomes across metropolitan areas increased substantially over this twenty year period. Almost all of the increase occurred in the 1980s.

Our final motivating fact is that the successful cities are specialized in idea-producing industries, while the less successful cities are in social services with some remaining manufacturing. Table 1 shows the top five industry groups measured by total payroll in the largest counties of the six metropolitan areas shown in 1977 and 2002. In 1977, manufacturing dominates four out of the six cities, sometimes by a very substantial margin. In 1977, more than one half of Wayne County's payroll was in manufacturing. Even in New York, the payroll in Finance and Insurance only slightly nudged out manufacturing.

By 2002, manufacturing remains the dominant sector in Detroit and Cleveland, but it is now a much smaller share of the total payroll. In 2002, more than fifty-three percent of the payroll in New York is in finance and insurance and professional, scientific and technical services. More than forty percent of the payroll of San Francisco lies in this two areas. Chicago and Boston are more mixed and they do both idea-oriented products and manufacturing. In the next section, we present a model that attempts to explain the divergence of city economies as a result of improvements in the ability to communicate ideas over space.

3 The Model

3.1 Basic setup

This model attempts to describe innovation and production in a closed economy where labor is mobile across space. We will address inter-urban inequalities in an extension that allows for a second city, but we begin with two locations: a city and the hinterland. Workers choose between three occupations: working in the traditional sector, working in the advanced sector and innovating in a way that produces more varieties of intermediate goods for the advanced sector.

Individual utility is defined over the traditional good Z and an advanced good Y that is produced with intermediate goods in the manner of Dixit and Stiglitz (1977). The traditional good Z is produced with a fixed technology that has constant returns to scale. The market for Z is perfectly competitive, so its price equals unit cost: $p_Z = c_Z(\mathbf{w})$. We treat Z as the numeraire, so that p_Z equals one. Individuals will also need to consume exactly one unit of location-specific capital as a residence

Our focus is on demand for the final advanced good Y, and we will characterize aggregate demand by the homothetic preferences of a representative household, whose budget share for Y is

$$\beta(p_Y) = \frac{p_Y Y}{p_Y Y + Z} \tag{1}$$

For example, if the utility function has constant elasticity of substitution σ, so that $U(Y, Z) = (1-\varsigma)^{\frac{1}{\sigma}} Y^{\frac{\sigma-1}{\sigma}} + \varsigma^{\frac{1}{\sigma}} Z^{\frac{\sigma-1}{\sigma}}$, then the budget share is $\beta(p_Y) = \left[p_Y^{\sigma-1} \frac{\varsigma}{1-\varsigma} + 1\right]^{-1}$. We will assume that elasticity of substitution is never below one; equivalently, that demand for the advanced good has no less than unitary own-price elasticity; hence that $\beta'(p_Y) \leq 0$.

The production of Y is based on measure n intermediate inputs, $x(j)$, which are aggregated with a Dixit-Stiglitz production function:

$$Y = \left[\int_0^n x(j)^\alpha \, dj\right]^{\frac{1}{\alpha}} \text{ with } \alpha \in (0, 1) \tag{2}$$

There is free entry in the production of the advanced good and the market for this good is perfectly competitive. However, each intermediate input is produced by a monopolistic competitor at a constant unit cost of c_x. As in Dixit and Stiglitz (1977), monopolistic competition by producers of intermediates, with constant elasticity of substitution implies mark-up pricing, so the price of the intermediate good, p_x, satisfies:

$$p_x = \frac{1}{\alpha} c_x(\mathbf{w}) \tag{3}$$

and monopoly profits

$$\pi = (1-\alpha) p_x \frac{X}{n} \tag{4}$$

where X is the total output of intermediate inputs by identical producers. Since the intermediate-goods producers are identical, optimizing behavior by the final-goods producers then implies that the cost of Y satisfies:

$$p_Y = n^{-\frac{1-\alpha}{\alpha}} p_x \tag{5}$$

As in Ethier (1982), greater variety enables greater specialization, and therefore productivity gains arising from the division of labor.

3.2 The Innovation Sector and Worker Heterogeneity

Differentiated varieties are produced by an innovative sector that thrives on proximity. If innovators locate in the city, then each worker is able to invent a.varieties of intermediate inputs, where a is a worker-specific measure of creativity. Given that the agglomeration of innovators is in the city, we assume that an innovator locating outside the city would only be able to produce $a/(1+\tau_n)$ varieties of intermediate input. We assume that τ_n is sufficiently high that all innovators chose to locate in the city. In section 3.6 we endogenize the urban edge in innovation by formally modelling knowledge spillovers.

Each worker requires κ_n units of location-specific capital (i.e. land) to produce innovation, and one unit of location-specific capital for a residence. Workers are heterogeneously endowed with creativity according to a Pareto distribution (cf. Helpman, Melitz, and Yeaple, 2004) with minimum $\underline{a} > 0$ and shape $\theta > 1$, so that

$$F(a) = 1 - \left(\frac{a}{\underline{a}}\right)^{-\theta} \text{ and } f(a) = \theta \underline{a}^{\theta} a^{-\theta-1} \tag{6}$$

We assume that all individuals have the same output in producing the intermediate goods or the traditional good, and that all heterogeneity is in creativity. As a result, creative people will all sort into the innovative sector, and this sector's employment will be characterized by a marginal worker with creativity t.The total amount of innovation is then:

$$n = L \int_t^{\infty} af(a)\, da = L\frac{\theta}{\theta-1}\underline{a}^{\theta} t^{1-\theta} \tag{7}$$

where L is the total number of workers in the entire economy; and employment in innovation, expressed as a function of the amount of innovation, equals:

$$L_n = L^{-\frac{1}{\theta-1}} \underline{a}^{-\frac{\theta}{\theta-1}} \left(\frac{\theta-1}{\theta}\right)^{\frac{\theta}{\theta-1}} n^{\frac{\theta}{\theta-1}} \equiv \psi_n n^{\frac{\theta}{\theta-1}} \tag{8}$$

where ψ_n is an inverse measure of productivity in this sector, which is decreasing in the total pool of workers, because a larger pool means that more able people will be available to this sector. This inverse productivity measure is also decreasing in the mean of the skill distribution $\underline{a}\theta/(\theta-1)$. If the total amount of innovation is n, then the output of the marginal innovator equals:

$$t = L^{\frac{1}{\theta-1}} \underline{a}^{\frac{\theta}{\theta-1}} \left(\frac{\theta}{\theta-1}\right)^{\frac{1}{\theta-1}} n^{-\frac{1}{\theta-1}} = \frac{\theta-1}{\theta\psi_n} n^{-\frac{1}{\theta-1}} \tag{9}$$

Free entry into this sector means that $t\pi$ must equal the opportunity cost of labor for this marginal worker plus the cost of κ_n units of location-specific capital. Heterogeneity in the ability to innovate both acts as a check on the amount of innovation, beacuse eventually the marginal innovator is not very good at innovating, and predicts more inequality in the innovative sector.

3.3 The Spatial Equilibrium

Production of final and intermediate goods can take place in either the city or the hinterland. Producing one unit of an intermediate good in the city requires ψ_x units of labor, and each unit of labor requires κ_x units of location-specific capital in production and one unit of capital as a residence. In the hinterland, producing one unit of the intertermediate good requires $\psi_x (1+\tau_x)$ workers and thus $\psi_x (1+\tau_x) \kappa_x$ units of location-specific capital. The added labor needed to produce in the hinterland is meant to reflect either the costs of communicating with the innovators who choose to locate in the city, or perhaps the cost of access to transport centers that are in the urban area.

Production of the traditional good requires ψ_Z unit of labor in the city and $\psi_Z (1+\tau_z)$ units of labor in the hinterland and κ_Z units of location-specific capital per unit of labor in production, and one unit in consumption. We normalize the units of labor so that $\psi_Z (1+\tau_z)$ equals one. We assume that the traditional sector is quite capital intensive, which is meant to reflect the heavy use of land in agriculture. The advanced production sector uses an intermediate level of capital, and innovation requires the least amount of capital, because that sector is in the business of producing ideas. As such,

$$\kappa_Z > \kappa_x > \kappa_n \geq 0 \tag{10}$$

We also assume that the value of proximity to the ideas in the city has the reverse ranking across sectors, so that

$$\tau_n > \tau_x > \tau_Z \geq 0 \tag{11}$$

The city is endowed with K units of location-specific capital and the hinterland is endowed with K^R.units of this same capital. We assume that rural capital is not a scarce resource, because $K^R > (1+\kappa_Z) L$, so that there would be excess land even if everyone lived in the hinterland and worked in the most land intensive sector. As as result, the price of rural capital will equal zero. On the other hand, urban capital is scarce, so that not all the population can be productively employed in the city even in the least land-intensive sector: $K < (1+\kappa_n) L$.

We are interested in the case where there is some intermediate good manufacturing in both the rural and urban areas, and if the intermediate goods producers are indifferent between these two locations, which is necessary for production to occur in both places, then the traditional producers, who have greater land requirements and less productivity losses due to distance from the city, will all prefer to locate in the hinterland. Since the price of the traditional output is normalized to one, and $\psi_Z (1+\tau_z)$ equals one, then the wage in the hinterland also equals one.

Workers must pay for their one unit of residential capital, so since they could earn a wage of one in the hinterland, they must be paid $1+w_K$ in the city, where w_K is the price of location-specific capital in the urban area. This implies that the cost of producing one unit of the intermediate good in the urban area will equal $\psi_x [1+(1+\kappa_x) w_K]$ and the cost of producing the same good in the hinterland will equal: $\psi_x (1+\tau_x)$.

When manufacturing of the intermediate good goes on in both the city and the rural area, then the price of urban capital must make intermediate goods producers indifferent between the two locations, which requires that:

$$w_K = \frac{\tau_x}{1+\kappa_x} \tag{12}$$

Indifference for the marginal worker between the innovative sector and the two manufacturing sectors implies that the value of research output for the marginal researcher, net of capital costs, must equal the wage that could be earned in the city manufacturing intermediate goods:

$$t\pi - w_K \kappa_n = 1 + w_K \tag{13}$$

To complete the equilibrium, we note that the total production of intermediate inputs combines rural and urban production, or

$$X = X_U + X_R \tag{14}$$

where X_U is urban prodcution and X_R is rural production.

The total amount of labor used in the three sectors must sum to the total amount of labor in the economy, which implies:

$$L = \psi_n n^{\frac{\theta}{\theta-1}} + \psi_x X_U + \psi_x (1+\tau_x) X_R + Z \tag{15}$$

We are interested in the case where capital is scarce in the city and is completely used up by residential and production uses associated with the innovative sector and the production of new varieties and intermediate goods:

$$K = \psi_n (1+\kappa_n) n^{\frac{\theta}{\theta-1}} + \psi_x (1+\kappa_x) X_U \tag{16}$$

3.4 Comparative Statics

The equilibrium in this model is defined by equations 1, 3, 4, 5, 9, 12, 13, 14, 15 and 16, which as we show in the appendix imply:

$$n = \left[\frac{1}{\psi_n} \frac{(1+\kappa_x) L + \tau_x K}{1+\kappa_x + (1+\kappa_n)\tau_x} \frac{(\theta-1)(1-\alpha)\beta(p_Y)}{\theta - (1-\alpha)\beta(p_Y)} \right]^{\frac{\theta-1}{\theta}} \tag{17}$$

Innovation reduces the cost of producing the advanced good, and therefore its final price p_Y. This decrease in price may then increase the share of the budget spent on the final good if demand is sufficiently elastic, and the increase in demand for the final good in turn drives innovation up further. To guarantee a stable equilbirum, we must assume that the budget share does not increase too much as price declines:

$$\frac{\theta - (1-\alpha)\beta(p_Y)}{\theta - 1} > -\frac{p_Y \beta'(p_Y)}{\beta(p_Y)} \frac{1-\alpha}{\alpha} \tag{18}$$

The right-hand side of this equation is the elastictity of the budget share with respect to the number of varieties. The left-hand side captures the extent to which heterogeneous ability creates decreasing returns in the innovative sector. The decreasing returns that come from drawing less and less able people into the innovative sector must offset the increasing returns that come from decreasing production costs with new varieties. The own-price elasticity of the budget share of Y, $-\frac{p_Y \beta'(p_Y)}{\beta(p_Y)}$, can identically be expressed as $\varepsilon - 1$, where ε is the (absolute value of) own-price elasticity of demand for Y.

The primary value of this model is to examine the impact that an improvement in communication technology would have on the success of the city. We assume that the parameter

τ_x, which represents the time losses in locating away from the city, captures the state of communication technology. An improvement in communication technology reduces τ_x. Improvement in communication may also reduce the value of τ_n, but as long as τ_n is suffciently large relative to τ_x, then innovation will remain in the city, and changes in τ_n will not impact equilibrium quantities.

In a stable equilibrium where manufacturing locates in both the city and the hinterland, a decrease in the cost of distance τ_x will always cause urban property values to decline. As it becomes easier to produce intermediate goods in the hinterland, the price of urban capital declines, since the value of being in the city for intermediate-goods producers declines. This effect captures the decline of old manufacturing cities in the first twenty-five years after World War II, when manufacturing suburbanized and then went to lower density areas within the U.S. The wages for production workers in the city will also fall, since they need to be paid less to compensate them for having to buy urban residential cpaital.

The reduction in the cost of urban capital, however, will be a boon to the innovative sector, because that capital is an input into production which has decreased in price. As the price of urban capital falls, the amount of urban innovation will rise because it has become cheaper to produce. This is one reason why decreasing communication costs will increase the amount of innovation.

A second reason is that improvements in communication technology cause the cost of producing the advanced good to fall. As this price falls, the budget share of Y then increases if demand is elastic, or in other words if the elasticity of substitution between the two goods in the utility function, σ, is above unity.[1] Then the market for the advanced good expands, making innovation more profitable, and thereby attracting previously extramarginal innovators.

Proposition 1 *As τ_x declines beacuse of an improvement in information technology, the price of intermediate inputs falls, the price of the advanced final good falls and all real incomes rise. As τ_x declines, output of the advanced good and employment in producing its inputs increase, and output of the traditional good and employment in its production contract. Innovation and employment in innovation increase as τ_x declines.*

Improvements in transportation technology are essentially reductions in the cost of producing the intermediate inputs that make up the final good. We should therefore not be surprised that the price of those inputs, and the price of the final good, declines. Those decliing good prices then drive real incomes up. As the advanced sector gains a cost advantage, employment in that sector increases and employment in the traditional sector decreases.

The reduction in communications technoloyg also increases the amount of innovation for two reasons, as discussed above. The returns to innovation rise as communication costs fall and the cost of urban capital declines as we discuss in the next proposition: .

Proposition 2 *As τ_x declines the price of urban capital, w_K, falls; the output and employment levels in urban manufacturing decline and wages for production workers in the city fall, but innovation and employment in its production increase, and the total population of the city increases.*

[1] Furthermore, if the advanced good were a luxury its budget share would increase with real income, and therefore decrease with p_Y. However, we retain the conventional assumption of homothetic preferences.

This proposition suggests how we might expect changes in communications tehcnology to impact various measures of urban success. The price of land, which is one widely used metric for the demand for a place, must fall, since the urban advantage that accrues to the sector that is on the margin between urbanizing and not declines. Urban manufacturing employment also declines because that urban edge in manufacturing falls. As the price of urban real estate falls, nominal wages in the city also fall, since those wages are set to keep real incomes for production workers equal between the city and the hinterland.

On the other hand, population in the city will increase because urban capital is fixed and manufacturing is such a heavy user of capital relative to innovation. For this process to work, we must have conversion of old manufacturing space to new residential space for innovators, and we have certainly seen much of that in old manufacturing areas such as lower Manhattan. Warehouses converted into lofts are a prime example of this process in action. The rise of the innovative sector in the city is another more positive sign of urban promise.

For the next proposition we assume that $\kappa_n = 0$ so that the distribution of innovators' income is Pareto like the distribution of abilty. In this case, it follows that:

Proposition 3 *If $\kappa_n = 0$, the ratio of the income of the worker who earns more than $\bar{P}$ percent of the urban workforce to the income of the worker who earns more than $\underline{P}$ percent of the urban workforce rises as τ_x declines whenever the first worker is in the innovative sector and the second worker is in manufacturing.*

This proposition shows that at least some measures of inequality will be increasing in the city as information technology improves. Decreasing communication costs increases the share of the population working in the highly unequal innovative sector. The real-world analogy to this is that as New Yorkers moved from working in highly equal unionized jobs in the textile industry to working in financial services jobs where the returns to ability (or luck) are immense, we witnessed a sizable increase in inequality.

3.5 A Purely Innovative City

In the previous version of the model, we assumed that there was some manufacturing both in and out of the city. We now consider the case where communication technology has improved to the point that production in the city entirely disappears and the city comes to specialize in innovation. To keep things simple, we continue to assume that the information costs associated with innovators leaving the city (τ_n) are such that innovation only occurs in the city.. In this case, the city is entirely innovative and all innovation is in the city. The total amount of innovation in the city and in society is limited by the amount of urban capital, so that the maximum level of innovation equals:[2]

$$\bar{n} = \left[\frac{K}{\psi_n (1+\kappa_n)}\right]^{\frac{\theta-1}{\theta}} \tag{19}$$

The amount of innovation equals this upper limit for a positive value of τ_x, and thus with a positive price of urban capital, if and only if urban capital is sufficiently scarce:

$$\frac{K}{(1+\kappa_n) L} < \frac{(\theta-1)(1-\alpha)\beta(\check{p}_Y)}{\theta-(1-\alpha)\beta(\check{p}_Y)} \text{ with } \check{p}_Y = \frac{1}{\alpha}\psi_x \left[\frac{K}{\psi_n (1+\kappa_n)}\right]^{-\frac{\theta-1}{\theta}\frac{1-\alpha}{\alpha}} \tag{20}$$

If this condition holds, then there is a threshold $\check{\tau}_x > 0$ so that if the cost of distance falls below $\check{\tau}_x$ innovation rises to the maximum level possible in the city. In that case, the equilibrium is described by equations listed in the appendix and Proposition 4 follows:

Proposition 4 *If τ_x declines below $\check{\tau}_x$, the amount of innovation, innovative employment and city population remain constant; output of intermediate goods and of the advanced final good increases; their prices decline and all real incomes increase.*

If τ_x declines below $\check{\tau}_x$, if and only if $\beta'(p_Y) < 0$ the price of urban capital increases, employment in the production of intermediate goods increases, and output and employment in the traditional sector contract.

Once the city has completely specialized in innovation, further improvement in information technology will not impact city population any further. Further imoprovements in the ability to communicate may instead start to increase the value of urban property if demand for the advanced good is sufficiently elastic. The elasticity of demand for the final good is important because it ensures that the falling production costs will make innovation more profitable. In that case, further improvements in communication technology increase the amount spent on the advanced good, which boosts demand for the ideas produced in the city. The model seems to suggest that during an earlier period, when manufacturing was still leaving cities like New York and Boston, improving communication technologies were associated with declining urban property values. However, in the post-1980 world, when these places have specialized highly in idea-production, the rise in real-estate costs may reflect the continuing improvement in the ability of communicating ideas which has acted to increase the returns to innovation.

[2] Symmetrically, there is also a minimum level of innovation below which all advanced manufacturing, and possibly some traditional production, would occur in the city:

$$\underline{n} = \left[\frac{K}{\psi_n \left[1+\kappa_n + \frac{\theta\alpha}{(\theta-1)(1-\alpha)} \frac{1+\kappa_x+(1+\kappa_n)\tau_x}{1+\tau_x}\right]}\right]^{\frac{\theta-1}{\theta}} < \bar{n}$$

This corner solution does not seem to be relevant for an advanced economy, and we simply assume that $n > \underline{n}$.

3.6 Two cities

Finally, we consider an extension of the model that is intended to capture the heterogeneous experiences of different older cities since 1970, and in particular the diverging fates of innovating and manufacturing cities. To do this we assume that the benefits of agglomerating production reflect not only current invention but also the industrial past. As a result, there is the same communication cost advantage of locating in either city, regardless of whether innovation is now taking place in the city, because the knowledge capital required to produce efficiently differentiated intermediates is inherited by both cities from their industrial past. We could also think of these benefits as representing access to city-specific transportation infrastructure like a port or a rail hub.

We also now assume that the urban advantage in producing new ideas is a reflection of knowledge spillovers that depend on the face-to-face interactions of researchers, and are therefore local. Each innovator's productivity is aS, where S is the external effect of aggregate human capital. In the manner of Fujita and Thisse (2003), we assume that the innovation knowledge spillovers in the first city are

$$S_1 = \left[\int_0^{L_n^1} h(j)\, dj + \eta \int_0^{L_n^2} h(j)\, dj \right]^{\delta} \tag{21}$$

where $\delta > 0$ measures the returns to scale in knowledge externalities, and $\eta \in (0,1)$ is an inverse mesaure of the difficulty of achieving profitable spillovers by means of occasional long-distance communication, rather than day-to-day proximity. Moreover, each worker's knowledge stock is assumed for simplicity to be identical, depending on worldwide scientific progress: $h(j) = h$ for all j. Hence

$$S_1 = h^{\delta} \left(L_n^1 + \eta L_n^2 \right)^{\delta} > S_2 = h^{\delta} \left(\eta L_n^1 + L_n^2 \right)^{\delta} \text{ for all } L_n^1 > L_n^2 \tag{22}$$

implying that is naturally efficient for all knowledge workers to congregate in the same location. While an unstable equilibrium where innovators split between the two cities is a possibility, we assume that the innovators, either through coordination or decentralized location choices, have succeeded in reaping the advantages of locating in a single place. The cities are otherwise assumed to be identical, and we will refer to the city where innovators cluster as the innovative city.

The presence of knowledge spillovers obviously works to increase the equilibrium amount of innovation; although the externality also generates increasing returns, for any finite δ a stable equilibrium still exists if final demand for the advanced good is not too elastic: condition 18 takes the stronger form

$$\frac{\theta - (1-\alpha)\beta(p_Y)}{(1+\delta)\theta - 1} > -\frac{p_Y \beta'(p_Y)}{\beta(p_Y)} \frac{1-\alpha}{\alpha} \tag{23}$$

The appendix contains the equations that characterize the equilibrium of this model, where the innovative city hosts both innovation and manufacturing of differentiated intermediates, while the manufacturing city is entirely specialized in manufacturing. In that case, Proposition 5 follows:

Proposition 5 *As τ_x declines, relative to the manufacturing city the innovative city will see the size of its innovative sector grow, the size of its manufacturing shrink, the size of its population grow, and its average income increase if $\kappa_n = 0$.*

This proposition empasizes that declining communication costs increase the degree of inequality across cities, as we saw in the previous section. As those costs decline, the innovative city will see its population and income grow more quickly than the income and population of the manufacturing city.

As before, there can be complete specialization when τ_x equals $\check{\tau}_x > 0$. When the innovative city is entirely specialized in innovation, and the manufacturing city entirely specialized in manufacturing:

Proposition 6 *If τ_x declines below $\check{\tau}_x$, the amount of innovation, innovative employment and population in both cities remain constant; in the hinterland, output and employment in the traditional sector decline, while output and employment in the advanced sector increase; the price of advanced goods declines and all real incomes increase.*

If τ_x declines below $\check{\tau}_x$, urban capital in the manufacturing city becomes cheaper both in absolute terms and relative to urban capital in the innovating city.

This last propsition is meant to capture the increasing divergence of both income and housing values in New York and Detroit.

4 Evidence on Urban Growth

In this section, we turn to the empirical implications of the model about disparity between areas. The model predicted that cities that specialized in innovation would benefit from declining communication costs, while cities that specialized in production would be hurt by those costs. The model also predicts that urban success would be accompanied by increasing specialization in innovative activities.

We start with the awkward task of defining specialization in innovation. We are not aware of a particularly clear way to do this and we believe that innovation is certainly not limited to those sectors that actually produce patents. The finance sector in New York, for example, is clearly enormously innovative in ways that can indeed reduce the costs of producing final goods. As such, we followed the prediction of the model that high human capital people will specialize in innovation. The prediction pushed us to use skilled occupations as a proxy for specialization in innovations. Specifically, we defined innovative occupations as those which were among the top twenty percent of occupations on the basis of education, where the share of workers with college degreees in 1970 is our measure of education. However, since our model is really about the private sector, we excluded those occupations which had more than one-half of their employees working for the government.

Table 2 gives a list of the twenty largest occupations ranked by education in 1970. While doctors and lawyers rank high on the list, perhaps justifiably so, the list of skilled occupations includes many different types of engineers. While there are many reasons to be skeptical about this method of measuring innovative activity, we think it provides a measure that is at least correlated with the level of innovation in the local economy. Moreover, at the very least this measure enables us to test the predictions of the model about the correlation between specialization in the high skill sector and urban success.

In Figure 4, we show the correlation between this measure of innovative occupations and the metropolitan-area fixed effect in a wage regression based on year 2000 Census Individual Public Use Micro Sample data. The wage regression has controlled for individual human capital measures, like years of schooling and age. The correlation between the wage residual and the measure of skilled occupations reminds us that in places with more skilled occupations, the wages of everyone appear to be higher, perhaps because of human capital spillovers (as in Rauch, 1993).

The model predicts that those cities that specialized in innovation were more likely to benefit from the improvements in information technology that have occurerd over the last twenty-five years. We test this hypothesis by looking at specialization in skilled occupations in 1980 and growth in both income and population since then. Figure 5 shows the 26 percent correlation between income growth at the metropolitan area level and the initial share of employment in the more skilled occupations. A one percent increases in skilled occupations in 1980 is associated with an approximately four percent increase in income growth since then.

Figures 6 and 7 show the correlation between initial specialization in skilled occupations and population growth, another measure of urban success. Figure 6 shows that specialization in skilled occupations is not correlated with population growth across the entire set of metropolitan areas. Figure 7 shows that the correlation is significantly positive in the set of older metropolitan areas in the Northeast and Midwest. As such, specialization in innovation does not seem to be important in the growing areas of the sunbelt, but it does seem to be related to the success of older places (as in Glaeser and Saiz, 2004). One interpretation of the greater importance of innovation in the rustbelt than in the sunbelt is that the cities in the sunbelt do not have the same high costs of production that limit urban manufacturing in the older areas. Later development of these places means that land is more readily available and accessible by highways. An alternative interpretation emphasizes the role of skilled people in opposing new housing in California.

Table 3 considers these relationship in a multivariate regression. The first regression shows the strong positive correlation between initial concentration in skilled occupations when we control for initial population, income and regional dummies. As the share of employment in these skilled occupations increases by one percent, we estimate that income grows by about five percent. This coefficient is almost unchanged from the coefficient estimated with no other controls. The second regression reproduces this result for the Northeast and the Midwest. The coefficient on skilled occupations increases slightly. In the third regression, we also control for the initial share of the adult population with college degrees. This control reduces our estimated coefficient on skilled occupations by about 40 percent, but the coefficient remains statistically and economically significant.

Regressions (4), (5) and (6) look at the relationship between skilled occupations and population growth. Regression (4) reproduces the result in Figure 6 showing that there is no correlation between population growth and skilled occupations across the entire United States. Regression (5) reproduces Figure 7 and shows that within the Norhteast and Midwest, there is a very strong correlation between growth and these skill measures. Regression (6) shows that in this case, controlling for initial skills does make the skill occupation coefficient insignificant.

We now turn to the model's predicted correlations about increasing innovation. Figure 8 shows that places that began within a higher concentration of workers in skilled industries increased the degree of that concentration between 1980 and 2000. An increase in the initial share of skilled occupations of ten percent is asssociated with a growth in the share of skilled occupation of 5.6 percent. Just as skilled places became more skilled over the period (Berry and Glaeser, 2005), places that started in more skilled occupations increased their concentration in those occupations. This supports the predictions of the model that decreasing communications costs increase the differences in specialization between cities.

The model also predicts that there will be a positive correlation between places that specialized further in idea production and income gorwth. Figure 9 shows the extremely strong correlation between changes in income and changes in the share of workers in skilled occupations. Places that specialized further in skilled occupations became richer.

While patents are only one form of innovation, they do at least represent a hard measure of innovative activity. As such, we can look at whether our measure of high human capital occupations is correlated with patenting and whether we see a correlation between increases in patenting and increases in income at the metropolitan area level. The correlation between our measure of skilled occupations and the logarithm of the number of patents at the metropolitan level is fifty-seven percent. The correlation between increases in patenting and increases in income is also significant. This 18 percent correlation is shown in Figure 10 which plots the growth in income between 1990 and 2000 ship between change in income and change in patents over the same period.

4.1 Inequality within Cities

A second implication of the model is that declining communication costs will increase the returns to innovative people and that urban inequality will rise. The model can also predict that inequality will rise faster in cities which are specialized in innovation and more successful.

Figure 11 shows that the 16 percent correlation between the increase in the variance of log incomes within metropolitan areas and the initial specialization of the metropolitan area in skilled occupations. Places that had more skilled occupations became more unequal. Figure 12 reproduces this result with another measure of inequality the difference between the log wage at the 90th percentile of the income distribution and the log wage at the 10th percentile of the income distribution. The correlation is weaker but it is still significant.

Table 4 examines whether these regressions hold up in a multivariate setting. Regression (1) shows that there is a positive correlation between initial specialization in skilled occupations and increases in the variance of log income even controlling for initial income, income variance, population and region dummies. Regression (2) shows that this relationship becomes statistically insignificant once we control for the share of the population with college degrees. Interestingly, the coefficient on skilled occupations does not get smaller, but just less precisely estimated. Regressions (3) and (4) reproduce (1) and (2) using the difference in the 90^{th} percentile log wage and the 10^{th} percentile log wage. In this case, the coefficient is positive, but the results are uniformly insignificant.

Figures 13 and 14 show that increasing inequality within cities is also, weakly, associated with rising income at the city level. Places that had faster income growth were also places that had more growth in the variance of log wages or the difference in the 90th percentile log wage and the 10th percentile log wage. Urban success and urban inequality have gone together.

5 Conclusion

The past forty years have seen a remarkable range of urban successes and failures, especially among America's older cities. Some places, like Cleveland and Detroit, seem caught in perpetual decline. Other areas, like San Francisco and New York, had remarkable success as they became centers of idea-based industries.

In this paper, we suggested that these urban successes and urban failures might reflect the same underlying technological change: a vast improvement in communication technology. As communication technology improved, it enabled manufacturing firms to leave cities, causing the urban distress of Detroit or Manhattan in 1975. However, declining communication costs also increased the returns to new innovations and since cities specialize in idea-production, this helped invigorate some cities.

The model suggests that future improvements in information technology will continue to strengthen cities that are centers of innovation, but continue to hurt cities that remain oriented to manufacturing. The primary reason to be wary of that view is the possibility that innovation will also leave dense agglomerations. While this is possible, there is a remarkable continuing tendency of innovative people to locate near other innovative people. Silicon Valley, for example, is built at lower densities than New York, because it is built for drivers not pedestrians, but it is certainly a dense agglomeration. As long as improvements in information technology continue to increase the returns to having new ideas, then the edge that proximity gives to innovation seems likely to keep such agglomerations strong.

A Appendix

A.1 Proof of Propositions 1 and 2

Equations 1, 3, 4, 5, 9, 12, 13, 14, 15 and 16 can be reduced to the system

$$\begin{cases} w_K = \frac{\tau_x}{1+\kappa_x} \\ p_x = \frac{1}{\alpha}\left(1+\tau_x\right)\psi_x \\ p_Y = \frac{1}{\alpha}\left(1+\tau_x\right)\psi_x n^{-\frac{1-\alpha}{\alpha}} \\ X_U = \frac{1}{(1+\kappa_x)\psi_x}K - \frac{(1+\kappa_n)\psi_n}{(1+\kappa_x)\psi_x} n^{\frac{\theta}{\theta-1}} \\ X_R = \left[\frac{\theta\alpha}{(\theta-1)(1-\alpha)}\frac{1+\frac{1+\kappa_n}{1+\kappa_x}\tau_x}{1+\tau_x} + \frac{1+\kappa_n}{1+\kappa_x}\right]\frac{\psi_n}{\psi_x}n^{\frac{\theta}{\theta-1}} - \frac{1}{(1+\kappa_x)\psi_x}K \\ X = \frac{\theta\alpha}{(\theta-1)(1-\alpha)}\frac{1+\frac{1+\kappa_n}{1+\kappa_x}\tau_x}{1+\tau_x}\frac{\psi_n}{\psi_x}n^{\frac{\theta}{\theta-1}} \\ Z = \frac{1-\beta(p_Y)}{\beta(p_Y)}\frac{\theta}{(\theta-1)(1-\alpha)}\left(1+\frac{1+\kappa_n}{1+\kappa_x}\tau_x\right)\psi_n n^{\frac{\theta}{\theta-1}} \\ n = \left[\frac{1}{\psi_n}\frac{(1+\kappa_x)L+\tau_x K}{1+\kappa_x+(1+\kappa_n)\tau_x}\frac{(\theta-1)(1-\alpha)\beta(p_Y)}{\theta-(1-\alpha)\beta(p_Y)}\right]^{\frac{\theta-1}{\theta}} \end{cases}$$

In an interior equilibrium (i.e. for $X_U \geq 0$ and $X_R \geq 0$) these equations imply that as τ_x declines:

1. The relative price of urban capital declines, since

$$w_K^U = \frac{\tau_x}{1+\kappa_x} \Rightarrow \frac{\partial w_K^U}{\partial \tau_x} = \frac{w_K^U}{\tau_x} > 0$$

   The wage of urban manufacturing workers is $1 + w_K^U$, and thus it identically declines.

2. The price of differentiated intermediates declines, since

$$p_x = \frac{1}{\alpha}\psi_x\left(1+\tau_x\right) \Rightarrow \frac{\partial p_x}{\partial \tau_x} = \frac{p_x}{1+\tau_x} > 0$$

3. Innovation increases, since for $\beta'\left(p_Y\right) \leq 0$

$$\begin{aligned} n &= \left[\frac{1}{\psi_n}\frac{\left(1+\kappa_x\right)L+\tau_x K}{1+\kappa_x+\left(1+\kappa_n\right)\tau_x}\frac{\left(\theta-1\right)\left(1-\alpha\right)\beta\left(p_Y\right)}{\theta-\left(1-\alpha\right)\beta\left(p_Y\right)}\right]^{\frac{\theta-1}{\theta}} \\ \Rightarrow \frac{\partial n}{\partial \tau_x} &= -\frac{\theta-1}{\theta\psi_n n^{\frac{1}{\theta-1}}}\left[\begin{array}{c} \frac{(1+\kappa_x)[(1+\kappa_n)L-K]}{[1+\kappa_x+(1+\kappa_n)\tau_x]^2}\frac{(\theta-1)(1-\alpha)\beta(p_Y)}{\theta-(1-\alpha)\beta(p_Y)} + \\ -\frac{(1+\kappa_x)L+\tau_x K}{1+\kappa_x+(1+\kappa_n)\tau_x}\frac{\theta(\theta-1)(1-\alpha)}{[\theta-(1-\alpha)\beta(p_Y)]^2}\beta'\left(p_Y\right) \end{array}\right] < 0 \end{aligned}$$

   As the technology of production does not change, this implies an increase in employment in the innovative sector.

4. The relative price of the advanced good declines, since

$$p_Y = \frac{1}{\alpha}\left(1+\tau_x\right)\psi_x n^{-\frac{1-\alpha}{\alpha}} \Rightarrow \frac{\partial p_Y}{\partial \tau_x} = \frac{p_Y}{1+\tau_x} - \frac{1-\alpha}{\alpha}\frac{p_Y}{n}\frac{\partial n}{\partial \tau_x} > 0$$

   It follows that the the real income of all agents increases.

5. Manufacturing of the traditional good contracts, since we can solve

$$\begin{aligned} Z &= \left(L + \frac{\tau_x}{1+\kappa_x} K\right) \frac{\theta\left[1-\beta\left(p_Y\right)\right]}{\theta-(1-\alpha)\beta\left(p_Y\right)} \\ &\Rightarrow \frac{\partial Z}{\partial \tau_x} = \frac{K}{\left(1+\kappa_x\right)L+\tau_x K} Z - (\theta+\alpha-1)\, Z \frac{\beta'\left(p_Y\right)}{\left[1-\beta\left(p_Y\right)\right]} \frac{\partial p_Y}{\partial \tau_x} > 0 \end{aligned}$$

As the technology of production does not change, this implies that employment in the traditional sector declines

6. Total manufacturing of intermediate inputs expands, since we can solve

$$X = \frac{1}{\psi_x} \frac{L+\tau_x K}{\left(1+\tau_x\right)} \frac{\theta\alpha\beta\left(p_Y\right)}{\theta-(1-\alpha)\beta\left(p_Y\right)} \Rightarrow \frac{\partial X}{\partial \tau_x} = -\frac{L-K}{\left(1+\tau_x\right)\left(L+\tau_x K\right)} X + \theta X \frac{\beta'\left(p_Y\right)}{\beta\left(p_Y\right)} \frac{\partial p_Y}{\partial \tau_x} < 0$$

7. Total output of the advanced final good expands

$$Y = n^{\frac{1-\alpha}{\alpha}} X \Rightarrow \frac{\partial Y}{\partial \tau_x} = \frac{Y}{X}\frac{\partial X}{\partial \tau_x} + \frac{1-\alpha}{\alpha}\frac{Y}{n}\frac{\partial n}{\partial \tau_x} < 0$$

8. Total employment in manufacturing of intermediate inputs expands, since we can solve

$$\begin{aligned} L_x &= \psi_x\left(1+\tau_x\right) X - \psi_x \tau_x X_U = \\ &= \frac{1}{\left(1+\kappa_x\right)} \left\{ \frac{(\theta-1)(1-\alpha)\beta\left(p_Y\right)}{\theta-(1-\alpha)\beta\left(p_Y\right)} \left[\begin{array}{c} \frac{\theta\alpha}{(\theta-1)(1-\alpha)} + \\ + \frac{1+\kappa_n}{1+\kappa_x+(1+\kappa_n)\tau_x} \end{array} \right] \left[\left(1+\kappa_x\right)L+\tau_x K\right] - \tau_x K \right\} \end{aligned}$$

and therefore

$$\begin{aligned} \frac{\partial L_x}{\partial \tau_x} = -\frac{(\theta-1)(1-\alpha)\beta\left(p_Y\right)}{\left(1+\kappa_x\right)\left[\theta-(1-\alpha)\beta\left(p_Y\right)\right]} \left[\begin{array}{r} \frac{\theta[1-\beta(p_Y)]}{(\theta-1)(1-\alpha)\beta(p_Y)} K + \frac{(\kappa_x-\kappa_n)+(1+\kappa_n)\tau_x}{1+\kappa_x+(1+\kappa_n)\tau_x} K + \\ + \frac{(1+\kappa_n)^2[(1+\kappa_x)L+\tau_x K]}{[1+\kappa_x+(1+\kappa_n)\tau_x]^2} \end{array} \right] + \\ + \frac{\theta(\theta-1)(1-\alpha)}{\left[\theta-(1-\alpha)\beta\left(p_Y\right)\right]^2} \beta'\left(p_Y\right) \frac{\partial p_Y}{\partial \tau_x} < 0 \end{aligned}$$

9. Urban manufacturing of intermediate inputs contracts, since

$$X_U = \frac{1}{\left(1+\kappa_x\right)\psi_x} K - \frac{\left(1+\kappa_n\right)\psi_n}{\left(1+\kappa_x\right)\psi_x} n^{\frac{\theta}{\theta-1}} \Rightarrow \frac{\partial X_U}{\partial \tau_x} = -\frac{\theta}{\theta-1}\frac{\left(1+\kappa_n\right)\psi_n}{\left(1+\kappa_x\right)\psi_x} n^{\frac{1}{\theta-1}} \frac{\partial n}{\partial \tau_x} > 0$$

As the technology of production does not change, this implies that employment in urban manufacturing declines.

10. Urban population increases, since

$$L^U = \frac{K + \left(\kappa_x-\kappa_n\right)\psi_n n^{\frac{\theta}{\theta-1}}}{1+\kappa_x} \Rightarrow \frac{\partial L^U}{\partial \tau_x} = \frac{\theta}{\theta-1}\frac{\left(\kappa_x-\kappa_n\right)\psi_n n^{\frac{1}{\theta-1}}}{1+\kappa_x}\frac{\partial n}{\partial \tau_x} < 0$$

A.2 Proof of Proposition 3

The income of an innovator with productivity a is

$$y(a) = a\pi - w_K \kappa_n$$

Thus for $\kappa_n = 0$, the income distribution of innovators follows a Pareto distribution with shape θ and minimum $1+w_K$ dictated by the indifference condition of the marginal innovator. Recalling definition 6, the value of percentile p in a Pareto distribution with minimum $1+w_K$ is $(1+w_K)(1-p)^{-\frac{1}{\theta}}$.

If fraction λ of the city population is employed in manufacturing and $1-\lambda$ in innovation, the value of percentile $\underline{P} \leq \lambda$ of the urban income distribution is the homogeneous income of manufacturing workers $1+w_K$; while percentile $\bar{P} > \lambda$ corresponds to percentile $p = \left(\bar{P}-\lambda\right)/(1-\lambda)$ of the income distribution of innovators. Thus their ratio is

$$\begin{aligned} \rho &= \left(\frac{1-\lambda}{1-\bar{P}}\right)^{\frac{1}{\theta}} \\ \Rightarrow \frac{\partial R}{\partial \tau_x} &= -\frac{1}{\theta}\frac{\lambda}{1-\lambda}R\frac{\partial \lambda}{\partial \tau_x} < 0 \end{aligned}$$

A.3 Proof of Proposition 4

When the city is completely specialized and the amount of innovation is fixed at $\bar{n}$, the equilibrium is described by

$$\begin{cases} \beta(p_Y) = \frac{p_x X}{p_x X + Z} \\ p_Y = \bar{n}^{-\frac{1-\alpha}{\alpha}} p_x \\ p_x = \frac{1}{\alpha}\psi_x (1+\tau_x) \\ \frac{\theta}{\theta-1}(1+w_K)\psi_n \bar{n}^{\frac{\theta}{\theta-1}} = (1-\alpha) p_x X \\ L = \psi_n \bar{n}^{\frac{\theta}{\theta-1}} + (1+\tau_x)\psi_x X + Z \\ K = \psi_n (1+\kappa_n)\bar{n}^{\frac{\theta}{\theta-1}} \end{cases}$$

which can be reduced to

$$\begin{cases} p_x = \frac{1}{\alpha}(1+\tau_x)\psi_x \\ p_Y = \frac{1}{\alpha}(1+\tau_x)\psi_x \bar{n}^{-\frac{1-\alpha}{\alpha}} \\ X = \frac{\theta\alpha}{(\theta-1)(1-\alpha)}\frac{(1+w_K)\psi_n}{(1+\tau_x)\psi_x}\bar{n}^{\frac{\theta}{\theta-1}} \\ Z = \frac{1-\beta(p_Y)}{\beta(p_Y)}\frac{\theta}{(\theta-1)(1-\alpha)}(1+w_K)\psi_n \bar{n}^{\frac{\theta}{\theta-1}} \\ \left[1+\frac{1-\beta(p_Y)}{\alpha\beta(p_Y)}\right](1+w_K) = \frac{(\theta-1)(1-\alpha)}{\theta\alpha}\left(\frac{L}{\psi_n \bar{n}^{\frac{\theta}{\theta-1}}} - 1\right) \\ \bar{n} = \left[\frac{K}{\psi_n(1+\kappa_n)}\right]^{\frac{\theta-1}{\theta}} \end{cases}$$

As τ_x falls below $\check{\tau}_x$, it straightforward that:

1. The amount of innovation is fixed at $\bar{n}$ by the urban capacity constraint; employment in the innovative sector and city population are likewise constrained.

2. The relative price of differentiated intermediates p_x declines.

3. The relative price of the advanced good p_Y declines, and therefore the the real income of all agents increases.

4. The relative price of urban capital increases if and only if $\beta'(p_Y) < 0$, since

$$\frac{\partial w_K}{\partial p_Y} = -\frac{\beta'(p_Y)}{\beta(p_Y)} \frac{1 + w_K}{1 - (1 - \alpha)\beta(p_Y)}$$

5. Output of the differentiated intermediates X increases, and so does employment in their production $(1 + \tau_x)\psi_x X$, if and only if w_K increases

   Thus employment in the traditional sector and its output contract if and only if $\beta'(p_Y) < 0$.

A.4 Proof of Proposition 5

When the marginal innovator has ability t, employment in innovation is

$$L_n = L[1 - F(t)] = L\underline{a}^{\theta} t^{-\theta}$$

and therefore knowledge spillovers are

$$S = (hL_n)^{\delta} = h^{\delta} L^{\delta} \underline{a}^{\delta\theta} t^{-\delta\theta}$$

and the total amount of innovation is

$$n = L \int_t^{\infty} Saf(a)\, da = h^{\delta} L^{1+\delta} \underline{a}^{(1+\delta)\theta} \frac{\theta}{\theta - 1} t^{1-(1+\delta)\theta}$$

For notational convenience, we capture the effect of the level of individual knowledge capital h by an adjusted inverse productivity measure

$$\tilde{\psi}_n \equiv h^{-\frac{\delta\theta}{(1+\delta)\theta-1}} \psi_n^{\frac{\theta-1}{(1+\delta)\theta-1}}$$

so that as a function of the amount of innovation employment is

$$L_n = h^{-\frac{\delta\theta}{(1+\delta)\theta-1}} L^{-\frac{1}{(1+\delta)\theta-1}} \underline{a}^{-\frac{\theta}{(1+\delta)\theta-1}} \left(\frac{\theta-1}{\theta}\right)^{\frac{\theta}{(1+\delta)\theta-1}} n^{\frac{\theta}{(1+\delta)\theta-1}} = \tilde{\psi}_n n^{\frac{\theta}{(1+\delta)\theta-1}}$$

and the productivity of the marginal innovator is

$$St = h^{\frac{\delta\theta}{(1+\delta)\theta-1}} L^{\frac{1}{(1+\delta)\theta-1}} \underline{a}^{\frac{\theta}{(1+\delta)\theta-1}} \left(\frac{\theta-1}{\theta}\right)^{-\frac{1-\delta\theta}{(1+\delta)\theta-1}} n^{\frac{\delta\theta-1}{(1+\delta)\theta-1}} = \tilde{\psi}_n \frac{\theta-1}{\theta} n^{\frac{\delta\theta-1}{(1+\delta)\theta-1}}$$

Thus the free-entry condition 13 becomes

$$\tilde{\psi}_n \frac{\theta-1}{\theta} n^{\frac{\delta\theta-1}{(1+\delta)\theta-1}} \pi = 1 + (1 + \kappa_n) w_K$$

and the equilibrium is defined by

$$\begin{cases} \beta\left(p_Y\right)=\frac{p_x X}{p_x X+Z} \\ p_Y=n^{-\frac{1-\alpha}{\alpha}} p_x \\ p_x=\frac{1}{\alpha} \psi_x\left(1+\tau_x\right) \\ \frac{\theta}{\theta-1} \tilde{\psi}_n\left(1+\frac{1+\kappa_n}{1+\kappa_x} \tau_x\right) n^{\frac{\theta}{(1+\delta) \theta-1}}=(1-\alpha) p_x X \\ X=X_1+X_2+X_R \\ L=\tilde{\psi}_n n^{\frac{\theta}{(1+\delta) \theta-1}}+\psi_x\left(X_1+X_2\right)+\psi_x\left(1+\tau_x\right) X_R+Z \\ \frac{1}{2} K=\tilde{\psi}_n\left(1+\kappa_n\right) n^{\frac{\theta}{(1+\delta) \theta-1}}+\psi_x\left(1+\kappa_x\right) X_1 \\ \frac{1}{2} K=\psi_x\left(1+\kappa_x\right) X_2 \end{cases}$$

which can be rewritten in analogy to the one-city case:

$$\begin{cases} p_x=\frac{1}{\alpha} \psi_x\left(1+\tau_x\right) \\ p_Y=\frac{1}{\alpha}\left(1+\tau_x\right) \psi_x n^{-\frac{1-\alpha}{\alpha}} \\ X_1=\frac{1}{\left(1+\kappa_x\right) \psi_x} \frac{K}{2}-\frac{\left(1+\kappa_n\right) \tilde{\psi}_n}{\left(1+\kappa_x\right) \psi_x} n^{\frac{\theta}{(1+\delta) \theta-1}} \\ X_2=\frac{1}{\left(1+\kappa_x\right) \psi_x} \frac{K}{2} \\ X_R=\left[\frac{\theta \alpha}{(\theta-1)(1-\alpha)} \frac{1+\frac{1+\kappa_n}{1+\kappa_x} \tau_x}{1+\tau_x}+\frac{1+\kappa_n}{1+\kappa_x}\right] \frac{\tilde{\psi}_n}{\psi_x} n^{\frac{\theta}{(1+\delta) \theta-1}}-\frac{K}{\left(1+\kappa_x\right) \psi_x} \\ X=\frac{\theta \alpha}{(\theta-1)(1-\alpha)} \frac{1+\frac{1+\kappa_n}{1+\kappa_x} \tau_x}{1+\tau_x} \frac{\tilde{\psi}_n}{\psi_x} n^{\frac{\theta}{(1+\delta) \theta-1}} \\ Z=\frac{1-\beta\left(p_Y\right)}{\beta\left(p_Y\right)} \frac{\theta}{(\theta-1)(1-\alpha)}\left(1+\frac{1+\kappa_n}{1+\kappa_x} \tau_x\right) \tilde{\psi}_n n^{\frac{\theta}{(1+\delta) \theta-1}} \\ n=\left[\frac{1}{\tilde{\psi}_n} \frac{\left(1+\kappa_x\right) L+\tau_x K}{1+\kappa_x+\left(1+\kappa_n\right) \tau_x} \frac{(\theta-1)(1-\alpha) \beta\left(p_Y\right)}{\theta-(1-\alpha) \beta\left(p_Y\right)}\right]^{\frac{(1+\delta) \theta-1}{\theta}} \end{cases}$$

The comparative statics are also analogous to those in Propositions 1 and 2, so that as τ_x falls n increases. This implies that in the first city the innovative sector grows, the manufacturing sector contracts, and population grows—none of which happens in the second city, where the only effect is a fall in the price of urban capital and therefore in the nominal wage.

When $\kappa_n=0$, the income of innovators in the first city is an invariant Pareto distribution with shape θ and minimum $1+w_K:$ thus its mean is $\left(1+w_K\right)\theta/\left(\theta-1\right)$. If a fraction λ of workers in the first city are employed in manufacturing and $1-\lambda$ in innovation, the ratio of average income across the two cities is then

$$\frac{\bar{y}_1}{\bar{y}_2}=\frac{\theta-\lambda}{\theta-1}$$

which decreases as the innovating city specializes more completely.

A.5 Proof of Proposition 6

As in the case of Proposition 4,when the innovating city is completely specialized and the amount of innovation is fixed at

$$\bar{n}_1=\left[\frac{K}{2 \tilde{\psi}_n\left(1+\kappa_n\right)}\right]^{\frac{(1+\delta) \theta-1}{\theta}}$$

the equilibrium is described by

$$\begin{cases} \beta\left(p_Y\right) = \frac{p_x X}{p_x X + Z} \\ p_Y = \bar{n}^{-\frac{1-\alpha}{\alpha}} p_x \\ p_x = \frac{1}{\alpha}\psi_x\left(1+\tau_x\right) \\ \frac{\theta}{\theta-1}\tilde{\psi}_n\left(1+w_K^1\right)\bar{n}^{\frac{\theta}{(1+\delta)\theta-1}} = \left(1-\alpha\right)p_x X \\ X = X_2 + X_R \\ L = \tilde{\psi}_n \bar{n}_1^{\frac{\theta}{(1+\delta)\theta-1}} + \psi_x X_2 + \psi_x\left(1+\tau_x\right)X_R + Z \\ \frac{1}{2}K = \tilde{\psi}_n\left(1+\kappa_n\right)\bar{n}_1^{\frac{\theta}{(1+\delta)\theta-1}} \\ \frac{1}{2}K = \psi_x\left(1+\kappa_x\right)X_2 \\ w_K^2 = \frac{\tau_x}{1+\kappa_x} \end{cases}$$

which can be reduced to

$$\begin{cases} \bar{n}_1 = \left[\frac{K}{2\tilde{\psi}_n(1+\kappa_n)}\right]^{\frac{(1+\delta)\theta-1}{\theta}} \\ w_K^2 = \frac{\tau_x}{1+\kappa_x} \\ p_x = \frac{1}{\alpha}\left(1+\tau_x\right)\psi_x \\ p_Y = \frac{1}{\alpha}\left(1+\tau_x\right)\psi_x \bar{n}_1^{-\frac{1-\alpha}{\alpha}} \\ X_2 = \frac{1}{\psi_x(1+\kappa_x)}\frac{K}{2} \\ X_R = \frac{\theta\alpha}{(\theta-1)(1-\alpha)}\frac{\left(1+w_K^1\right)\tilde{\psi}_n}{(1+\tau_x)\psi_x}\bar{n}_1^{\frac{\theta}{(1+\delta)\theta-1}} - \frac{K_2}{\psi_x(1+\kappa_x)} \\ X = \frac{\theta\alpha}{(\theta-1)(1-\alpha)}\frac{\left(1+w_K^1\right)\tilde{\psi}_n}{(1+\tau_x)\psi_x}\bar{n}_1^{\frac{\theta}{(1+\delta)\theta-1}} \\ Z = \frac{1-\beta(p_Y)}{\beta(p_Y)}\frac{\theta}{(\theta-1)(1-\alpha)}\left(1+w_K^1\right)\tilde{\psi}_n\bar{n}_1^{\frac{\theta}{(1+\delta)\theta-1}} \\ \left[1+\frac{1-\beta(p_Y)}{\alpha\beta(p_Y)}\right]\left(1+w_K^1\right) = \frac{(\theta-1)(1-\alpha)}{\theta\alpha}\left[\frac{L+\frac{\tau_x}{2(1+\kappa_x)}K}{\tilde{\psi}_n\bar{n}_1^{\frac{\theta}{(1+\delta)\theta-1}}} - 1\right] \end{cases}$$

It follow that as falls below $\check{\tau}_x$:

1. The amount of innovation is fixed at $\bar{n}_1$ by the urban capacity constraint; employment in the innovative sector is likewise constrained, and so is population in both cities.

2. The price of urban capital in the manufacturing city w_K^2 declines.

3. The relative price of differentiated intermediates p_x declines.

4. The relative price of the advanced good p_Y declines, and therefore the the real income of all agents increases.

5. Manufacturing of the traditional good contracts, since we can solve

$$\begin{aligned} Z &= \left[1+\alpha\frac{\beta\left(p_Y\right)}{1-\beta\left(p_Y\right)}\right]^{-1}\left[L+\frac{\tau_x}{2\left(1+\kappa_x\right)}K - \tilde{\psi}_n\bar{n}_1^{\frac{\theta}{(1+\delta)\theta-1}}\right] \\ \Rightarrow \frac{\partial Z}{\partial \tau_x} &= \left[1+\alpha\frac{\beta\left(p_Y\right)}{1-\beta\left(p_Y\right)}\right]^{-1}\left\{\frac{K}{2\left(1+\kappa_x\right)} - Z\frac{\alpha\beta'\left(p_Y\right)}{\left[1-\beta\left(p_Y\right)\right]^2}\frac{\partial p_Y}{\partial \tau_x}\right\} > 0 \end{aligned}$$

Hence, employment in manufacturing the traditional good declines; employment in manufcaturing intermediates increase, and *a fortiori* output of advanced goods increases.

6. Finally, $w_K^1 > w_K^2$ because by definition of $\check{\tau}_x$

$$\left[1+\frac{1-\beta\left(p_Y\right)}{\alpha\beta\left(p_Y\right)}\right]\left(1+w_K^2\right)<\frac{\left(\theta-1\right)\left(1-\alpha\right)}{\theta\alpha}\left[\frac{L+\frac{\tau_x}{2\left(1+\kappa_x\right)}K}{\tilde{\psi}_n\bar{n}_1^{\frac{\theta}{\left(1+\delta\right)\theta-1}}}-1\right]$$

for all

$$w_K^2=\frac{\tau_x}{1+\kappa_x}<\frac{\check{\tau}_x}{1+\kappa_x}$$

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Figure 1:
Population Growth by MSA

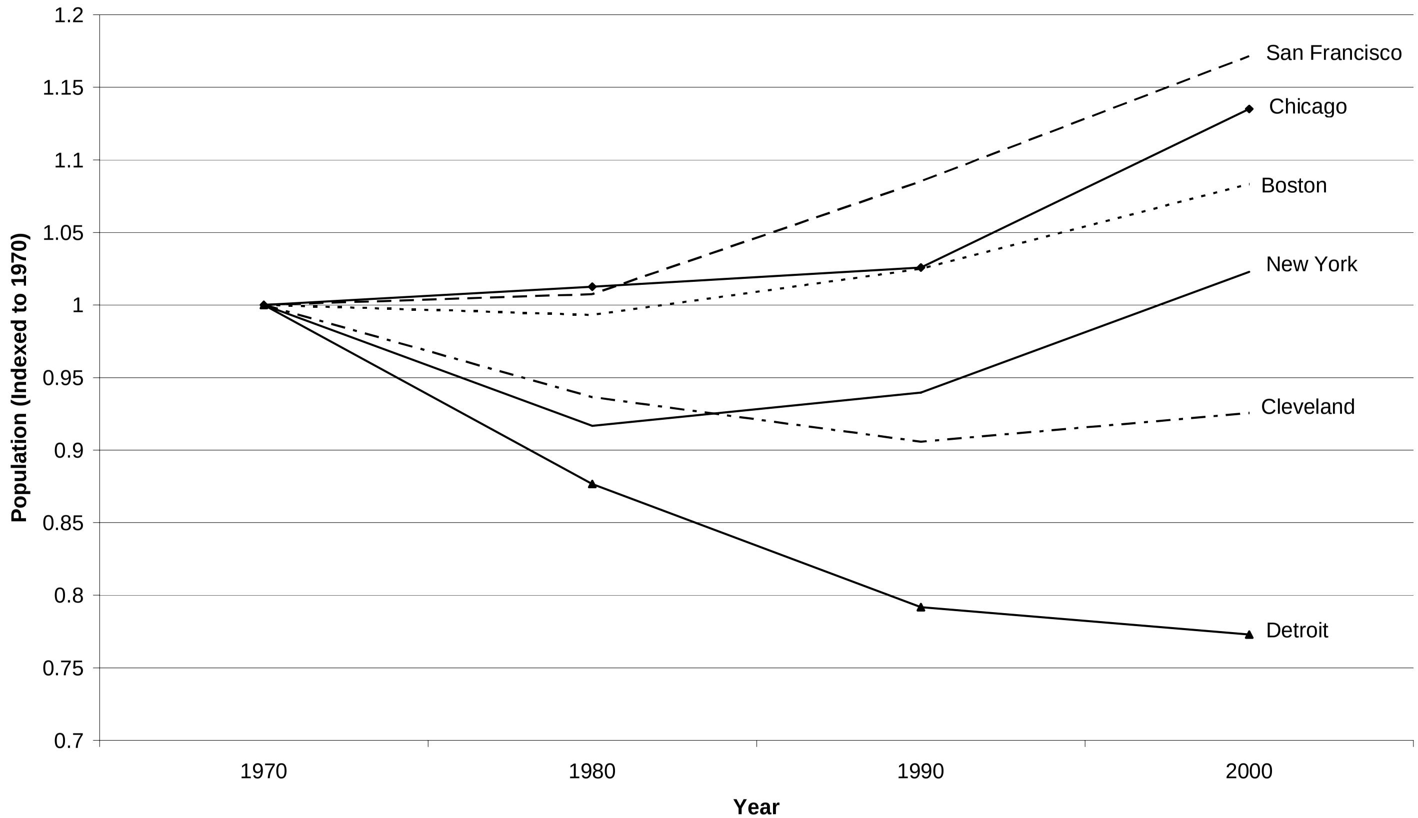
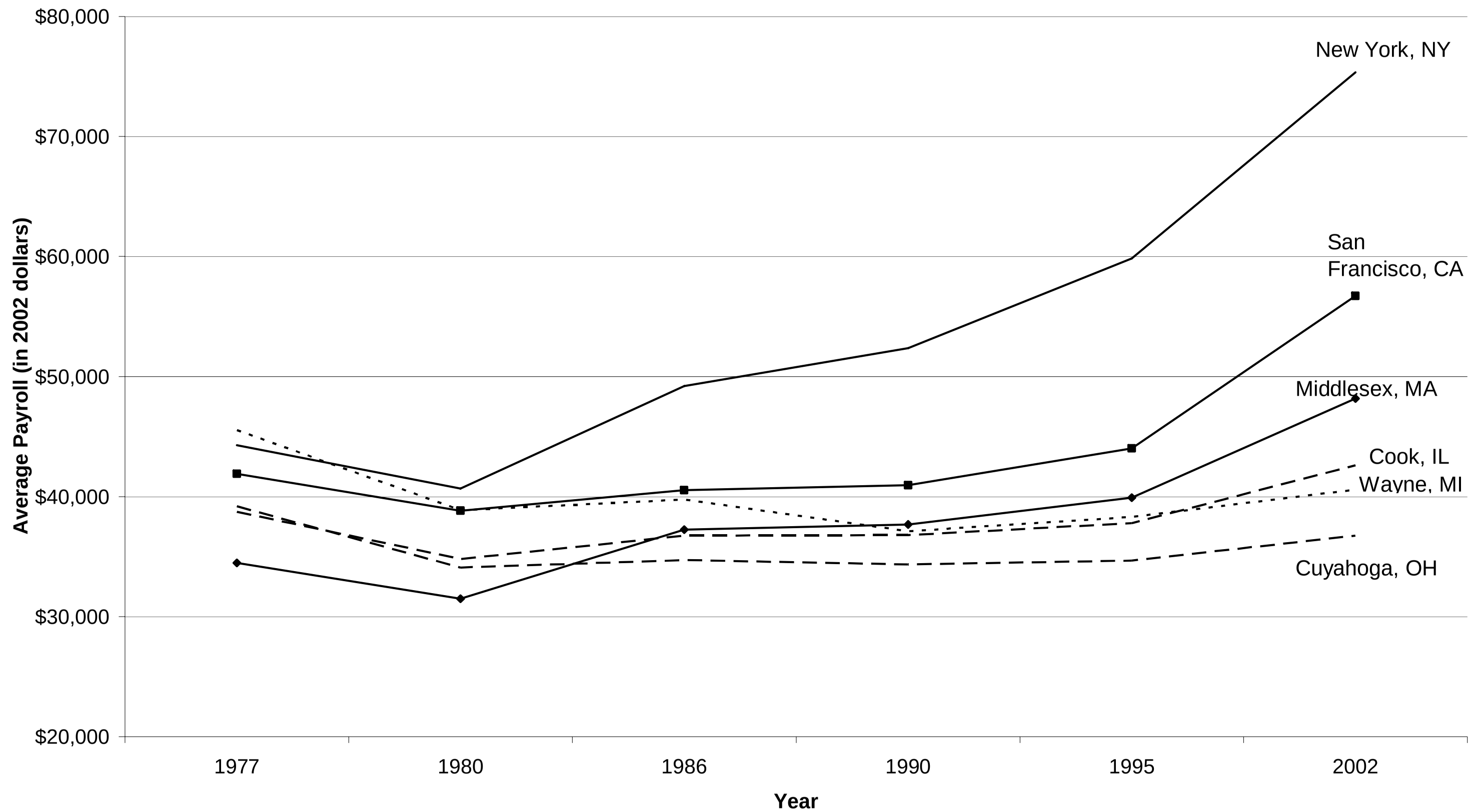


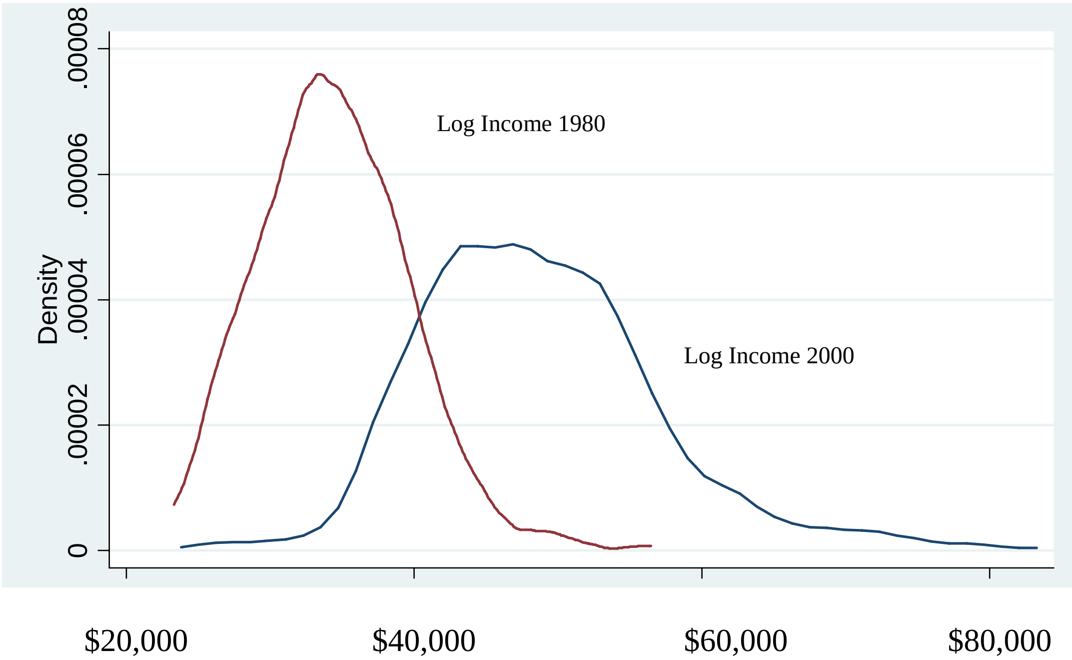
Figure 2:
Average Payroll by County

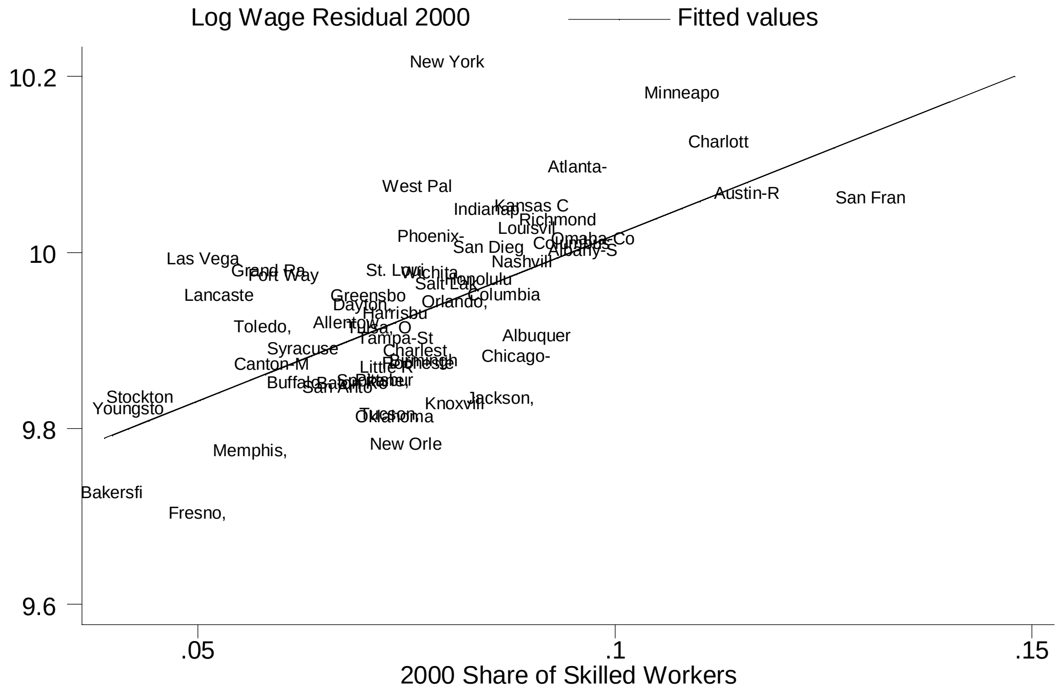


Source: County Business Patterns

Figure 3:

Density Distribution of Log Median Family Income in 1980 and 2000 across MSAs





Log Wage Residual 2000
Fitted values
10.2
10
9.8
9.6
.05
.1
.15
2000 Share of Skilled Workers
New York
Minneapo
Charlott
Atlanta-
West Pal
Austin-R
San Fran
Kansas C
Richmond
Phoenix-
San Dieg
Omaha-Co
Albany-S
Nashvill
Las Vega
Grand Ra
Fort Way
St. Loui
Wichita
Honolulu
Salt Lak
Columbia
Lancaste
Greensbo
Dayton
Orlando,
Harrisbu
Toledo,
Tulsa, O
Tampa-St
Albuquer
Syracuse
Charlest,
Chicago-
Canton-M
Little R
Buffalo
San Anto
Stockton
Youngsto
Jackson,
Knoxvill
Tucson
Oklahoma
Memphis,
New Orle
Bakersfi
Fresno,

Figure 4

Table 1
Major Industries by County As Percent of Total Annual Payroll - 1977 and 2002

County	1977		2002	
	Top Industries	% Total Annual Payroll	Top Industries	% Total Annual Payroll
Chicago	Manufacturing	36.03%	Finance & insurance	14.00%
(Cook County)	Retail Trade	10.62%	Professional, scientific & technical services	12.72%
	Wholesale Trade	10.35%	Health care and social assistance	11.03%
	Finance, Insurance, and Real Estate	9.37%	Manufacturing	11.01%
	Transportation and Other Public Utilities	8.41%	Wholesale trade	6.77%
Cleveland	Manufacturing	44.07%	Manufacturing	15.94%
(Cuyahoga County)	Wholesale Trade	9.92%	Health care and social assistance	15.01%
	Retail Trade	9.52%	Finance & insurance	10.44%
	Transportation and Other Public Utilities	8.77%	Professional, scientific & technical services	9.40%
	Health and Social Services	6.70%	Wholesale trade	8.27%
Boston	Manufacturing	39.26%	Professional, scientific & technical services	18.85%
(Middlesex County)	Retail Trade	10.89%	Manufacturing	12.92%
	Wholesale Trade	9.31%	Information	8.91%
	Educational Services	7.24%	Wholesale trade	8.30%
	Health and Social Services	6.77%	Health care and social assistance	8.23%
New York	Finance, Insurance, and Real Estate	22.96%	Finance & insurance	39.50%
(New York County)	Manufacturing	19.85%	Professional, scientific & technical services	14.25%
	Wholesale Trade	11.18%	Information	7.91%
	Business Services Incl. Legal Services and Computer Services	10.68%	Management of companies & enterprises	6.70%
	Transportation and Other Public Utilities	9.77%	Health care and social assistance	5.91%
San Francisco	Transportation and Other Public Utilities	23.37%	Finance & insurance	23.07%
(San Francisco County)	Finance, Insurance, and Real Estate	17.14%	Professional, scientific & technical services	21.26%
	Manufacturing	11.85%	Information	8.40%
	Construction	10.16%	Health care and social assistance	7.89%
	Retail Trade	8.27%	Management of companies & enterprises	4.86%
Detroit	Manufacturing	55.22%	Manufacturing	20.46%
(Wayne County)	Retail Trade	8.83%	Health care and social assistance	11.66%
	Transportation and Other Public Utilities	7.17%	Management of companies & enterprises	8.56%
	Health and Social Services	6.86%	Professional, scientific & technical services	6.17%
	Wholesale Trade	6.61%	Transportation & warehousing	6.01%

Table 2
Top Occupations of Skilled Workers

1	Physicians
2	Dentists
3	Lawyers
4	Physicists and astronomers
5	Veterinarians
6	Geologists
7	Chemical engineers
8	Optometrists
9	Petroleum, mining, and geological engineers
10	Other health and therapy
11	Chemists
12	Architects
13	Economists, market researchers, and survey researchers
14	Pharmacists
15	Clergy and religious workers
16	Metallurgical and materials engineers, variously phrased
17	Aerospace engineer
18	Electrical engineer
19	Civil engineers
20	Mechanical engineers

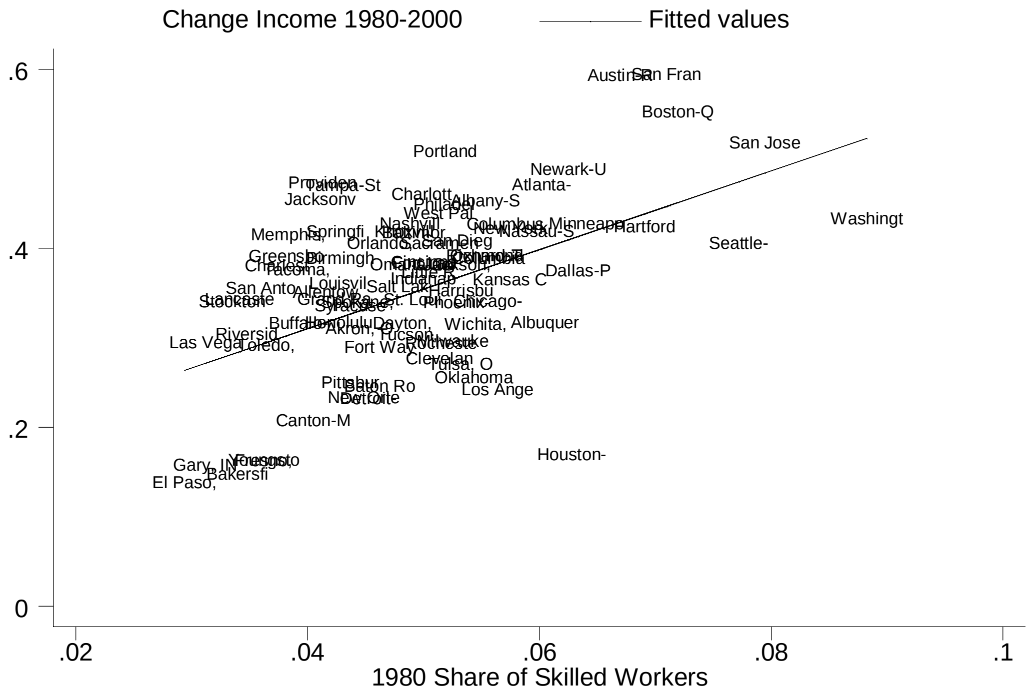
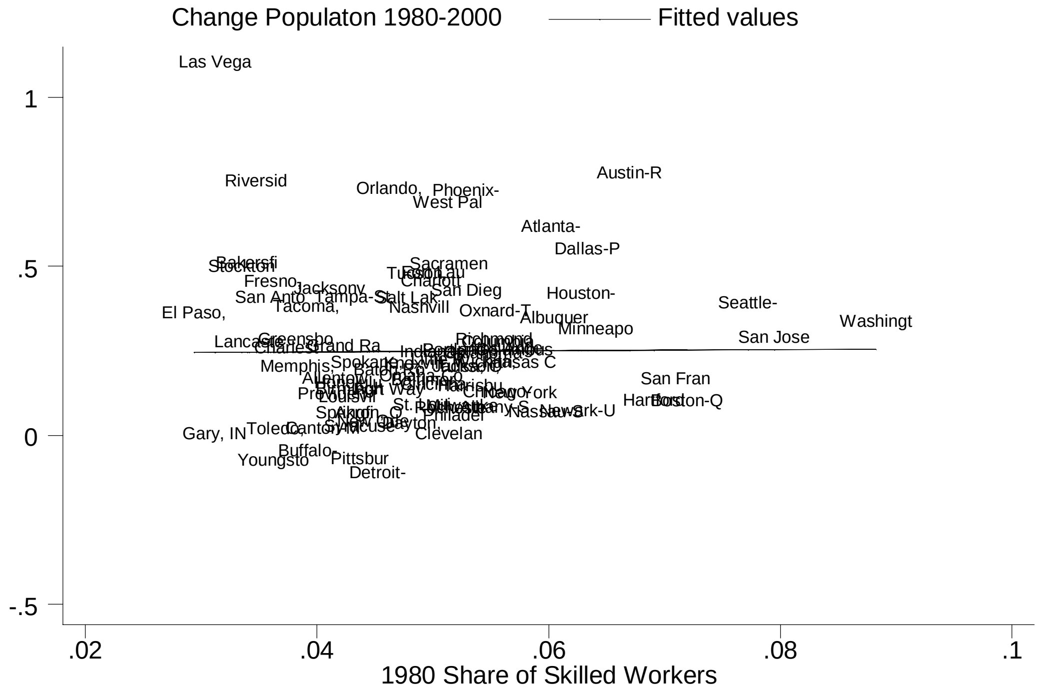

Change Income 1980-2000
Fitted values
.6
.4
.2
0
.02
.04
.06
.08
.1
1980 Share of Skilled Workers
San Fran
Boston-Q
San Jose
Portland
Newark-U
Atlanta-
Jacksonv
Charlott
Albany-S
West Pal
Hartford
Washingt
Memphis,
Springfi
Orlando,
Seattle-
Greensbo
Birmingh
Tacoma,
Dallas-P
Kansas C
San Anto
Louisvil
Salt Lak
Harrisbu
Stockton
St. Loui
Chicago-
Dayton,
Wichita,
Albuquer
Riversid
Akron,
Tucson,
Las Vega
Toledo,
Fort Way
Clevelan
Oklahoma
Los Ange
Canton-M
Houston-
Bakersfi
El Paso,

Figure 5


Change Populaton 1980-2000
Fitted values
Las Vega
Riversid
Orlando,
Phoenix-
West Pal
Austin-R
Atlanta-
Dallas-P
Sacramen
Houston-
Seattle-
Washingt
San Jose
Minneapo
Albuquer
Oxnard-T
San Dieg
Nashvill
Fresno,
Jacksonv
El Paso,
Tacoma,
Memphis,
San Fran
Boston-Q
Chicago
Clevelan
Gary, IN
Toledo,
Buffalo,
Youngsto
Pittsbur
Detroit-
1
.5
0
-.5
.02
.04
.06
.08
.1
1980 Share of Skilled Workers
Figure 6

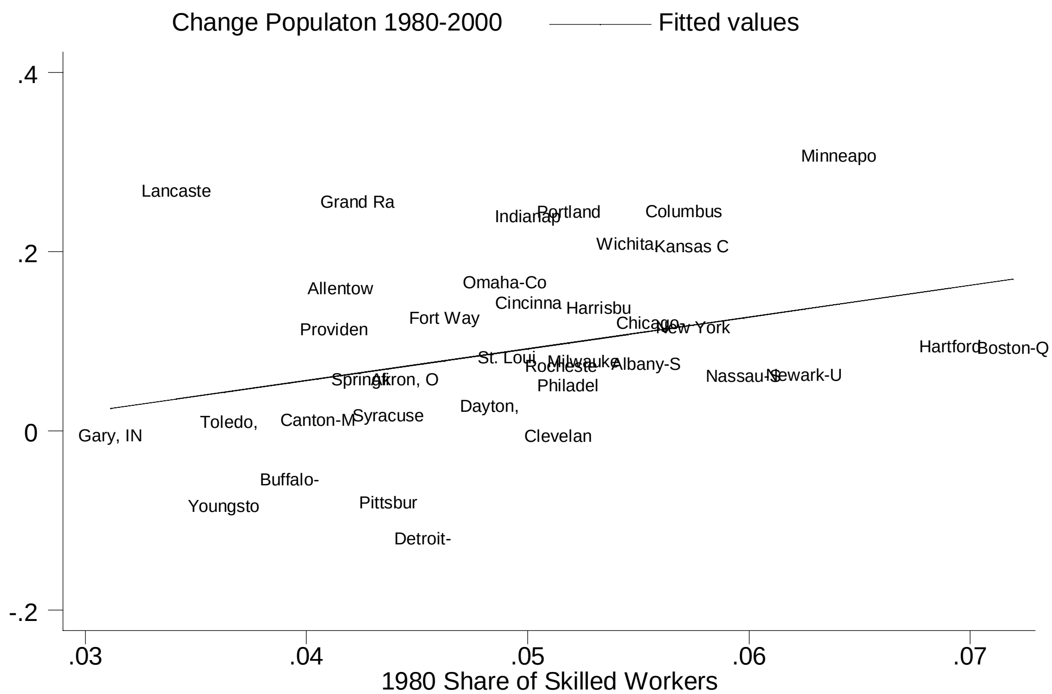
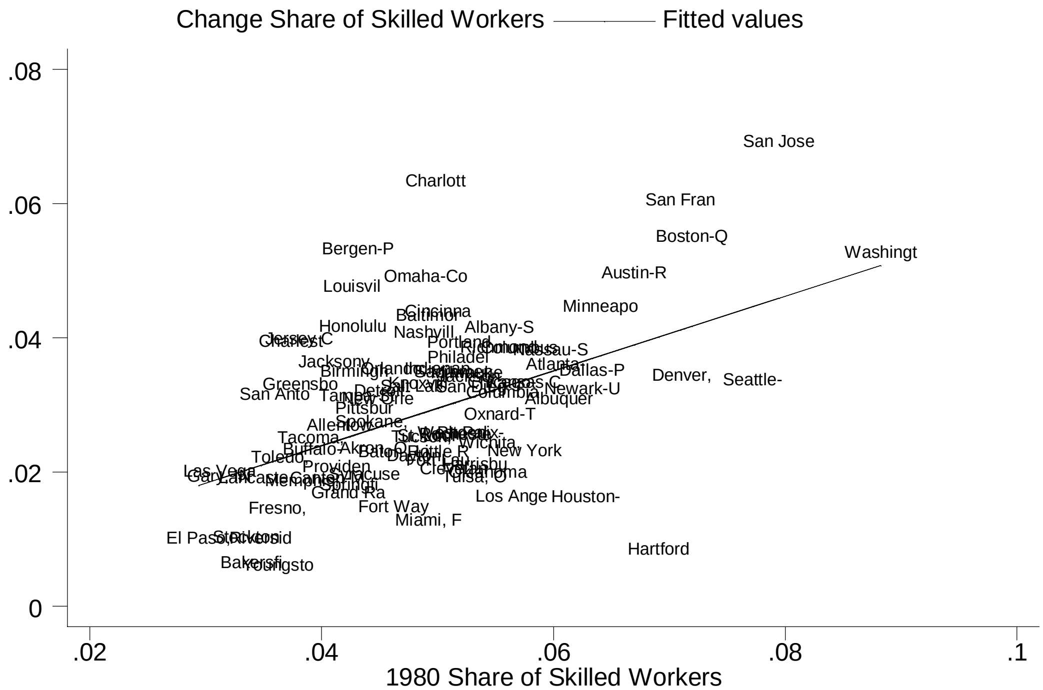

Change Populaton 1980-2000
Fitted values
.4
.2
0
-.2
.03
.04
.05
.06
.07
1980 Share of Skilled Workers
Minneapo
Lancaste
Grand Ra
Indianap
Portland
Columbus
Wichita
Kansas C
Allentow
Omaha-Co
Cincinna
Harrisbu
Fort Way
Providen
Chicago
New York
Hartford
Boston-Q
St. Loui
Milwauke
Rocheste
Albany-S
Springfi
Akron, O
Nassau-S
Newark-U
Philadel
Dayton,
Syracuse
Canton-M
Toledo,
Gary, IN
Clevelan
Buffalo-
Youngsto
Pittsbur
Detroit-

Figure 7

Table 3

	Change in Log Income			Change in Log Population		
	(1)	(2)	(3)	(4)	(5)	(6)
Share of Skilled Workers in 1980	5.757	6.684	3.839	1.437	6.071	0.564
	(0.943)	(1.076)	(1.698)	(2.129)	(1.941)	(3.494)
Log Income 1980	-0.266	-0.351	-0.278	-0.21	-0.216	-0.254
	(0.101)	(0.108)	(0.101)	(0.228)	(0.195)	(0.189)
Log Population 1980	-0.007	-0.003	-0.005	-0.013	-0.046	-0.044
	(0.013)	(0.012)	(0.013)	(0.029)	(0.022)	(0.021)
Share of Population with BA in 1980			0.676			2.084
			(0.499)			(1.117)
Northeast Dummy	0.062	0.054	0.054	-0.029	-0.04	-0.063
	(0.026)	(0.019)	(0.026)	(0.058)	(0.033)	(0.035)
South Dummy	0.016		0.006	0.203		
	(0.026)		(0.027)	(0.059)		
West Dummy	0.008		-0.011	0.316		
	(0.025)		(0.028)	(0.056)		
Constant	2.941	3.729	3.026	2.431	2.73	3.045
	(1.031)	(1.123)	(1.027)	(2.327)	(2.027)	(1.96)
R-squared	0.417	0.700	0.431	0.443	0.263	0.338



Change Share of Skilled Workers
Fitted values
.08
.06
.04
.02
0
.02
.04
.06
.08
.1
1980 Share of Skilled Workers
San Jose
Charlott
San Fran
Boston-Q
Bergen-P
Washingt
Omaha-Co
Austin-R
Louisvil
Minneapo
Cincinna
Honolulu
Albany-S
Nashvill
Philadel
Jacksonv
Atlanta
Dallas-P
Denver,
Seattle-
Greensbo
San Anto
Newark-U
Albuquer
Pittsbur
Oxnard-T
Tacoma
Wichita
Toledo
New York
Providen
Los Vega
Grand Ra
Los Ange
Houston-
Fresno,
Fort Way
Miami, F
Hartford

Figure 8

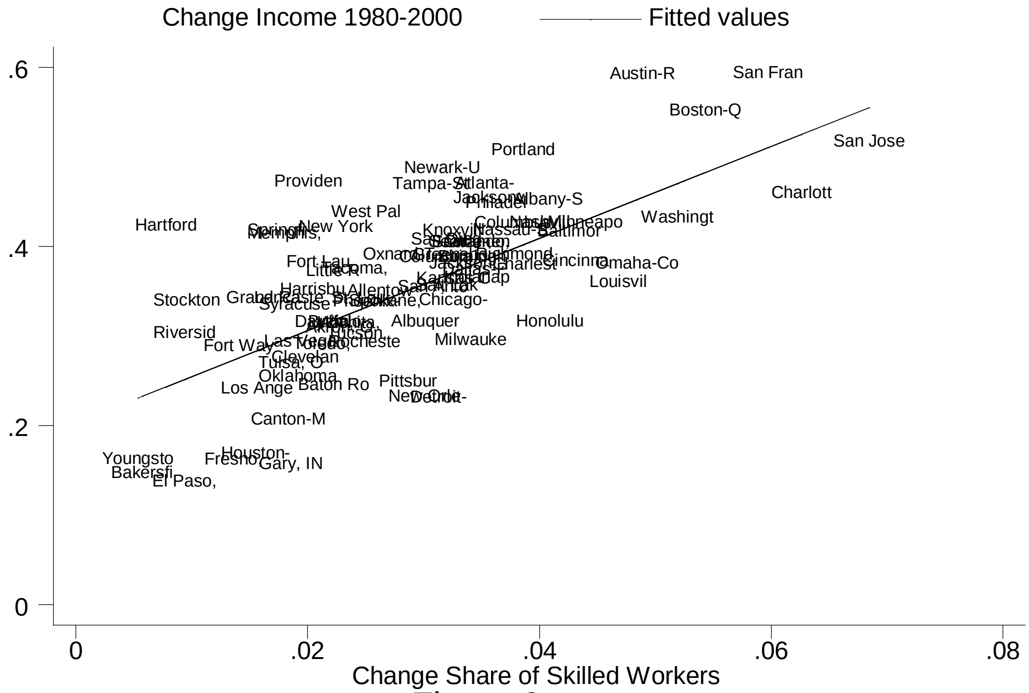

Change Income 1980-2000
Fitted values
.6
.4
.2
0
0
.02
.04
.06
.08
Change Share of Skilled Workers
Austin-R
San Fran
Boston-Q
San Jose
Portland
Newark-U
Providen
Charlott
West Pal
Washingt
Hartford
New York
Louisvil
Omaha-Co
Stockton
Chicago-
Albuquer
Honolulu
Riversid
Milwauke
Pittsbur
Los Ange
Baton Ro
Canton-M
Houston-
Youngsto
Fresno
Gary, IN
Bakersfi
El Paso,

Figure 9

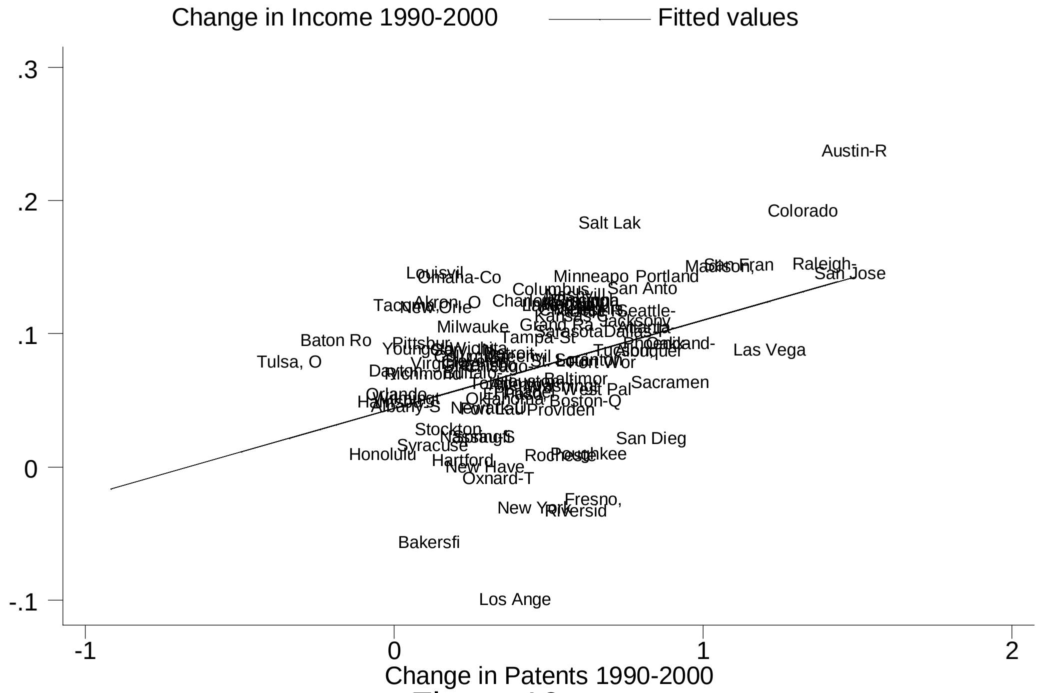
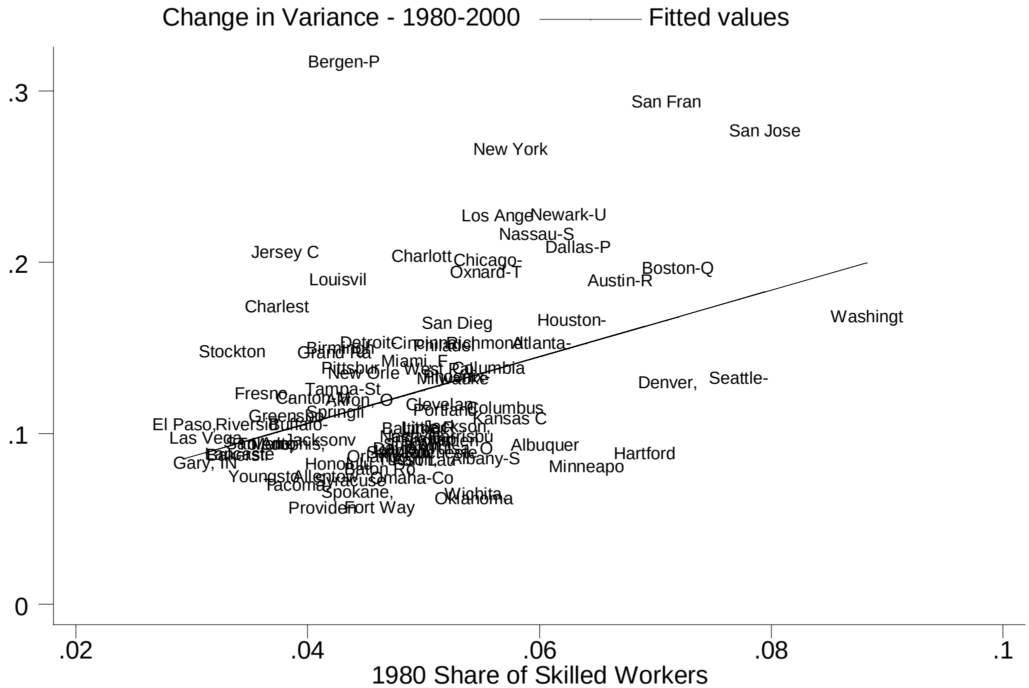

Change in Income 1990-2000
Fitted values
.3
.2
.1
0
-.1
-1
0
1
2
Change in Patents 1990-2000
Austin-R
Colorado
Salt Lak
Raleigh-
San Jose
Las Vega
Sacramen
San Dieg
Baton Ro
Tulsa, O
Honolulu
Bakersfi
Los Ange
Oxnard-T

Figure 10


Change in Variance - 1980-2000
Fitted values
1980 Share of Skilled Workers
.3
.2
.1
0
.02
.04
.06
.08
.1
Bergen-P
San Fran
San Jose
New York
Los Ange
Newark-U
Nassau-S
Dallas-P
Jersey C
Charlott
Chicago-
Oxnard-T
Boston-Q
Austin-R
Louisvil
Charlest
San Dieg
Houston-
Washingt
Stockton
Detroit
Atlanta-
Miami, F
Columbia
Milwauke
Denver,
Seattle-
Fresno
Tampa-St
Akron, O
Portland
Columbus
Kansas C
El Paso
Buffalo-
Las Vega
Jacksonv
Albuquer
Hartford
Gary, IN
Albany-S
Minneapo
Baton Ro
Omaha-Co
Spokane,
Wichita
Oklahoma
Providen
Fort Way
Figure 11

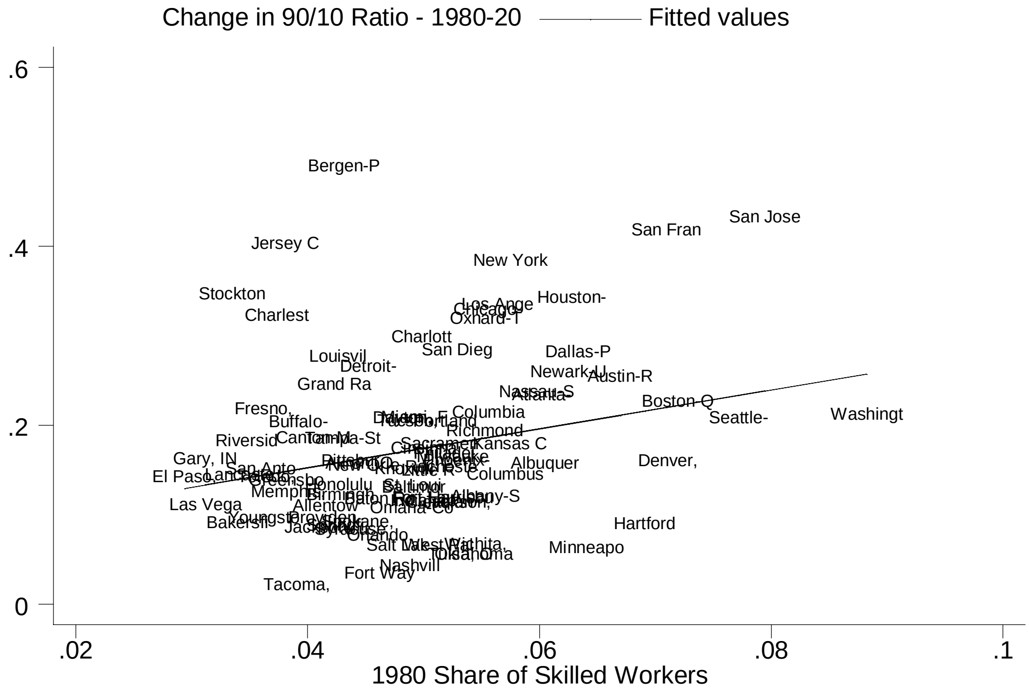
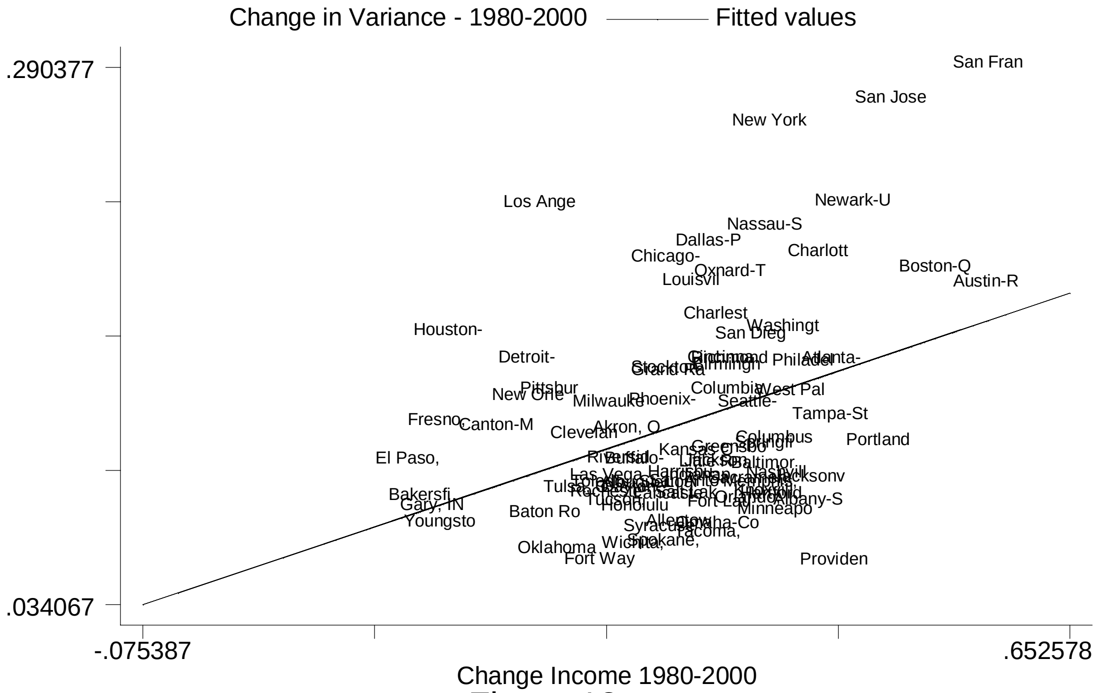

Change in 90/10 Ratio - 1980-20
Fitted values
.6
.4
.2
0
.02
.04
.06
.08
.1
1980 Share of Skilled Workers
Bergen-P
San Jose
San Fran
Jersey C
New York
Stockton
Houston-
Charlest
Los Ange
Chicago
Oxnard-T
Charlott
San Dieg
Dallas-P
Louisvil
Detroit-
Newark-U
Austin-R
Grand Ra
Nassau-S
Atlanta
Boston-Q
Fresno,
Columbia
Seattle-
Washingt
Buffalo-
Richmond
Riversid
Kansas C
Gary, IN
Albuquer
Denver,
San Anto
El Paso,
Columbus
Honolulu
Memphis
Albany-S
Las Vega
Allentow
Omaha-Co
Hartford
Bakersfi
Orlando
Wichita,
Minneapo
Nashvill
Fort Way
Tacoma,

Figure 12

Table 4

	Change in Variance of Log Income		Change in 90/10 Income Ratio	
	(1)	(3)	(3)	(4)
Share of Skilled Workers in 1980	1.158	1.224	1.088	1.351
	(0.516)	(0.941)	(0.947)	(1.729)
Variance of Log Income 1980 or 90/10 Income Ratio 1980	-0.139	-0.14	-0.455	-0.458
	(0.206)	(0.207)	(0.157)	(0.159)
Log Income 1980	0.05	0.051	0.077	0.079
	(0.055)	(0.056)	(0.101)	(0.103)
Log Population 1980	0.03	0.03	0.054	0.053
	(0.008)	(0.008)	(0.013)	(0.014)
Share of Population with BA in 1980		-0.023		-0.093
		(0.276)		(0.509)
Northeast Dummy	0.015	0.015	0.01	0.011
	(0.014)	(0.014)	(0.025)	(0.026)
South Dummy	0.033	0.033	0.069	0.07
	(0.016)	(0.017)	(0.030)	(0.032)
West Dummy	0.039	0.038	0.098	0.01
	(0.015)	(0.017)	(0.028)	(0.032)
Constant	-0.859	-0.862	-0.842	-0.852
	(0.564)	(0.569)	(1.04)	(1.05)
R-squared	0.412	0.412	0.346	0.347



Change in Variance - 1980-2000
Fitted values
.290377
.034067
-.075387
.652578
Change Income 1980-2000
San Fran
San Jose
New York
Los Ange
Newark-U
Nassau-S
Dallas-P
Charlott
Chicago-
Oxnard-T
Boston-Q
Louisvil
Austin-R
Charlest
Washingt
Houston-
San Dieg
Detroit-
Philadel
Atlanta-
Pittsbur
New Orle
Milwauke
Phoenix-
Columbia
West Pal
Seattle-
Tampa-St
Fresno
Canton-M
Clevelan
Akron, O
Columbus
Portland
El Paso,
Baltimor
Jacksonv
Bakersfi
Gary, IN
Baton Ro
Honolulu
Albany-S
Minneapo
Youngsto
Tacoma,
Oklahoma
Wichita,
Spokane,
Fort Way
Providen

Figure 13

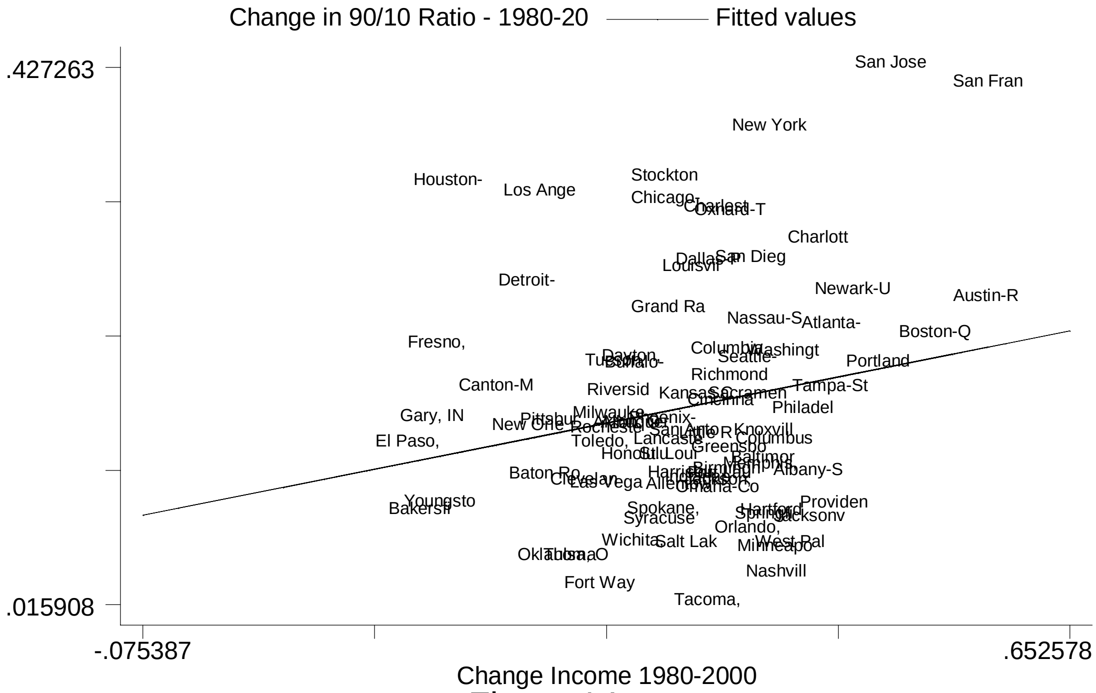

Change in 90/10 Ratio - 1980-20
Fitted values
.427263
.015908
-.075387
.652578
Change Income 1980-2000
San Jose
San Fran
New York
Houston-
Los Ange
Stockton
Chicago-
Oxnard-T
Charlott
Detroit-
Newark-U
Austin-R
Grand Ra
Nassau-S
Atlanta-
Boston-Q
Fresno,
Portland
Richmond
Canton-M
Riversid
Tampa-St
Philadel
Gary, IN
El Paso,
Knoxvill
Columbus
Baton Ro
Albany-S
Youngsto
Bakersfi
Providen
Spokane,
Syracuse
Orlando,
Wichita
Salt Lak
Nashvill
Fort Way
Tacoma,

Figure 14