Young People, Skills and Cities

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October 2001

Abstract

Young highly educated workers developed in the 70's and 80's a preference for working in larger cities, that are also large agglomeration of highly educated workers. Highly educated young workers in 1990 were over-represented in cities, in spite of the lower wage premium they earned for working in crowded metropolitan areas if compared to their older colleagues. There must be some extra-benefit that young workers acquire in cities and are willing to pay for. In the model we develop to explain these stylized facts this extra-benefit is given by a dynamic externality of human capital. Agglomerations of educated workers arise endogenously, as workers are attracted to dense areas, which improve their learning from others. If the skills accumulated in cities are easily transferrable, it is efficient for educated people to work in dense areas as young and move to less dense areas as mature workers. Once the "learning period" is over workers are attracted to smaller and less dense locations where there is less competition from other skilled workers and housing price is lower. Our model explains why young workers were attrected into large cities in the 70's and 80's and why, once they have accumulated their human capital, some of them moved to smaller towns.

JEL Classification Code: R0, R3, J3

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1 Introduction

Learning by doing and learning from others are important determinants of workers' skills and productivity and at least on the theoretical ground they could be responsible for sustained productivity growth (Arrow [3], Romer [32] and Lucas [27]). Working in a local environment which promotes interactions with skilled people generates valuable learning opportunities for young workers. Cities, and among them, those with denser employment and larger concentration of educated workers, provide such an environment and young workers are attracted to them. "Great are the advantages which people, following the same trade, get from near neighborhood to one another" Marshall[1] says, and Lucas[2] asks: "what can people be paying Manhattan or downtown Chicago rents for, if not for being near other people?".

This "preference" for large cities, though, does not apply to all workers homogeneously. We argue, using stylized evidence and reference to previous work that in the 90's, young workers were more willing to pay the high rents in denser urban areas than their older colleagues. They also received a smaller wage premium, for working in crowded cities, than their older colleagues. We claim that the reason for this is that working in dense cities during the early phases of their career benefits workers allowing accumulation of valuable skills. Workers are willing to forego part of their real wage for this "investment". The early years of a worker's career are those during which she acquires most of her professional human capital. Once that period is over, the attractiveness of a crowded city, with high rents and high competition on the job, decreases, and (at least some) older workers move towards less crowded working environments. Large and dense cities, while expensive and overcrowded, are laboratories for new skills and they should experience a flow of incoming young workers, and of outgoing older ones.

In the present paper we develop a general equilibrium overlapping generation model which explains the stylized facts about learning, wages and location of young and old workers. Two elements are crucial in understanding the interaction between learning, concentration of young educated workers and migration of older (mature) workers. These two factors are the "intensity" of local learning and the "transferability" of skills. We analyze the aggregate equilibrium behavior in a model with two locations, as these two characteristics change. The increase of electronically mediated contacts across workers represents an intensification of the learning potential in cities if face to face contacts (as Gaspar and Glaeser [13] argue) are complements to electronic ones. This would increase the density of people in cities, but if what they learn cannot be easily transferred, there would not be a tendency of older workers to move out. The "specificity" of human capital will somehow reduce the lifetime benefits from learning in dense cities. Only a tendency towards increased transferability of skills generated by increased standardization of processes and tasks requiring high skills, induces the second effect of out-migration of older workers.

[1]The quote is from "Principles of Economics", A. Marshall 1890

[2]The quote is from Lucas[26].

The seventies and eighties were the period of increased flexibility in the U.S. labor market, small firms thrived as large firms went through a slowdown (Piore and Sabel [30]), flexibility and portability of skills, as well as the importance of learning became key ingredients of skilled workers success. We think that the emphasis on versatility of skills, plus increasingly standardized technical and computational languages and the introduction of the computers (1980) increased the transferability of human capital across locations. Such was the engine that brought concentration of young educated in cities as they could learn from interactions there, and retain the higher productivity while moving out of cities when older.

Our model shows that from an undifferentiated distribution of skills between two locations, as the intensity of local learning increases, an endogenous tendency towards the concentration of skills arises. One location becomes more populated, with higher density of educated workers, allowing intense learning, and exhibiting higher price of housing. If skills are strongly "location" specific, and most of them would be lost in moving, then people will not move during their life. Cities in steady state differ in density and learning potentialities but not in the fraction of young and old. What generates the concentration of young workers is the increased transferability of skills: People learn in larger cities while young and move to less crowded cities, to enjoy less competition and lower housing prices, when old. Large, costly, skill-intensive cities become in steady state the place where learning takes place for educated workers, early in their career. Smaller, more livable, inexpensive cities attract older workers offering them higher real wages.

We simulate our stylized model using parameters compatible with observed statistics for US cities in the 70's and in the 90's. We find, interestingly, that as transferability of skills increases above values close to those suggested by empirical evidence for the 80's the equilibrium of the economy shifts from a situation with no migration to one in which young people work in denser areas and migrate to less dense areas when old.

The paper is organized as follows: Section 2 provides some stylized facts on experience premia, concentration of young educated workers in U.S. cities for 1970 and 1990. Section 3 reviews the existing literature on learning and local externalities in cities. In Section 4 we develop the model and its equilibrium conditions are defined. In Section 5 the equilibrium in steady state is described with the help of some simulations analyzing the effect of a change in the "local learning intensity" and in the "appropriability of human capital". Section 6 discusses the results and summarizes the existing evidence on internal migrations of workers and human capital specificity.

2 Stylized Facts on Productivity and Learning

The literature has pointed out the existence, in the 90's of two interesting relationships. The first is that in urban areas, and particularly in large cities, the share of college educated workers is larger than outside urban areas (Table 1, Glaeser and Mare [15]). Cities are, therefore, concentration of highly educated workers. The second is that urban areas, and especially large cities, seem to attract a disproportionately large fraction of young educated workers, rather than of educated workers in general (Table 1, Glaeser [14]).

Less attention has been devoted to the analysis of the evolution, over the last decades, of skills in cities and to the analysis of the premium to experience, paid in cities and outside of them. This section documents that, while the concentration of highly educated workers in cities exists at least since the 70's, the disproportionate presence of young is a phenomenon beginning only later, and perceivable in 1990. On the contrary both in 1970 and 1990 the experience premium paid to educated workers was significantly larger in urban areas, in particular in larger cities, as compared to non-urban areas or smaller cities. Highly educated workers crowd larger cities since the 70's, but young educated overcrowd cities since the 90's in spite of the smaller premium that they receive to live there, compared to their older colleagues.

We document the above-mentioned facts, using three different possibilities in the comparison between more dense and less dense areas. Table 1 reports some summary statistics from US census data in year 1970 and 1990 relative to the comparison between Urban and Non-urban areas, and between seven Megalopolis[3] and the other main metropolitan areas. Table 2, on the other hand considers only 167 main Metropolitan Statistical Areas (MSA's), excluding the megalopolis, and analyzes correlation of size, skills and premia across them for 1970 and 1990.

The first four columns show the comparison between Megalopolis and other cities, and between Urban and non -urban areas, for the year 1990, while the following four columns do the same for the year 1970. First, let me point out the similarities between 1970 and 1990 statistics. From the first row, we notice that in both years, the denser areas exhibit larger share of college graduates in the work-force. In terms of experience composition of the overall work-force, the dense areas do not appear to have any larger share of young workers (second row). If tastes of workers are similar between skilled and unskilled, this says that it is not a preference of young people in general, to generate the concentration of young skilled in cities. Finally the experience premium of skilled workers, calculated only for white males with college education or more, (fifth row) shows that in both years there is a tendency of denser areas to have larger premia. This tendency is not noticeable in the comparison between Megalopolis and other cities in 1970, though. This means also that, taking the urban-non urban comparison, young workers worked in cities rather than in the non urban areas, for a much smaller premium than older workers (third and fourth row). While in 1990 old workers requested a premium of four dollars per hour (4.5 in 1970) to work in cities, young workers only required a premium of two dollars per hour (2.2 in 1970) to work in cities. If we think that the wage differentials offset, on average, different housing costs between the two locations, then this

[3]We define Megalopolis those Metropolitan Areas with more than two millions employees in 1990. They are Los Angeles, New York, Chicago, Philadelphia, Boston, Detroit and Washington

means that young workers accepted to work in cities at lower real wages than they would have got outside. Notice, that between 1970 and 1990, the data also show the well known overall increase in the share of college graduates and the increase in the share of young, due to the entrance in the market of the baby-boomers. The well known increase in experience premium between 1970 and 1990 is shown across locations. Different tendencies between 1970 and 1990 statistics are portrayed in the last three rows. If we decompose the share of workers with college degree or higher, between young (less than twenty years of experience) and old (more than twenty years of experience), we notice that while in the 70's the two groups are in same ratio between more dense and less dense areas, in the 90's the group of young is much larger, relative to the old, in denser areas. If any difference existed in 1970, it was of a larger Young to Old ratio of educated outside denser areas, while in 1990 it is rather strong the tendency to a larger Young to Old ratio for college educated in dense areas.

The same stylized facts, also emerge from the cross sectional analysis of 167 MSA for which we have comparable data in 1970 and 1990, from the US census. Table 2 reports some elasticities, obtained by OLS regression of a dependent variable on the logarithm of employment relative to the year 1990 and 1970. Such coefficients capture how variables are linearly correlated to the size of an MSA. The first and fourth row confirm the similarity between 1970 and 1990 in terms of skill concentration in large cities and experience premia in large cities. An increase by 3.6% (by 1% in 1970) in the share of college graduates is associated to a doubling of employment across cities, while the experience premium increases by 2% for each doubling of employment in 1990 (by 7% in 1970). On the other hand, while in 1990 the difference between the share of college educated young and old workers was positively and very significantly correlated with employment (second row) in 1970 it did not depend on it. In order to show that the higher concentration of educated young workers in cities is not driven by family-size we have repeated the test including only single male head of families (third row). Older worker may prefer smaller cities as they have larger families and housing is too expensive in cities. Considering single white male workers the correlation between share of young workers and city size is still positive and very significant. This says that in 1990 the difference in shares of young and old educated workers was positively associated with large cities, while in 1970 no such correlation existed. This in spite of the fact (documented in the last two rows) that in 1990 young workers were paid a premium of only 6.8% of their hourly wage per each doubling in size of the city, while older workers were paid a premium of close to 9% of their wage for each doubling.

To summarize, the model we propose should reconcile the following stylized facts:

1) Larger cities have been (at least) since 1970 concentration of educated workers and such a tendency is still present in 1990.

2) In 1970 educated workers receive larger experience premia in larger cities and they still do in 1990.

3) Only in 1990 larger cities have become more attractive for educated young workers than for educated older workers

4) In 1970 and 1990 young educated workers were willing to work in large cities for a wage premium lower than that required by their older colleagues.

3 Related Literature on Local Learning

The present paper analyzes the role of learning from interactions and learning from others in determining the location decisions of workers, and their productivity. We assume the existence of a dynamic externality of human capital at the city level, which has been analyzed in the literature in several ways, and some evidence of its existence has been provided. For the innovative activity (Audretsch and Feldman [2], Foster and Rosenzweig [11] and Jaffe et al. [18]), for the accumulation of personal skills (Glaeser [14], Glaeser and Mare [15]) and for urban growth (Eaton and Eckstein [10], Glaeser et al.[16], Simon [33]) evidence supports the thesis that local interactions and therefore concentration of educated people are beneficial to learning. While rigorous efforts to quantify externalities of human capital on productivity have provided more controversial results (Moretti[28] and Rauch [31] find sizeable effects while Acemoglu and Angrist [1] and Ciccone and Peri[7] do not) that work has focussed on static externalities of human capital on productivity, rather than on dynamic learning externalities which affects accumulation of human capital. The present work allows only dynamic externalities of human capital, namely externalities in the process of accumulation of human capital itself, via experience on the job. We rule out any externalities in production, whose existence has been empirically denied by Ciccone and Peri[7], in the context of a production function compatible with the one we use in this paper.

The paper also shares an interest with the literature on new technologies, telecommunications and the future of cities. If enhanced and faster ways of communication are potentially changing the role of cities, this does not mean that they are making them "obsolete". As Gaspar and Glaeser [13] argue, the role of cities as centers of information might actually be increased, if telecommunication complements, rather than substitutes, for face to face interactions. Recently Leamer and Storper [25] have argued that, as information technologies allow for easier diffusion of knowledge, they also increase the complexity and time-dependence of productive activity. This is likely to make agglomerations more important. The traditional role, emphasized by Jacobs [17], of cities as ground for cross-fertilization of ideas, could become more and more important as original knowledge becomes the most important input for production and for accumulation of human capital. If new technologies allow for easy transferability of acquired skilled, so that workers could learn in some large cities and then move to smaller ones, then the large metropolis of the new millennium could "specialize" in being the crowded and busy learning fields for young professionals. Intense learning interactions plus transferability of processes and of technical language give cities a comparative advantage in generating learning for young skilled workers.

4 A Model of Two Locations

4.1 The Production Function

We consider an economy with two locations (could be city A and city B or a city and its hinterland), two types of workers (denoted as highly educated H and less educated L) and two generations (denoted as young Y and old O). In each period a new generation enters the labor market and at the end of each period an old generation exits. The structure is that of an overlapping generation model (OLG). Each person stays in the labor market for two consecutive periods, first as a young and then as an old. She contributes to the production of a tradable homogeneous good and to the accumulation of skills of other workers. Each highly educated worker is mobile between cities, and decides where to locate at the beginning of each period. Nevertheless, while at the beginning of her Youth, she can choose the location at no cost, at the beginning of her Old age if the worker decides to change city she has to pay a cost. This cost is the loss of a fraction (θ) of the skills accumulated on job during the first period. These skills are at least in part location-specific. Less educated workers are assumed for simplicity as non-mobile.

In the economy there are also unproductive house-owners, who collect rents from the houses (land) they own, consume the tradable good and the land services, and are not mobile between cities. They do not enter the labor market and are introduced in the model in section 4.3, when considering the market for housing (land). An homogeneous tradable good [4] the numeraire is produced in each city using all types of labor in the way specified by the production function (1) below. No physical capital is used in production[5]. Output of the tradable good in each period t for each city c is therefore[6]:

$$Y_t^c = \Omega_t \left[\left(\sum_{j \in L_c} e_L^{jc} l^{jc} \right)_t^{\gamma} + \Lambda \left(\sum_{j \in H_c} e_H^{jc} h^{jc} \right)_t^{\gamma} \right]^{\frac{1}{\gamma}} \qquad c = A, B \quad 0 < \gamma < 1, \quad \Lambda > 1 \tag{1}$$

Ω_t denotes total factor productivity at time t. we assume that it grows at exogenous rate and, for simplicity, we set this rate to 0 and standardize the level of Ω_t to one. We are not interested in analyzing the aggregate growth rate of productivity in the economy, but rather its relative level in different locations and the migration decisions of workers. The first term in brackets represents the contribution to production, in city c, of less educated workers (L_c). Worker j's supply of labor l^{jc} is scaled up by its effectiveness e_L^{jc}, which is a measure of skills accumulated on the job by less educated workers in city

[4] We rule out, therefore, pecuniary externalities due to transport costs, in order to concentrate on dynamic learning externalities.

[5] As long as capital is mobile between cities none of the results obtained is affected by this simplification.

[6] The subscrip t denoting calendar time, counts as one period the lenght of each period of life for the agents.

c. we assume perfect substitutability of workers with different experience levels. The second term in brackets represents the contribution of highly educated workers (H_c). Again, their personal supply of labor h^{jc} is multiplied by their effectiveness e_H^{jc}. We allow for a skill biased technological component Λ which is equal across cities and larger than one to capture the fact that highly educated workers are more productive than less educated. This implies that the available technology is equal across cities, and allows us to concentrate on the effects of the learning externality and on the concentration of skills that arises endogenously. Consistently with the empirical evidence[7] we assume the two types of labor to be different factors, with elasticity of substitution larger than one[8]. Notice that this implies that an increase in the productivity of highly educated (Λ) increases their demand.

We assume that each of the less educated workers L, supplies one unit of labor. Due to the specificity of their human capital or due to moving costs, less educated workers are not mobile between cities and their total number is standardized to one in each city per each generation. Each of the more educated workers H, supplies one unit of labor and the total number of workers in each generation is standardized to one[9].

With a slight abuse of notation we denote with h_Y^A and h_o^A the total number of young and old highly educated workers in city A. Therefore $h_Y^B = (1 - h_Y^A)$ and $h_o^B = (1 - h_o^A)$ are the total number of young and old educated workers in city B. As we allow for educated workers to move between their first and second period of life we allow for $h_Y^A \neq h_o^A$.We standardize the effectiveness of workers, when young, to one, and denote with e_L^c and e_H^c the effectiveness of less and more educated workers, respectively, when old. Total production in city c at time t is:

$$Y_t^c = [(1 + e_L^c)_t^\gamma + \Lambda\,(h_Y^c + h_o^c e_H^c)_t^\gamma]^{\frac{1}{\gamma}} \qquad c = A, B \quad 0 < \gamma < 1 \qquad (2)$$

Each factor, in equilibrium, is paid its marginal productivity. Wages of the different types of workers can be easily derived from (1). Before doing that, though, we introduce the process of "local learning", which contains the dynamic externality.

4.2 Dynamic externalities and Learning

We focus our attention on dynamic "learning". During their early years of activity due to formal and informal interactions with other workers in the same city workers build up their "effectiveness". The interactions are thought as face-to-face interactions, (or at least as face-to-face initiated interactions[10]) and

[7]Katz and Murphy [24] estimate an elasticity between College and High School educated workers equal to 1.4, Ciccone and Peri [8] estimate it to be around 3.5.

[8]Recall that in this case the elasticity of substitution between the two composite factors is: $\frac{1}{1-\gamma}$

[9]For simplicity we are assuming no population growth.

[10]Differently from Gaspar and Glaeser [13] here these interactions do not involve costs but are by-products of working in the same city. Their caracteristics of being complementary to

therefore require physical proximity, namely working in the same city. This type of "learning" is a pure externality , i.e. by-product of the interactions for which none of the workers is compensated. The dynamic effect on accumulation of human capital depends on the total amount of skills working in the city. More educated and more experienced co-workers help faster learning in young workers.

The model does not analyze the effect of learning on the long run growth of productivity, pushing aside, in fact, the issue and assuming exogenous (and equal to zero) long run growth of productivity. We believe that empirical evidence has overwhelmingly rejected the idea that, over the last few decades, across regions and cities in OECD countries, self-sustaining externalities have been conducive to divergent growth. Be it because of decreasing returns to capital, or because of diffusion of knowledge, we share with several authors[11] the view that, within a country, the distribution of relative per capita income in regions, and of relative size and densities in cities, have moved around a balanced growth path. The relative levels of productivity, wages, densities of workers and experience premia in balanced growth path, on the other hand, is affected by local externalities. Is on these "relative level" effects of externalities that we concentrate our attention.

To capture the phenomenon of learning in a city, we use a function that describes the accumulation of a worker's effectiveness. Accumulation depends positively on the total skills in a city and takes place only when the worker is young. For given personal characteristics, a worker who is in a city with higher density of skills will increase more her effectiveness. To keep things simple, we assume that the effect of city-skills on the accumulation of personal skills is identical for more and less educated. Each agent accumulates human capital (effectiveness) as a Cobb-Douglas combination of the total amount of human capital in each group of workers in the city. Interaction with different group of skills increases accumulation, due to a complementarity among skills in this learning function. The evolution of the effectiveness of agent j, with schooling level I, in city c is:

$$(e_I^{jc})_{t+1} = 1 + \phi (h_Y^c)_t^{\alpha_1} (h_o^c e_H^c)_t^{\alpha_2} (e_L^c)_t^{\alpha_3} \quad I = L, H, \quad c = A, B \tag{3}$$

This expression implies that the average young worker in city c, either highly or less educated, accumulates effectiveness over her initial level (one), as a function of the human capital for each group in the city[12]. Each group of co-workers, interacting with a young worker, increases her effectiveness. The contribution of each group to the learning externality depends on its total skills (size of the group times effectiveness). These are combined in a Cobb- Douglas function with elasticities reflecting the importance of a group in generating the externality, and the function has constant return to scale, so that the return to three

electronic interactions still apply.

[11]On Regional Convergence see Chapter 11 of the textbook Barro and Sala-i-Martin [4] and references thereof, on stability in distribution of city-size see Eaton and Eckstein [10].

[12]We could easily add a positive term ($\overline{e}$), capturing common accumulation of skills, which does not depend on the location.

factors is $\alpha_1+\alpha_2+\alpha_3 < 1$[13]. We assume that the contribution to the externality is stronger from highly educated than from less educated ($\alpha_1 \geq \alpha_3$, $\alpha_2 \geq \alpha_3$ and $\alpha_1 + \alpha_2 \geq 0.5$) . In general we also assume that the contribution to the externality is stronger from young educated than from old educated ($\alpha_1 > \alpha_2$) in order to capture the fact that newly educated might incorporate more up-to date skills. Therefore, the accumulation of skills depends on the average level of human capital of each group, and on the number of highly educated, young and old workers (h_Y^A and h_o^A) relative to less educated (whose number is 1) in the city.

$\phi > 0$ is a parameter capturing the extent of learning. It can be thought as a measure of the ability to learn from interactions or of the frequency of interactions. Improvements in the technology for learning from interactions and for intensifying face-to-face initiated interactions would increase this parameter. In particular, if virtual interactions are complementary to face to face interactions (as Gaspar and Glaeser [13] argue), Information Technology improvements cause an increase in this parameter.

Given that the accumulation function of human capital is identical for more (H) and less (L) educated, assuming in each city the same initial conditions for the two groups we have $(e_H^c)_t = (e_L^c)_t = e_t^c$. Averaging expression (3) across individual for each city , we obtain the following dynamic system that describes the evolution of human capital of old workers:

$$e_{t+1}^A - e_t^A = 1 - e_t^A + \phi(h_Y^A)_t^{\alpha_1}(h_o^A)_t^{\alpha_3}(e^A)_t^{\alpha_2+\alpha_3} \tag{4}$$

$$e_{t+1}^B - e_t^B = 1 - e_t^B + \phi(h_Y^B)_t^{\alpha_1}(h_o^B)_t^{\alpha_3}(e^B)_t^{\alpha_2+\alpha_3} \tag{5}$$

It is easy to find the steady state of this dynamic system, setting to 0 the left hand side of both equations (4) and (5). As $\alpha_2+\alpha_3 < 1$, there is a unique, globally stable steady state for e_t^A and e_t^B, once h_Y^A, h_o^A reach constant values. The values of accumulated effectiveness (e^A and e^B) in steady state, in city A and B are given by the solution to the following two conditions:

$$e^A = 1 + \phi(h_Y^A)^{\alpha_1}(h_o^A)^{\alpha_3}(e^A)^{\alpha_2+\alpha_3} \tag{6}$$

$$e^B = 1 + \phi(h_Y^B)^{\alpha_1}(h_o^B)^{\alpha_3}(e^B)^{\alpha_2+\alpha_3} \tag{7}$$

Effectiveness, accumulated during the early phase of one's working life depends, therefore, positively on the learning technology (ϕ) and on the density of more educated workers in the city h_Y^A and h_o^A[14].

[13] Remember that the amount of human capital of young, less educated is equal to one in each city.

[14] This is true if $\phi \leq \frac{1}{\alpha_1+\alpha_2}$

4.3 Wages, Housing Prices and Interest Rate

In the rest of the Paper we concentrate on the steady state equilibrium of the economy. In this equilibrium the number of young and old educated workers in a city is equal over time (although young workers in a city can be more or less than old workers in that city implying migration during their life). Wages equal marginal productivity for each worker in city c[15]:

$$w^c_{LY} = \frac{\partial Y^c}{\partial l^c_Y} = (Y^c)^{(1-\gamma)} (1 + e^c)^{\gamma-1} \tag{8}$$

$$w^c_{LO} = \frac{\partial Y^c}{\partial l^c_O} = (Y^c)^{(1-\gamma)} (1 + e^c)^{\gamma-1} e^c \tag{9}$$

$$w^c_{HY} = \frac{\partial Y^c}{\partial l^c_Y} = (Y^c)^{(1-\gamma)} \Lambda(h^c_Y + h^c_o e^c)^{\gamma-1} \tag{10}$$

$$w^c_{HO} = \frac{\partial Y^c}{\partial l^c_Y} = (Y^c)^{(1-\gamma)} \Lambda(h^c_Y + h^c_o e^c)^{\gamma-1} e^c \tag{11}$$

Notice that, because of the constant return to scale property, the sum of wages paid to all workers exhaust the total product in the city:
$w^c_{LY} + w^c_{LO} + h^c_Y w^c_{HY} + h^c_o w^c_{HO} = Y^c = [(1 + e^c)^\gamma + \Lambda(h^c_Y + h^c_o e^c)^\gamma]^{\frac{1}{\gamma}}$
Due to the assumed restriction on γ, the production function exhibits decreasing returns to educated workers alone. This means that, increasing their relative supply in a city $(h^c_Y + h^c_o e^c)$, decreases their return relative to the wage of less educated[16]. The "schooling premium" both for young and old is: (w^c_{HY}/w^c_{LY}) =$(w^c_{HO}/w^c_{LO}) = \left[\Lambda(h^c_Y + h^c_o e^c)^{\gamma-1}\right] / \left[(1 + e^c)^{\gamma-1}\right]$.[17] The expression is increasing in Λ, and decreasing in h^c_Y and h^c_o. Finally, the accumulated effectiveness is responsible for the increase in wage of workers when old. The "experience premium", for both highly and less educated, is in fact: (w^c_{LO}/w^c_{LY}) =$(w^c_{HO}/w^c_{HY}) = e^c$.

In order to study the location decisions of the agents we want to capture in a parsimonious way, the relevant incentives and costs to move into or out of a city for the highly educated workers. On one hand, moving in a location with many highly educated workers implies an increase in learning when young. On the other hand it means also an increase in competition and a decrease in wage (due to decreasing returns) as well as higher price for housing. To account for the price of housing, we assume that each worker consumes during each period of life a composite bundle, G made of the Cobb-Douglas combination of the tradable numeraire C and housing services from land T, whose price in city c is p^c_T. The lifetime utility of a worker is separable and logarithmic:

[15]We used the identity :$(Y^c)^{(1-\gamma)} = \ (1 + e^c)^\gamma + \Lambda(h^c_Y + h^c_o e^c)^\gamma \ \ \frac{1-\gamma}{\gamma}$

[16]This is consistent with what found in Ciccone and Peri [7]

[17]Notice that, as $\Lambda > 1$ the wage of highly educated is always larger than the wage of less educated.

$$\log(G_i)_t + \frac{1}{1+\beta}\log(G_i)_{t+1} \quad where \quad G_t = C_t^{\delta} T^{t\,1-\delta} \quad 0<\delta<1, \quad \beta \geq 0. \tag{12}$$

β is the inter-temporal discount rate, which we assume equal for all workers in both cities. Also, as we assumed zero aggregate growth, we also set the inter-temporal discount β to 0. This is equivalent to a situation in which growth rate and inter-temporal discount are positive but the "magnifying" effect for future income due to growth, is balanced by the inter-temporal discount. we assume the existence of a bond market countrywide whose interest rate, in terms of the numeraire is r. The rent for the housing services in city c, p_T^c, is paid to non working local land (house) owners, who spend all their income to maximize their inter-temporal utility which is identical to (12). Without loss of generality the amount of land (and of land-owners) is assumed to be the same in each location and it is normalized to one. The total income of land-owners in city c is, therefore, equal to p_T^c.

Let's denote with E_J^I the total expenditure in steady state of a worker with schooling we$(=L,H)$ in period $J\ (=Y,O)$ of her life. The optimal allocation between C and T in each period implies that $C_J^I=\delta E_J^I$ and $T_J^I=(1-\delta)E_J^I$. The optimal inter-temporal allocation of expenditure between the two periods of life, in steady state is as follows:

$$\left(E_Y^I\right)_t = \frac{1}{2+r}\left[w_{IY} + \frac{w_{IO}}{1+r}\right] \tag{13}$$

$$\left(E_O^I\right)_t = \frac{1+r}{2+r}\left[w_{IY} + \frac{w_{IO}}{1+r}\right] \tag{14}$$

wherew_{IY} and w_{IO} are the wages for young and old workers with education I (we have omitted all the superscript denoting the city; the above relations hold for workers in both cities). The term in square brackets represents the present discounted value of nominal lifetime income for a worker of schooling I.

We can calculate the total workers' expenditure in each period, in steady state, in city c, (E_{tot}^c), by adding the expenditure of each group of workers, multiplied by the number of that type of workers in the city. In particular, substituting (8)-(11) into expressions (13) and (14), collecting terms and adding we obtain:

$$E_{tot}^c \;=\; \left[(1+\frac{e^c}{1+r})\left((1+e^c)^{\gamma-1} + (\frac{1}{2+r}h_Y^c + \frac{1+r}{2+r}h_o^c)\Lambda(h_Y^c + h_o^c e^c)^{\gamma-1}\right)\right] * (Y^c)^{(1-\gamma)} \tag{15}$$

The total expenditure of workers in the above expression (15), has two components. The term $(Y^c)^{(1-\gamma)}$ is common to wages of all groups and depends on total production in the city. The term in square brackets is the sum of the specific components of expenditures for each group. Within it $(1 + \frac{e^c}{1+r})$ captures the fact that for each group the present discounted value of lifetime income is given by first period wage income plus the second period income discounted at rate $\frac{1}{1+r}$. The second term within the first square brackets, captures the specific component of income for each of the four groups, multiplied by the share spent in the period.

The value of p_T^c is a function of E_{tot}^c, and can be obtained by equating the total expenditure on land services of people living in city c to the total income accruing to land owners in the same city. Recall that the total quantity of land is one and that each person (both workers and land-owners) spends a fraction $(1 - \delta)$ of her total expenditure on housing services. Therefore:

$$(1-\delta)E_{tot}^c + (1-\delta)p_T^c = p_T^c \tag{16}$$

And solving: $p_T^c = \frac{1-\delta}{\delta}E_{tot}^c$. The price of land in a city is proportional to the total Expenditure of workers in the city. This is due to the fact that larger expenditure on land services, whose supply is fixed, generates an increase in their price (a typical crowding effect). The increase in price of land represents a second channel, besides decreasing returns to skilled workers, through which congestion effects balance the benefits of local human capital externalities. In equilibrium the benefits and the costs of increasing the density of highly educated in a city offset exactly.

Let's consider inter-temporal trade between cities and the determination of the steady state interest rate. In order to do this we equate the total production of the tradable good in the economy with its total consumption. Even if the whole economy itself (made of the two locations) is an open economy, this assumption implies that in steady state (long run) the equilibrium must be sustainable. If the economy trades with the foreign market it cannot have a systematic deficit or surplus: the long run real interest rate should guarantee balanced trade budget, on average. The equilibrium condition for r is therefore obtained by equalizing total expenditure on the tradable good, made by workers and land owners, to the total production of the good for the two cities. Each group of workers spends a fraction δ of her income in the tradable good. Adding the income of workers and land owners we get[18]:

$$E_{tot}^A + E_{tot}^B = Y^A + Y^B \tag{17}$$

The above equation provides the equilibrium condition determining r for the economy.

[18]The total expenditure in the tradable good for the whole economy is obtained by simplifying the following expression: $\delta E_{tot}^A + \delta \quad \frac{1-\delta}{\delta}E_{tot}^A \quad + \delta E_{tot}^B + \delta \quad \frac{1-\delta}{\delta}E_{tot}^B$

4.4 Location decision, density and migrations

4.4.1 Sub-game perfect stationary Nash Equilibrium

The "natural" price index for each location in the economy is the price to purchase one unit of the composite consumption bundle G. This index is specific to each city, as the price of housing is different across cities: $p^c = \zeta(p^c_T)^{1-\delta} = \kappa(E^c_{tot})^{1-\delta}$,where ζ, κ are constants, independent from the location[19]. Comparison of real income between the two cities is crucial to determine the choice of location for highly educated workers.

Highly educated workers, are mobile in each period. We need, therefore, to solve this problem backwards. Consider, without loss of generality, that A is the location with high density of educated young workers ($h^A_Y > 0.5$)[20]. The advantage of working in A while young is that the worker benefits from the learning externality by increasing her future human capital. Such incentive to stay in A, though, disappears at the beginning of the second period. In that moment, being in A will only give the workers the disadvantages due to high price of housing and high competition of skilled workers. Therefore, she will move if the real income she will earn as an old worker in B, accounting for the fact that part of her effectiveness ($\theta \in (0,1)$) will be lost, is higher than the real income she will earn as old in A. Therefore old educated workers will also move from A to B, driving down wages of old educated workers in B to the level which makes them indifferent between staying in A or moving to B. If θ is particularly large, though, the cost of moving to B would be prohibitive and therefore all workers who were in A as young will remain there as old as well. There is a convenient way of representing the nominal wage that a worker, who worked as young in city A would earn as old in B. From (10) and (11) we have that $w^A_{OH} = (w^A_{YH})e^A$, therefore if the worker moves to B, loosing a fraction θ of her acquired human capital, his wage there would be:$(w^B_{YH})[1 + (1-\theta)(e^A - 1)]$.For simplicity we call RW_A the real wage per unit of efficiency (also real wage of young educated worker) in location A: $RW_A = \frac{w^A_{YH}}{(E^A_{tot})^{1-\delta}}$ and RW_B the real wage per unit of efficiency (or of a young educated worker) in location $B : RW_B = \frac{w^B_{YH}}{(E^B_{tot})^{1-\delta}}$. The equilibrium conditions for the second period are:

$$h^A_Y = h^A_O \quad \text{and} \quad \left[RW_A * e^A \geq RW_B[1 + (1-\theta)(e^A - 1)]\right]_{at \quad h^A_Y = h^A_O} \tag{18}$$

or

$$h^A_Y > h^A_O \text{ and } RW_A e^A = RW_B[1 + (1-\theta)(e^A - 1)] \tag{19}$$

$h^A_O > h^A_Y$ is never an equilibrium. In fact as $h^A_O > h^A_Y > 0.5$ this equilibrium imply people migrating from B to A at the beginning of the second period. As

[19] $\zeta = \frac{\delta^\delta}{(1-\delta)^{(1-\delta)}}, \kappa = \delta^{2\delta - 1}$

[20] An identical symmetric reasoning applies when city B is the one with higher density of young educated workers.

$RW_A < RW_B$ it would not be rational (sub-game perfect) for any worker to do this.

Given the above conditions for the second period how do highly educated worker choose to locate in the first period? The representative worker will move to the city with high density of highly educated up to the point in which the lifetime income from being there is equal to the lifetime income from being in the less crowded city, anticipating the possible move to that city, once old. It could be the case, though, for the self-reinforcing nature of the externalities that is convenient for all young educated workers to locate in A. In this case we have $h_Y^A = 1$ while part of the workers will move away when old, just enough as to make condition (19) hold.

The equilibrium condition, determining the relative number of young educated workers in each city, $(h_Y^A, h_Y^B = 1 - h_Y^A)$ is given therefore by the following conditions. Lifetime real income (RI) and therefore utility for highly educated workers in city A, and in city B, is equated if both cities have some young workers, while if all the young are concentrated in A then lifetime income in A must be larger than in B. Formally [21]:

$$h_Y^A < 1 \text{ and } \underbrace{RW_A \left(1 + \frac{e^A}{1+r}\right)}_{RI_A} = \underbrace{RW_B \left(1 + \frac{e^B}{1+r}\right)}_{RI_B} \tag{20}$$

or

$$h_Y^A = 1 \text{ and } \underbrace{RW_A \left(1 + \frac{e^A}{1+r}\right)}_{RI_A} > \underbrace{RW_B \left(1 + \frac{e^B}{1+r}\right)}_{RI_B} \tag{21}$$

Substituting into the above expressions the definition of real wages , collecting terms on the left hand side we get the following expression for $RI_A - RI_B$:

$$RI_A - RI_B = \frac{w_{YH}^A}{(E_{tot}^A)^{1-\delta}} \left(1 + \frac{e^A}{1+r}\right) - \frac{w_{YH}^B}{(E_{tot}^B)^{1-\delta}} \left(1 + \frac{e^B}{1+r}\right) \tag{22}$$

The fractions $\frac{w_{YH}^A}{(E_{tot}^A)^{1-\delta}}$ and $\frac{w_{YH}^B}{(E_{tot}^B)^{1-\delta}}$ capture the real wage of educated people when young. They are decreasing in the intensity of educated workers $(h_Y^A + h_o^A e^A)$ because of decreasing returns and crowding effects. The terms in brackets, on the other hand, capture the benefits from increased accumulation of skills. They are increasing in the density of highly educated. The relative contribution of these two terms determines the existence of equilibria with concentration of educated workers.

The equilibrium values in steady state for the model is given by the variables $(h_Y^A, h_o^A, e^A, e^B, r)$ which jointly solve the five equations (6), (7), (17), (18) or

[21] I have simplified identical terms on both sides of the equality.

(19) and (20) or (21) . Notice that in the symmetric equilibrium allocation $h_Y^A = h_Y^B = h_o^A = h_o^B = 0.5$ is always an equilibrium, satisfying the equilibrium conditions (6), (7), (17), (18) and (20) at the interest rate $r = 0$. As we will see, though, such equilibrium becomes unstable, as the intensity of local learning ϕ grows above a critical value. In that case agglomeration of skilled workers arises, as a consequence of local learning, and larger and more educated cities, will be associated with faster learning.

5 Equilibria

5.1 Stability: Interior and Corner Solutions

In this section we analyze potential equilibria as function of two key parameters of the model: the intensity of local learning ϕ and the transferability of human capital $(1-\theta)$.

It is useful, to begin with the analysis of $(RI_A - RI_B)$ described in equation (22) as a function of h_A^Y, assuming that people live the whole life in the same location. In this case $h_A^Y = h_A^O = h_A$. These equilibria are sustained by large θ and hold as long as condition (18) holds. They represent only minor variation on the usual "agglomeration equilibria" described in several economic geography models.

The point $h_A = 0.5$, it is always a (sub-game perfect) equilibrium. Let's consider, without loss of generality, the evolution of real lifetime income differentials $(RI_A - RI_B)$ as h_A increases towards one. Two opposite effects take place: The first is that the real wage in location A for young workers decreases, due to decreasing returns to skills and to the increase in housing prices. The other is that the experience premium increases, as the learning externality becomes stronger due to more skilled people in A. Eventually the crowding effect prevails and $RI_A - RI_B$ decreases for h_A close enough to one. In the proximity of 0.5, though, it all depends on the strength of the externalities. In particular for ϕ large enough the real income differentials (which is 0 in $h_A = 0.5$) will be increasing.

The sufficient condition to have a "stable" equilibrium with agglomeration is that $\partial(RI_A - RI_B)/\partial h_A > 0$ in the symmetric equilibrium $h_A = 0.5$. If ϕ is small then $\partial(RI_A - RI_B)/\partial h_A < 0$ holds globally and the symmetric dispersed equilibrium is the only one possible. Therefore, if the function $(RI_A - RI_B)$ is monotone in h_A, only one equilibrium exists, and it is the symmetric one. If $\partial(RI_A - RI_B)/\partial h_A$ is positive then the symmetric equilibrium would be unstable and there would be two stable equilibria on its sides. This type of behavior is known as "bifurcation of equilibrium": passing a threshold value of ϕ, the dynamic behavior of the system changes. In this case we are in the presence of a so-called "pitchfork" bifurcation (as defined in Fujita et al. [12] Chapter 3 Appendix A). The symmetric stable equilibrium become unstable and two stable asymmetric equilibria arise. These equilibria become more and more distant as the value of the parameter increases.

The concept of "stability" used here is the usual "evolutionary stability" used in Economic Geography and described in Fujita et al [12] Section 1.3: A certain distribution of skills ($h_A > 0.5, h_B < 0.5$) is stable if real lifetime income is equated in the two locations and by increasing the share of skilled workers in A, the lifetime income of those workers becomes lower than in B, while decreasing this share it becomes higher. In this case we have an interior solution with skilled workers in both locations. If such an interior equilibrium does not exist, then the solution is a corner one, given that the lifetime income in the location with all workers is larger than the potential lifetime income in the other location.

As ϕ increases the equilibrium moves, from the symmetric one towards one with larger and larger concentration of skills and workers in location A. Such an equilibrium is also sub-game perfect and evolutionary stable. The three figures B1, B2 and B3 in the Appendix B.1 show the function $RI_A - RI_B$ for $h_A \in [0.5, 1]$ and identify the equilibrium, for three values (low in figure B1, intermediate in figure B2 and high in figure B3) of ϕ. The values of the other parameters are as follows: $\gamma = 0.75$ is chosen to have elasticity of substitution between high and low educated equal to 4, $\Lambda = 1.55$ is chosen to match the average college premium, $\delta = 0.75$ gives a share of expenditure in housing of families equal to 0.25. $\alpha_1 = 0.4$, $\alpha_2 = 0.3$, $\alpha_3 = 0.2$ are parameter values which captures the larger contribution to the externality of educated people and, among them, of young people[22]. For these values of the parameters the equilibrium without migration can be sustained for large values of the specificity of human capital: $\theta \geqslant 0.65$. The value $\theta = 0.65$ is the value that satisfies conditions (18) with equality. Below it the equilibrium without migration cannot be sustained. The increasing strength of the externality (ϕ) leads to increasingly agglomerated equilibria. Progressively the experience premium increases in the dense location and decreases in the less dense location. As long as the transferability of human capital is low, increased learning generates increase premia and larger lifetime income in both cities. We consider large value of ϕ as our starting point, as cities have been for a while concentration of skills.

For ϕ large ($= 1.5$ in our case) as θ decreases, the equilibrium without migration violates, at $\theta < 0.65$, condition 18. At this point it is convenient for workers who have accumulated effectiveness in location A to move to location B, when old, to take advantage of the higher wages for skilled and lower prices. The equilibrium without migration ceases to be sub-game perfect. The new equilibrium satisfies condition (19). It turns out that, imposing condition (19) and the other equilibrium conditions, in the range $h_A^y \geq h_B^y$[23] the function $(RI_A - RI_B)$ is strictly increasing and it is positive in $h_A = 1$[24]. In this case the corner solution is the only possible equilibrium. Therefore, the only stable equilibrium is the corner allocation, with all young workers in A , while the number of old workers

[22]Several other simulations and robustness checks have been performed with different values of the parameter. They are available upon request. Their qualitative features are identical to those of the simulation reported in the paper.

[23]Recall that this is a necessary condition for the solution.

[24]The proof is available upon request and requires the condition $\alpha_1 > \alpha_2$.

in A, and therefore the number of migrants $(h_A^Y - h_A^O)$, is determined to satisfy (19) and is strictly smaller than one. The three figures in Appendix B.2 show the lifetime income differential between A and B and the number of migrants in the relevant interval in which Migrants= $h_A^Y - h_A^O > 0$. Outside of this interval we cannot have a sub-game perfect equilibrium and sometimes the solution to the conditions (6), (7), (17) and (19), for given h_A^Y yields negative interest rates or negative h_A^O. Keeping $\phi = 1.5$ we allow transferability of human capital to increase from its critical value $\theta = 0.65$ (figure B4).to $\theta = 0.4$ (figure B5) and then to $\theta = 0.1$. (figure B6). The only sub-game perfect, evolutionarily stable equilibrium for each case is the one in which all young workers are in A and part of them move to B when old in order to satisfy condition (19). The number of migrants in equilibrium increases as the transferability of skills increases.

Summarizing briefly the qualitative results, when the intensity of learning from others (ϕ) is low, the economy exhibits only the symmetric equilibrium. As ϕ increases, while transferability of skills is still low, agglomeration equilibria arise. Location A becomes the concentration of high skilled workers and promotes large acquisition of skills. As transferability increases (θ decreases) migration arises as the only possible equilibrium: the static sub-game perfect equilibrium has all young in city A and some of them moving out of it once old, to take advantage of less competition and less crowding in the other city.

5.2 Simulation: transferability and intensity of learning

In this section we analyze more systematically the effect on equilibrium density, wages and income in city A and B as ϕ and θ vary . We describe briefly the effects of increase in ϕ, the importance of face-to-face interactions for learning, assuming that our starting point is a situation where θ is large. More time is spent on the analysis of the equilibria as a function of θ, which is the novel feature of our model. We simulate the equilibria as transferability increase for high values of learning intensity.

If we represent in a diagram the evolution of the share of skilled workers in city A as the intensity of learning from interactions (ϕ) increases we obtain a classic example of pitchfork bifurcation. Figure C1 is obtained for the values of the parameters described in Section 5.1, $\theta \geq 0.65$ as ϕ increases. It shows that as ϕ increases over the critical value of 1.22, two potential equilibria with agglomeration arise. One of the two equilibria has location A become the location where most educated workers concentrate, while the symmetric one has city B becoming crowded with educated workers . Considering the equilibrium in which city A attracts educated workers, we have $e_A > e_B$, and the experience premium in A become larger as the density increases. Real wage of young, though, is larger in city B where lower density increases productivity of educated and decreases housing prices. Real wage of old workers, is larger in A, as a result of the large accumulation of effectiveness during the first period. This is illustrated in figure C2 that shows the evolution of real wages in equilibrium as ϕ increases. Real lifetime income of workers is equal in the two cities, as workers are free to move at the beginning of their career and chose to move up to the point in which lifetime incomes are equalized. Workers in A are willing to forego higher wages when young, in order to accumulate larger amount of skills and have larger wage as old.

This type of equilibrium, explains the large experience premium in cities, as well as their high density of educated workers but does not generate a larger fraction of young workers among the educated in city A. This situation, in which agglomeration economies are at work and cities are concentration of skills is the departure point of our analysis. Namely such was the situation in the 60's. The introduction of more standardized techniques, the increase in transferability of skills, the "globalization" of the technical languages promoted the potential for migration with small loss of specific human capital. We represent in figure C3 in Appendix C.2 the evolution of educated workers' location as specificity of skills decreases from $\theta = 1$ to $\theta = 0$. The figure shows that, from the equilibrium without migration and with concentration of educated workers in A, as θ drops below 0.65 (which is the critical value for which 18 holds with equality) a unique stable equilibrium with migration arises. All young educated workers move to A , while some of them move out of A, once old in order to satisfy condition 19. People who migrate from A to B, at the end of their youth, are just enough as to equate the real wage of old educated workers who move to the real wage of those who stay. In this equilibrium, old workers in B earn as much as the old in A, but if some young were to be in B they would earn much less as they would not accumulate any skills due to the complete absence of young workers. While skilled old workers are people who started in A and therefore get the same real wage as in A, unskilled in B are paid less than in A. Figure C4 shows the real wages earned by young and old people in A and B. For values of θ smaller than 0.65 the figure shows the initial widening of the experience premium. The real wage of young in B is always larger than for young in A, but the gain in skills from being in A generate full concentration of young there. As transferability increases (θ decreases) the experience premium in A as well as the real wage of old skilled workers in A decreases. This is due to the fact that, as a larger and larger share of old skilled move to B this harms the accumulation of skills in location A. At the point of perfect transferability of skills ($\theta = 0$) city A is almost only populated with young educated and this decreases the possibility of learning (which in our example depends on the presence of all groups of skills).

The key insight of this simulation, though, is that passing the critical value of θ the economy moves to a new equilibrium where:

- Experience premia are higher
- Denser cities attract Young educated workers while less dense cities attract older workers.
- Educated workers move during their life, at the beginning of the second period.

These three facts are consistent with what observed between the 60's and 1990.

6 Discussion: Mobility and Specificity of Human Capital

The present paper concentrates on two important characteristics of skills, in particular of those skills acquired during the working life of a person. The first is the possibility of accumulating them, through interactions with other skilled workers in the local working environment. The second is the possibility of transferring these skills, acquired in one location to another location. Only if both aspects are present cities attract educated young in spite of paying them low premia for living in an expensive environment. Workers are willing to give up some of their real wage as young, to benefit from the learning externality. Once old, though, some leave the cities and take advantage of the acquired skills in less dense and competitive locations.

This simple model accounts for all the stylized facts described in section 2. It also implies that the increased concentration of young skilled in dense areas observed between 1970 and 1990 is the result of a shift in equilibrium. The assumption needed for these results is that human capital specificity decreased during that period and it was rather large before it. Moreover a further implication of our model is that in 1990 we should observe more mobility of educated workers than in 1970.

We discuss here some suggestive evidence on mobility of workers, and some anecdotal evidence on specificity of skills and its decline. Table 3 shows the percentage of white, male, single workers in the age range between 35 and 45 who moved across counties or states in the US. Our choice is meant to control for family and cultural characteristics which could affect the moving decisions. Moreover we select the age group, likely to have already worked for 10-20 years, which corresponds to workers at the end of their first period in our model. We calculate these numbers from the PUMS 1990 and 1970 data and we consider two groups: workers with college degree or more and high school graduates. While we see mobility increasing from the 70's to the 90's we clearly see that for educated workers the fraction of people moving in the age range more than doubles, while for high school graduates increases by 25-50%. Generic increased mobility would not produce the above results, what we observe is higher mobility of highly educated, in a period of their life in which they are likely to have already accumulated relevant working experience. This is compatible with larger transferability of skills for educated workers in 1990 than in 1970.

Finally we want to convey some anecdotal evidence on skills' specificity. While hard to measure specificity of human capital can be inferred from the loss in wage of workers who are displaced from their firm. The tenure premium is a way to infer that. If a worker who moves out of a job for causes independent from her will suffers a wage loss, the theory of human capital attributes it to the loss of specific capital. The existing measures, are for firm-specific (rather than city-specific) human capital, but they help us to have an idea of the size of such specificity (parameter θ in the model), as firm-specific human capital should be a lower bound of city-specific human capital.

Our Table 4 summarizes results taken from Table 1 and Table 7 in Topel [34]. He uses US workers in 1984 and 1986 and shows that the loss in wage due to displacement is both substantial and increasing with prior tenure. The loss in productivity of a worker with 20 years of tenure if he is displaced is 44% of his wage, a substantial fraction. In the same table we also report Topel's estimate of the yearly return to experience and the return to tenure. We can think that the return to tenure relative to total return (tenure+experience) is the fraction of specific capital accumulated θ. The estimates for such a ratio which could be derived from Topel's paper (see his Table 5 and 7) range from 0.40 to a 0.60. These values are not too far from the 0.65 which is the critical value of θ in our experiment. Similarly Neal [29] , using data for workers in 1984-86-88 and 90, finds that the loss from displacement after ten years of tenure is 27% larger than after only one year of tenure. Again this denotes an estimate of specific human capital which is substantial.

Organizational changes in the '80s and 90's (the personal computer was introduced in 1980) have brought standardization of the software used in accounting, managing, programming and this could have had an important effect on increased skills' transferability. Moving from a firm to another must have become easier, in terms of tasks and skills's portability. It is fair to say, though, that little is known on how human capital specificity: how it has changed with technological evolution, how it depends on the skill-intensity of the job and other facts. Given the theory we have developed, though, the analysis of such specificity and of the impact of information technology on it, is crucial to assess the future of cities as location for educated young people.

A Tables

Year	1990				1970			
Area	**Within main SMSA's**		**Overall**		**Within Main SMSA's**		**Overall**	
All numbers are relative to employed people.	*Mega*	*Other Cities*	*Urban Areas*	*Non Urban Areas*	*Mega*	*Other Cities*	*Urban Areas*	*Non Urban Areas*
Share of College +	0.29	0.23	0.25	0.20	0.16	0.14	0.135	0.11
Share of Young*	0.59	0.60	0.60	0.60	0.42	0.42	0.41	0.41
Wage [a] of White Male Young* College +	20	19	19	17	22.5	19.7	19	16.8
Wage [a] of White Male Old** College +	31	26	28	24	28.5	25.0	23.5	19
Experience Premium	1.55	1.36	1.47	1.41	1.26	1.26	1.23	1.13
Share of Young* College +	0.20	0.15	0.17	0.13	0.10	0.09	0.08	0.06
Share of Old** College +	0.09	0.08	0.08	0.07	0.06	0.05	0.055	0.04
Ratio Young/Old College +	2.22	1.87	2.12	1.85	1.66	1.8	1.45	1.5

*** Experience < 20 years.**
**** Experience >=20 years.**
[a] Hourly wage in 1990 U.S. $.
(source: Author's Calculations on U.S. Census 1970, 1990)

Table 1: Stylized Facts for Urban Areas and Large Cities

Year	1990		1970	
Independent Variable	**ln(Empl)**	**R^2**	**ln(Empl)**	**R^2**
Share of College +	0.036* (0.004)	0.28	0.01* (0.0045)	0.05
White Males College +: (Share Young*-Share Old**)	0.09* (0.02)	0.05	0.01 (0.02)	0.01
Single White Males College +: (ShareYoung*-Share Old**)	0.047* (0.018)	0.04	-0.01 (0.02)	0.01
White Males College +: Log(Experience Premium)	0.02* (0.01)	0.02	0.06* (0.02)	0.07
White Males Old** College +: Log(Wage[a])	0.089* (0.007)	0.31	0.07* (0.01)	0.15
White Males Young* College +: Log(Wage[a])	0.068* (0.008)	0.23	0.006 (0.01)	0.01

* Experience < 20 years.
** Experience >=20 years.
[a] Hourly wage in 1990 U.S. $.
(Source: OLS regressions on PUMS 1970, 1990 data)
White Robust standard error in parenthesis, *=significant at 99%

Table 2: Correlations across SMSA

Variable	1965-70	1985-90
% of workers moving between counties (white, males, single, 35-45, College+):	21%	51%
% of workers moving between states (white, males, single, 35-45, College+):	7.5%	17%
% of workers moving between counties (white, males, single, 35-45, High School):	20%	33%
% of workers moving between states (white, males, single, 35-45, High School):	6%	8%

Table 3: Mobility of college educated and high-school educated workers.

Table4: Wage change of displaced workers

Years of Seniority on Prior Job	0-5	6-10	11-20	21+
Average percentage Change in Weekly wage	-9.5%	-22.3%	-28.2%	-43.9%
Return to Experience:**0.07**	Return to Tenure:**0.06**			
Source: Topel [34], Table 1, Table 7				
Workers January CPS 1984, 1986				

B Simulations of $RI_A - RI_B$

B.1 Equilibria without Migration: $\mathbf{h}_A^Y = \mathbf{h}_A^O$

Values of the common parameters in this Section's Simulation: $\gamma = 0.75$, $\Lambda = 1.55$, $\delta = 0.75$, $\alpha_1 = 0.4$, $\alpha_1 = 0.3$, $\alpha_1 = 0.2$, $\theta \geq 0.65$

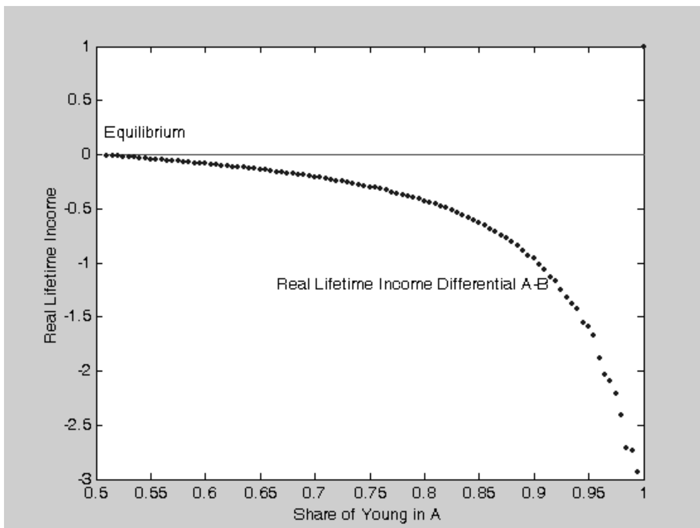

Figure B1: $\phi = 1$, Low Externalities: Equilibrium without Migration

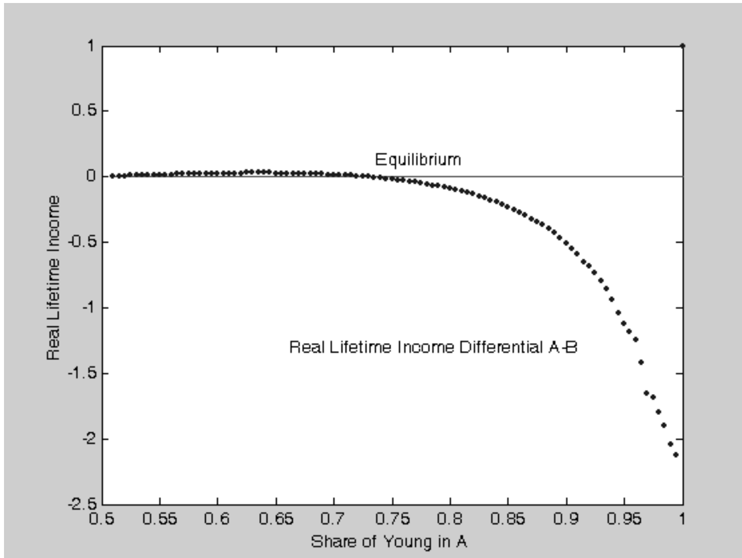

Figure B2: $\phi = 1.3$, Intermediate Externalities: Equilibrium without Migration.

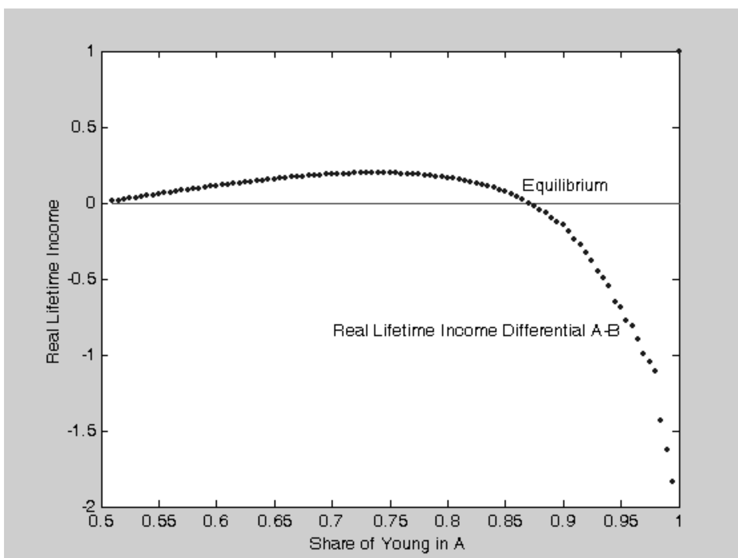

Figure B3: $\phi = 1.5$, Large externalities: Equilibrium without Migration.

B.2 Equilibria with migration: $\mathbf{h}_A^Y > \mathbf{h}_A^O$

Values of the common parameters in this Section's Simulation: $\gamma = 0.75$, $\Lambda = 1.55$, $\delta = 0.75$, $\alpha_1 = 0.4$, $\alpha_1 = 0.3$, $\alpha_1 = 0.2$, $\phi = 1.5$

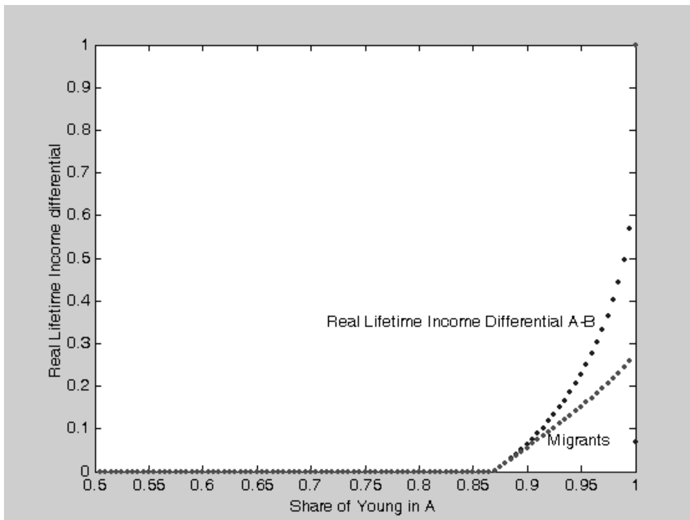

Figure B4: $\theta = 0.65$, critical value.

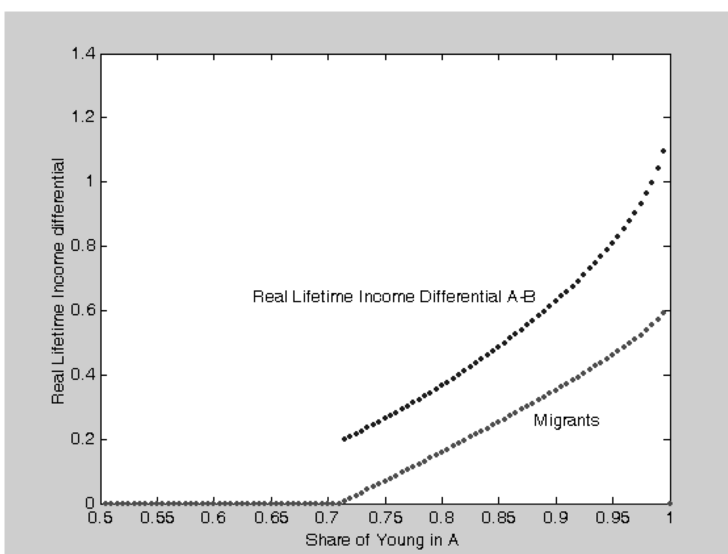

Figure B5: $\theta = 0.4$,high transferrability of human capital

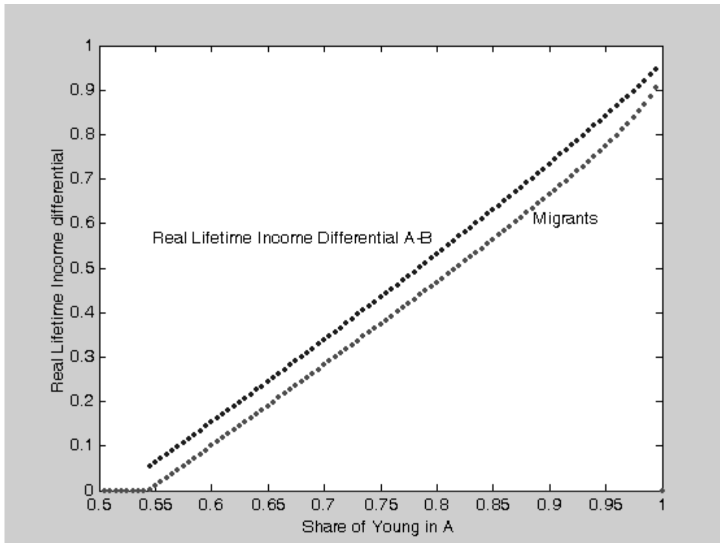

Figure B6: $\theta = 0.1$, very high transferrability of human capital

C Equilibria: Workers' location and Real Wages

C.1 Equilibrium without migration as ϕ increases

Parameters' values in the simulation: $\gamma = 0.75$, $\Lambda = 1.55$, $\delta = 0.75$, $\alpha_1 = 0.4$, $\alpha_1 = 0.3$, $\alpha_1 = 0.2$, $\theta \geq 0.65$

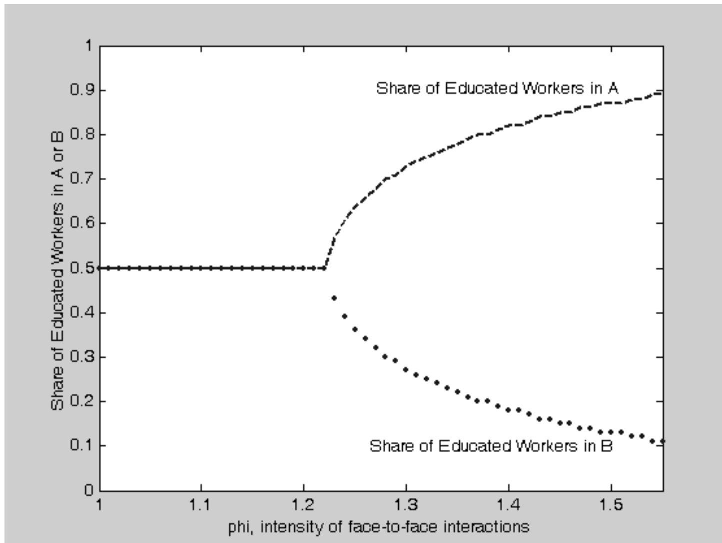

Figure 1: Figure C1: Share of Educated Workers as a function of ϕ

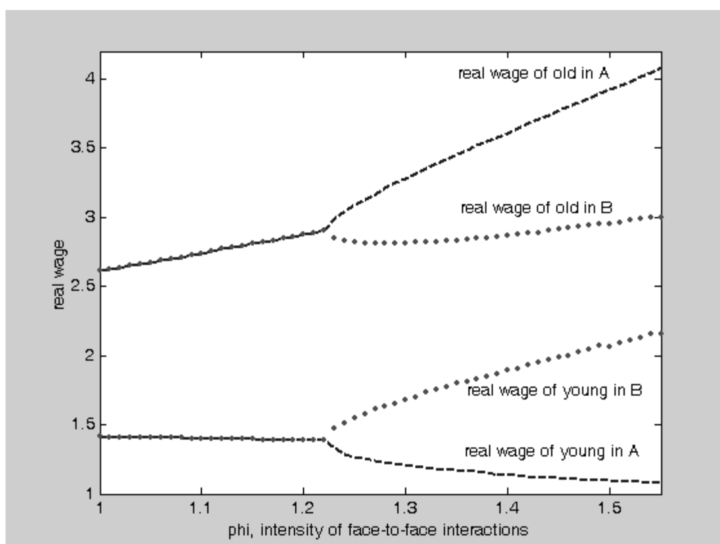

Figure C2: Real wages as a function of ϕ

C.2 The arising of intra-life migration, as θ decreases

Parameters' values in the simulation: $\gamma = 0.75$, $\Lambda = 1.55$, $\delta = 0.75$, $\alpha_1 = 0.4$, $\alpha_1 = 0.3$, $\alpha_1 = 0.2$, $\phi = 1.5$

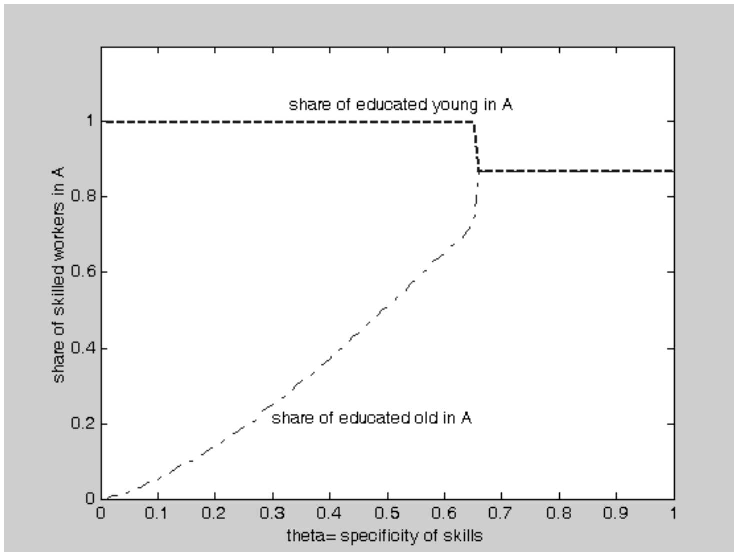

Figure C3: Share of educated workers as a function of θ.

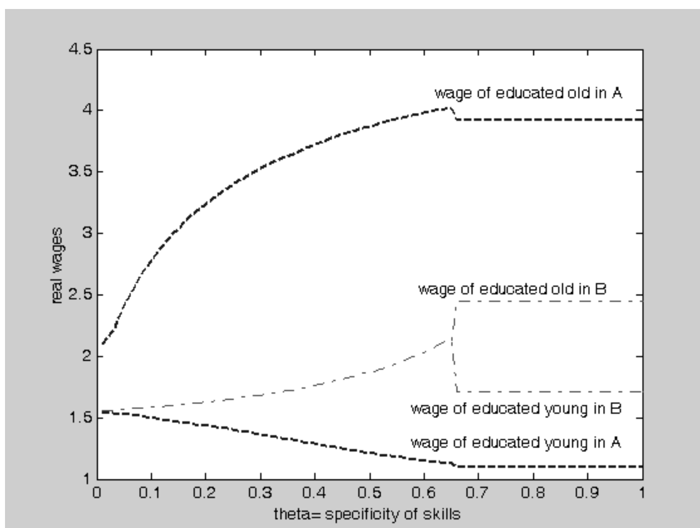

Figure C4: Real Wages as functions of θ

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