Human Capital Externalities in US Cities

Giovanni Peri*
University of California, Berkeley
Bocconi University and IGIER

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Abstract

In an empirical analysis, considering 236 U.S. cities in the period 1980-1990, we document a strong positive correlation between local supply of skills and their return. In SMSA's where the average education of workers is high the education premium is also high. This is true both considering the levels of the variables in 1980, 1990 and considering their changes. Technical progress, as well as physical capital investments, may be driven by local pressures to enhance the productivity of those factors which are locally abundant. Therefore we may interpret this regularity as a sign that in cities where educated workers are abundant firms will invest in skill-complementary machines and techniques. Acemoglou (1998) claims that this idea could explain the time evolution of education premia in the 80's. Here I bring some compelling evidence that it may provide an explanation for the behavior of education premia across cities.

Key-Words: Cities, Human Capital Externalities, Skill Premium

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* For Correspondence: IGIER, Universita' Bocconi, via Salasco, 5 20136 Milano, Italy. Email: giovanni@econ.berkeley.edu. I am thankful to Antonio Ciccone, Enrico Moretti and participants to various seminars for suggestions and advise. I thank Antonio Ciccone and Douglas Almond for allowing me to draw from our joint work. I acknowledge the Alfred P. Sloan Foundation for financial support during the year 1997-98.

1 Introduction

In the last two decades the industrialized world has experienced a deep transformation in the technologies for communication and diffusion of information. The consequences of these changes on the economic and social institutions could be very deep. The spatial organization of production could very well undergo important transformations and already some professionals foresee a future where cities and economic agglomeration will disappear as information technology will make face-to-face contact obsolete. Nevertheless serious studies of the recent evolution of city employment, population and productivity do not seem to detect any tendency towards their decline[1]. On the contrary evidence relative to the last two decades reveals that agglomeration economies have played and continue to play an important role in the location decisions of firms and in their evolution.

The main stream of urban and regional economy explains cities through transport costs (Alonso, 1964; Krugman, 1991a and 1991b; Ciccone and Hall, 1996). Although transport cost may be still playing a role the main reason that keeps production in cities does not seem any more the possibility of locating near the consumers. As shown theoretically in Krugman and Venables (1995) and empirically in Dumais , Ellison and Glaeser (1996), this force, potentially very strong at the dawn of industrialization, may have be loosing its importance in the recent decades, due to constant fall in transport costs. It is not to exploit closeness to the market that firms seem to remain in cities but to remain close to “ideas” and to a pool of “human capital” from which they draw their labor force. If we only concentrate on the “cost side”, in fact, the increased costs of urban congestion, urban dis-amenities (see Glaeser and Sacerdote, 1996) and high rents should have moved production away from cities unless some important factors prevent firms from leaving.

The advantage of cities, must be found in their specific characteristic of being a dense agglomeration of people and, therefore a concentration of workers, human capital and ideas. Various general studies (Glaeser et al. 1992; Jaffe, Trajtenberg and Henderson, 1993; Henderson, Kuncoro and Turner, 1995) and case-specific or circumstantial evidence (Jacobs, 1968 and Saxenian, 1993) have contributed to strengthen the view of cities as poles of technological innovation and discovery. It may very well be the

[1] See Glaeser (1998) for a review of the recent literature.

case that the new information technology, by improving the exchange and the processing of information, will enhance the role of cities as informational nodes of the network. As Gaspar and Gleaser (1997) argue, if electronic interactions are complement to face-to-face interactions then cities should be the places that benefit most from information technology. Preliminary evidence seems to confirm that the large majority of telephone and email interactions take place between people in physical proximity (Imagawa, 1996). Similarly to innovative ideas, useful information that increases productivity of workers or allows them to optimize the productive match with a firm, circulate more easily in cities. The urban environment promotes frequent exchange and interactions across workers and therefore may speed up the learning of useful skills over time (Glaeser and Mare, 1994). Being in a city where the general level of skills (human capital) is high may result in an even faster accumulation of skills (Lucas 1988, Rauch 1994).

The high level of skills of workers in a city may also act as an attractive force for firms that have invested in capital-intensive technologies. If the pool of workers from which firm draw their labor is highly skilled this may direct those firms to adopt technologies and machines that complements skills making them more productive.

This may generate the type of externalities described in Acemoglou (1996). In that model, an increase in the average level of human capital will induce firms, who are subject to random matching with workers, to increase the amount of investment in physical capital, which is a complement of high skills. As a result firms in high-human capital environment will operate with more physical capital. This will benefit the productivity of all workers, also of the less skilled ones, who happen to be matched with these industries. On the other side, the workers who will have the largest benefits are those occupying the high-skill end of the range as they benefit most from complementarities with physical capital. Moreover, by increasing the skill premium, these technologies may act as "attractors" for highly skilled workers.

Characterizing and measuring the effects of human capital in a city and understanding the channel through which it operates is therefore a crucial issue if we want to understand what are the characteristics of a city that improve the productivity of its workers, and attract new firms. The present paper uses a very large collection of data on US urban workers, from the 1980 and 1990 PUMS of the Census. The goal is to improve on the findings of the previous studies by using more detailed evidence, by comparing different effects in a unified approach and by addressing some endogeneity problems. In particular, comparing the present study to Rauch (1994), which is probably the study closest to ours, we find several problem with his approach that affects the results. We are able to distinguish between static “matching” externalities, and dynamic “learning” externalities and to control for local technological and labor market characteristics.

The results that we describe throughout the paper seem to support the idea that the effect on productivity of high human capital may act via an endogenously generated channel. Firms operating in high human capital environment, or predicting an increase in the future level of human capital will invest intensely in technologies and machines which are complementary to high skill levels. This in turn will attract more educated workers, as the skill-premium will increase and will further increase the average level of human capital of the city. This results may explain the strong correlation between average level of education and the return to education that we find throughout the paper (Borjas, Bronards and Trejo, 1992 find similar effects). That effect disappears, though, when we use exogenous instruments for human capital. This results, therefore, show that there is not support for the hypothesis of human capital varying exogenously and productivity of workers increasing as a consequence (therefore invalidating the study by Rauch, 1994, who assumes exogenous average education).

We also analyze in some detail the dynamic “learning” externalities, that could be thought as the consequence of “on the job learning” (Lucas, 1993) in a city. They do not seem to be very strong, or at least they do not seem to depend on the quality of the city-environment in which workers operate[2]. We extend the analysis and consider the effect of local industrial concentration and diversity as well as the role of cultural diversity on this externality. We estimate a positive effect of economic diversity and a negative effect of ethnic and cultural fractionalization, but they are not significant. In conclusion we do not find strong evidence that local diversity improves productivity via increased learning[3].

The paper is organized as follows. Section 2 presents stylized model and describes the estimation procedure, section 3 presents the data set and some preliminary evidence. Section 4 presents the main results of the paper and section 5 proposes an interpretation of the results. Section 6 concludes.

[2] Our data, covering only 10 years may not be the most appropriate to detect dynamic externalities.

2. The Model

The production of a city is described as an aggregate production function, that uses labor, capital and some local factors to produce a composite good. Different industries in the city employ types of workers, potentially in different proportions, from a city-wide labor market so that, except for local market condition in the short run, different industries in a city should pay the same wage. Workers are mobile within cities and their productivity depends on some personal characteristics, as marital status, race, education and experience, and on city-wide characteristics, that affect local market, local firms' decisions and may generate externalities. We may represent a city's production function as follows:

$$(1) \qquad Y_C = F(H_{0,0,1}L_{0,0,1},....H_{m,n,o}L_{m,n,o},K_{1,c}...K_{o,C},S_C)$$

$H_{I,j,k}$ is the effectiveness of labor with l years of education, j years of experience and working in sector k, while $L_{I,j,k}$ is the corresponding amount of labor employed. $K_{i,C}$ is the amount of capital used in industry i and S_C is some city-specific factor (as infrastructures) that we will consider as a shifter. The productivity of a worker depends on the marginal product of function F and on "effectiveness of labor", H.

F is affected by personal characteristics, industry-characteristics, the amount of capital factor used and city-wise characteristics. H, specific to the worker-firm combination, depends on worker's personal characteristics and on the quality of the match with the firm (affected by city-wise market conditions). Therefore, assuming that the relevant workers' characteristics are education and experience and that city-wise externalities may affect the productivity of each of these characteristics, it is convenient to define wages (i.e. marginal productivity of workers) as function of personal characteristics that we want to control for (X_P), industry-specific characteristics (X_I) and city-specific characteristics (X_C) . Again using the fact that across industries similar worker should receive the same wage we may write:

[3] If mobility of workers is high the effect of local diversity on productivity may be visible only on employment data. Glaeser et al (1992) Henderson, Kuncoro, Turner (1995) and Peri (1998a) find evidence of such effect on employment growth.

$$(2)\qquad w_{00} = F_{00}(H_{0,0,1}L_{0,0,1},\ldots H_{m,n,o}L_{m,n,o},\ldots K_{1,C},\ldots K_{o,C},S_C)*H_{0,0} = \\ = F_{0,0}(X_p, X_i, X_C)*H_{0,0}(X_P, X_C)$$

$$(3)\qquad w_{E,0}/w_{00} = F_{E,0}/F_{00}(H_{0,0,1}L_{0,0,1},\ldots H_{m,n,o}L_{m,n,o},\ldots K_{1,C},\ldots K_{o,C},S_C)*(H_{E,0}/H_{0,0}) = \\ = f_{E,0}(X_p, X_{j,} X_C)*h_{E,0}(X_p, X_C)$$

$$(4)\qquad w_{0,A}/w_{00} = F_{0,A}/F_{00}(H_{0,0,1}L_{0,0,1},\ldots H_{m,n,o}L_{m,n,o},\ldots K_{1,C},\ldots K_{o,C},S_C)*(H_{0,A}/H_{0,0}) = \\ f_{0,A}(X_p, X_{j,} X_C)*h_{0,,A}(X_p, X_C)$$

where I have suppressed the industry subscript as wages are determined in the city-market.

The first expression denotes the wage of the worker with no education and experience (w_{00}) as a function of the industry and the of city characteristics (and personal characteristics that we want to control for). Expression (3) and (4), denote the education premium and the experience premium as function of city and industry characteristics.

The above expressions provide a fictious but useful categorization of all types of workers as a combination of three “primary” factors for whom the expressions provide the price. The first factor (2) is “pure labor”, i.e. labor without skills as it has no experience and no education. The second factor (3) represents the skills accumulated with education, that we will assume linearly increasing with years of education in our empirical analysis. The third factor (4) represents the skills accumulated via experience, which we will assume as a quadratic function of years of experience. Any kind of worker could be thought as the combination of these three factors. The price of these three factors, therefore, will be the focus of the analysis in the empirical part.

Although the expression are completely general we have separated them into two parts, F and H as the theory provides us with some indication concerning at least the sign of the effect of some characteristics. The first term, F (or f) is affected by relative supplies and complementarieties in the production function. If labor is not very mobile across industries, then the relevant variables determining price of skills are the city-industry supply of skills. If labor is mobile across industries, what will matter in determining the return to factors, is the city-wise supply of factors. If educated or experienced workers are very abundant in a city, this should cause their marginal productivity to decrease (lower f_{E0} and f_{0A}) while the marginal productivity of the "pure labor" factor (F_{00}) should increase. Vice-versa if they are relatively scarce this should increase the wage of the less skilled worker while decreasing education and experience premium.

The second term of expression (2) , (3) and (4) called H (or h) captures the "productive effectiveness" of the worker (or the increase in effectiveness with age and education) and is affected by the quality of learning and by the quality of the worker-industry match. It is on this variable that the city-externalities operate.

If there are static matching externalities, such that the quality of the match of workers and firms depend on the "thickness" of the market than the density or the total employment of cities should have a positive effect on H_{00}. Typical search models (Diamond, 1982) will suggest that in an environment where more workers look for a firm and more firms look for a worker it will be easier for a firm to find the right worker. This externality will improve the average quality of the "firm-worker" match and increase the

Finally, and most importantly for our story, there is a third way through which the local supply of skills may affect productivity, (and in turn be affected by it). This channel has been pointed out by Acemoglu (1998), and here I adapt his argument.

A firm in an environment with higher human capital may have incentives in investing more in physical capital, which complement workers' skills. This may generate a positive effect on the productivity of all the worker, but larger on those with higher skills (education). This explanation allows for an "endogenous" channel, through which the average level of human capital may have an effect on productivity that in turn affects human capital as more educated people will be attracted. As a result of this process we will observe more supply of skills and higher premium for them in some cities.

Finally a typical dynamic externality which, in our notation will affect h_{0A} is the type of "on the job" learning externality modeled in Lucas (1993) and measured in Glaeser and Mare (1994). Not only workers in denser environment may benefit from it, but the characteristics of the city environment, such as the average level of human capital, the industrial and cultural diversity, may affect its intensity. Therefore in cities with higher level of education, with more industrial and cultural diversity the opportunities for learning are more intense and this could have a positive effect on $h_{0,A}$.

With our data set we are able to distinguish between the above-described effects of local skills and local employment on productivity, and moreover in the easy framework constructed we might also address the problem of distinguishing them from pure local market effect due to demand and supply of skills.

3. The Data and Descriptive Statistics

The Data we will use for the empirical analysis are taken from the 5% sample of the PUMS (Public Use Microdata Sample) of the 1980 and 1990 U.S. Census. For reason of disk space I have extracted a 50% random sample from the 5% PUMS, so that 2.5% of the sample of all the individual of the United States is represented. I have used only working persons, resident in 236 SMSA's (which I will call, somewhat improperly, "cities") that are identified in both census years. The measure of their productivity is their hourly wage, in 1990 US $[4], calculated as the yearly salary divided by the weeks worked in one year times the hours worked in one week. The total number of urban workers in the sample I use are, therefore 1,631,528 in 1980 and 1,797,852 in 1990. The decade 1980-1990 has been studied in detail by many labor economists and some stylized facts are well known. Median wage did not rise while a drastic increase in wage inequality, particularly in the education premium and in the experience premium was experienced (see Bound and Johnson, 1992 Juhn, Murphy and Pierce, 1993 and Katz and Murphy, 1992 for an account of these stylized facts). Moreover the gap in wages between white and blacks has risen, while that between men and women has decreased. Table 1, that reports simple averages and the coefficients of a standard Mincerian wage estimated only for urban workers, confirms that those stylized facts are true also for the population of urban workers. The estimated equation is:

[4] The data on wages for 1980 are therefore multiplied by the GNP deflator to transform them in 1990 $.

$$(5) \quad \log(wage)_i = \alpha + \beta\ (Education) + \beta_2(Experience) + \beta_3(Experience^2) + \beta_4(sex) + \beta_5(non-white)$$

where Education is measured as years of schooling[5], Experience is measured in years of potential experience[6], sex is a dummy whose value is one for females and non-white is a dummy whose value is one for non-white workers.

Table 1

Dependent Variable in the Regression: log(wage)

year	*average wage*	α	β_1	β_2	β_3	β_4	β_5	R^2
1980	12.34 $	1.22	0.064	0.037	-0.0005	-0.38	-0.04	0.25
1990	12.95 $	0.78	0.088	0.044	-0.0006	-0.29	-0.07	0.27

The estimate of the intercept, α captures the wage of the person with no education and no experience. We can observe the dramatic drop of this estimate from 1980 to 1990 equal to about 30% of the initial value. The education premium increases from 6.4% in 1980 to 8.8% in 1990 while the experience premium in 1990 becomes steeper in the early years (coefficient on the linear term increases of almost 20%) but levels-off more rapidly (the coefficient on the quadratic term also increases), as compared to 1980. Finally in the considered decade the difference of wage between sexes is reduced of 25% of its initial value, while the white-nonwhite gap is almost doubled.

[5] For the 1990 sample some years of education are grouped together (for example 1st, 2nd, 3rd and 4th grade are together) In this case we have attributed the mean value of the interval as years of schooling.

[6] Experience = Age-(Years of Education)-6;

In order to capture the productivity of the three stylized factors described in the previous section, i.e. "raw labor", "education-skills" and "experience-skills", we run a regression as (5) separately for each city-industry. Cities are defined as the 236 SMSA's while industries are 30 sectors, whose definition is somewhat finer that the SIC two-digit classification. The list of industries considered can be found in the appendix. We run a total of 7080 regressions and we consider the estimates of coefficient α in each regression as the productivity of raw labor in that city-industry (w_{00}), the estimates of β as the productivity of education-skills in that city-industry ($w_{E0}/E*w_{00}$) and a linear combination of β_2 and β_3 that we will call γ as the productivity of experience-skills cumulated in one half of the typical working life ($w_{0,20}/w_{0,0}$)[7]. Given the number of observation we are able to estimate more than 6950 of each coefficient for each year. We have excluded only those city-industries for which we did not have enough observation to estimate all coefficients and relative standard errors. This approach is extremely general because it allows each city-industry to be a separate market and to price all the skills and characteristics of workers differently. We will see that, once we allow different markets in different cities, the industry-dummies do not have a very relevant independent role. This confirms that the relevant market is the city-wise market probably due to high inter-industry mobility. Before presenting a useful decomposition that will allow us to capture the importance of city-location in productivity let me point out here a major limit of the previous work by Rauch (1994). In his paper Rauch considers all the characteristics of the workers as having a "national" price, and he only allows the intercept of the Mincerian regression to be different across cities and to depend on the average education and experience in the city. This procedure results in capturing all the effects of city characteristics correlated with the average education of the city, in those coefficients. If we reproduce Rauch's method, and estimate equation (5) on the whole urban population, allowing only the intercept to be city-specific, and then we regress the 236 estimated α on the average city education and experience, weighting each observation by the standard error of the estimate, we obtain the coefficient estimate reported in Table 2

[7] We consider ($20*\beta_2+400*\beta_3$) which represent the "typical" experience premium after 20 years in a city- industry.

Table 2

Dependent Variable: Estimates of α_ι (city-specific intercept) from equation (5)

Std. Errors in Parenthesis

year,	*Average City-Education*	*Average City-Experience*
1980	0.068	0.005
	(0.012)	(0.004)
1990	0.088	0.012
	(0.017)	(0.006)

The table shows that the estimates for 1980 are not far from Rauch's estimates (who estimates a coefficient on average education equal to 0.05, with std error 0.013 and a coefficient on average experience of 0.0046, std error 0.0036) and the method produces much larger estimates for 1990, consistent with the estimates of Almond (1997) who uses Rauch's method. We will see that when we allow different cities to price differently all types of skills the effect of average human capital on the intercept will not be significant and also will not vary much from 1980 to 1990 (not to mention the fact that in most cases results to be negative).

In order to clarify the role of industries in determining the productivity of workers' characteristics we use an ANOVA decomposition, (see Stockman, 1988, for an application) that allows us to see how the productivity of our three basic factors depend on cities and how it depends on industries. We decompose the three estimated productivities of raw labor, education skills and experience skills, which, from now on, I will call α, β and γ, according to the following model:

(6) $$x_{c,i} = C(c) + I(i) + \varepsilon$$

$x_{c,i}$ is the price of a factor in city c, industry i, C(c) (c=1,2,...236) is a set of dummies equal to one for all industries in city c and zero elsewhere, and I(i) (i =1, 2, ...30) is a set of dummies equal to one for industry i in all cities and zero all other industries. Finally ε captures the part of the estimated productivity which is idiosyncratic to the city-industry. The model allows to decompose the fraction of total variance of city-industries productivity which is due to cross-city variation and the fraction due to cross-industry variation.

Table 3

Decomposition of the Variance of city-industry prices of Labor Characteristics

Variable/Year	*Component*	*% of Variance explained*	*F statistics (no group-effect)*	*p-value*
α, 1980	City	4.2	1.13	0.09
model R^2 =0.046	Industry	0.4	0.94	0.55
β, 1980	City	4.0	1.07	0.23
model R^2 =0.044	Industry	0.4	0.93	0.60
γ,1980	City	5.0	1.33	0.001
model R^2 =0.056	Industry	0.6	1.45	0.05
α, 1980	City	5.1	1.39	0.0001
model R^2 =0.056	Industry	0.4	1.01	0.44
β, 1980	City	4.2	1.12	0.09
model R^2 =0.048	Industry	0.6	1.03	0.11
γ,1980	City	0.33	0.93	0.57
model R^2 =	Industry	0.4	0.90	0.85

Table 3 reports the fraction of total variance (sum of squares) of each estimated coefficient which is explained by the cross-city variation (component C(c) in the model) and by the cross-industry variation (component I(i) in the model). The rest of the variance is due to city-industry idiosyncratic factors.

As can be seen, most of the variance is explained by idiosyncratic factors, possibly also for the potentially large measurement errors in each city-industry productivity, but the city-component is always more significant than the industry component and it contributes almost ten times more than the industry component to explain the sum of squares of productivity of factors, both in 1990 and 1980. We can reject four times out of six at the 10% significance level the hypothesis of no city-specific effects, while we can reject that hypothesis only once out of six estimates for industry-specific effects. Therefore we can say that, almost all the variation in prices of labor characteristics explained by the above model, can be explained as cross-city variability.

4. Empirical Results on Externalities

4.1 City-Industries

The simplification introduced in section 3, that allowed us to summarize the relevant skills of workers with three measures of factor productivity, allows us to analyze the effect of local skills on the productivity of those three factors. In this section we will measure the effect of some city-characteristics on the three estimates of productivity of labor skills. We will consider the average level of education and of experience of city-workers, to see if they affect the productivity of raw labor or that of educated and experienced labor. The interesting thing in so doing is that we can compare our results to those of Rauch (1994), who uses measures of city average education and average experience. Also, the average education and average experience are natural measures of the supply, at the city level, of the factors whose price is captured by β and γ. Therefore in an explanation driven by the supply of factors at the city level, those factors should have negative effect on the prices β and γ. Vice-versa, if externalities of the static and dynamic type are important or the "Acemoglou (1998)" effect is at work, the negative effect, described above could be reduced and even reversed by the positive effect of the externality. On the other hand the effect of these variables on α, should be positive as more education means decreased relative supply of "raw labor". We will also consider the effect of total employment in the city, which in search models should have a positive effect on productivity of the average worker, if, in larger cities, the probability of a good match is increased.

The model that we estimate for all three variables (α, β, and γ) as dependent variables is:

$$(7) \qquad x_{c,i} = a_i + b_1(Ave.Edu)_{c,i} + b_2(Ave.Exp)_{c,i} + b_3(\log Empl)_{c,i} +$$
$$b_4(Ave.Edu)_c + b_5(Ave.Exp)_c + b_6(\log Empl.)_c$$

The model is a simple linear approximation that expresses the "price" or productivity of the labor skills in city-industries ($x_{c,i}$ represents alternatively α, β or γ) as a function of local supplies of skills in the city-industries and in the cities. The local characteristics could be interpreted also as local relative supply of the three factors so that in a purely competitive model with no externalities they should have a negative effect on prices. On the other side we are considering the possibility that exactly those factors may have a beneficial external effect to productivity, and so a positive effect could be interpreted as strong evidence in favor of externalities or of the Acemoglu effect. Table 4 reports the results of the regressions for 1980 and 1990.

Table 4

Std. Errors in parenthesis. Industry dummies included.

Method of Estimation WLS, weights = std errors of the estimates in the 7040 city-industries regressions

year	*1980*			*1990*		
Dependent Variable	α	β	γ	α	β	γ
Education	0.01	0.003***[8]	0.04***	-0.008	0.004***	0.022
city	(0.02)	(0.001)	(0.01)	(0.02)	(0.001)	(0.020)
Experience	-0.01	0.0009*	-0.002	0.04***	0.009	-0.023***
city	(0.008)	(0.0005)	(0.003)	(0.01)	(0.006)	(0.008)
log(Empl) city	0.002	-0.0003	0.0008	0.03**	0.0005	-0.002
	(0.01)	(0.0006)	(0.004)	(0.01)	(0.001)	(0.01)
Education	-0.01	-0.0008	-0.01**	-0.005	0.001	-0.001
city-industry	(0.01)	(0.0006)	(0.004)	(0.01)	(0.0008)	(0.01)
Experience	0.003	-0.0001	0.001	-0.004	0.0003	-0.002
city-industry	(0.002)	(0.0001)	(0.001)	(0.003)	(0.0002)	(0.002)
log(Empl)	0.03***	-0.0003	0.00008	0.006	0.0001	0.005
city-industry	(0.01)	(0.0006)	(0.004)	(0.01)	(0.0009)	(0.01)
R^2	0.07	0.02	0.03	0.03	0.02	0.01

As a first remark, note that the city-wise variables have a significant effect on productivities in seven estimates, while city-industry variables only in two. Also the t-statistics on the industry dummies (not reported in the table) are never significant (in none of the regression) and in two

[8] ***, **, *, significant at the 1, 5, 10% level.

cases (β in 1980 and γ in 1990) the hypothesis that coefficients on dummies are jointly zero cannot be rejected at the 5% significance level. The only coefficient that is significant in both years is the positive effect of average city education on β, the education premium. This is a very strong result as it means that in those cities where education skills are more abundant, they are paid more than average while where they are less abundant they are paid less than average. A supply-driven explanation, would give the opposite result of a negative correlation between average education in the city and β.

Two other significant effects, the one of average experience on α and the one of average experience on γ, are in accordance with the "market-driven" explanation; increase in the supply of the experience-skills makes those skills less valuable and increase the value of raw labor. On the other hand the significant effect of average city-education on the experience premium in 1980 is in accordance with the idea that local learning externalities could play an important role; cities with more educated labor force promote better learning and accumulation of skills over time. Finally the positive effect of total employment on α could also be due to an externality; cities with a larger labor force are normally denser and this may increase the quality of productive matches.

As we have noticed the industry-composition does not seem to have a systematic effect on productivity, and the proposed explanation is that for given level of skills mobility across industries within a city is rather large. This could certainly be "endogenously determined" as similar industries tend to cluster in a city allowing a worker to have a larger market for her skills. As the paper focuses on localization externalities, we will proceed merging industries in a city. This will improve dramatically the precision of the estimates of α, β and γ, which now are relative to a whole city, and, as we will see, it will not alter significantly the results of Table 5. Table 6a and 6b show the effect of city-wise characteristics on the estimates of productivity at the city-level. In the rest of the paper we will concentrate on cities as units of analysis.

4.2 Cities

Table 6a and 6b show the estimates of the effects of city-employment, city-education and city-experience on α, β and γ estimated as described in section 3, but now merging the data for all industries within a city. I have reported the results in two separate tables, one relative to 1980 and the other to 1990.

Table 6a

236 cities, year: 1980, Method of Estimation:WLS

weights = std errors of the estimates of α, β, γ.

all regressions include an intercept. Std Errors in parenthesis

Dependent Variable	a	b	g	a	b	g
Education	-0.04	0.004**	0.05***	-0.08*	0.008***	0.037*
City	(0.04)	(0.002)	(0.015)	(0.045)	(0.003)	(0.019)
Experience	-0.019	0.0016**	-0.004	-0.01	0.0018*	-0.01
City	(0.012)	(0.0008)	(0.005)	(0.01)	(0.0010)	(0.007)
log(Empl)	0.013	0.001	0.002	0.02*	0.0006	0.0007
city	(0.014)	(0.0008)	(0.005)	(0.01)	(0.0009)	(0.006)
State-Dummies	No	No	No	Yes	Yes	Yes
R^2	0.01	0.04	0.11	0.32	0.26	0.30

Table 6b

236 cities, year:1990, Method of Estimation:WLS

weights = std errors of the estimates of α, β, γ.

All regressions include an intercept. Std Errors in parenthesis

Dependent Variable	a	b	g	a	b	g
Education	-0.02	0.005***	0.02	-0.05	0.007***	0.02
City	(0.03)	(0.002)	(0.02)	(0.04)	(0.002)	(0.02)
Experience	0.04***	-0.0002	-0.028***	0.028*	0.0001	-0.022***
City	(0.015)	(0.0009)	(0.006)	(0.015)	(0.002)	(0.007)
log(Empl)	0.05***	0.0007	-0.012*	0.035**	0.001	-0.01
city	(0.015)	(0.0009)	(0.006)	(0.015)	(0.001)	(0.007)
State-Dummies	No	No	No	Yes	Yes	Yes
R^2	0.08	0.04	0.12	0.44	0.27	0.37

The only coefficient which is significant in all specifications and in both years is the effect of average city education on β. The point estimate is between 0.5 and 0.8 %, which is larger than what estimated in the city-industry regression, but as also the standard error of the estimates are larger. The estimates in the two cases are not significantly different. Average city-experience continues to have the standard "market effect" in 1990 on experience premium and on return to raw labor. Also total employment is close to be always significant and positive in its effect on α . So, the only factor that may have a positive external effect, neutral across skills, is the total employment of a city. This effect may be due to a "density" externality a-la Ciccone-Hall[9] (1996), or to a search externality.

Table 6a and 6b also report the parameter estimates when we control for state-effects. Different areas in the U.S. might be systematically associated with higher average levels of human capital, and be more productive for example for their institutional arrangements. The inclusion of state dummies does not alter the results, showing that within-state variation across cities is an important determinant of the differences in productivity. Our results are not driven by some large regional phenomena, but genuinely by the cross-city variation in average education, experience and employment.

One econometric problem, particularly relevant for the effect of employment on productivity is that employment is highly endogenous. Cities where productivity is high, may attract workers generating the correlation described above for a mechanism of causation running from productivity to employment, rather than vice-versa. It is therefore extremely important to find some instrumental variables to correct this bias. In Table 7 the IV estimation is presented. The instrument used are variables correlated with the population of a city (and its employment) but not its productivity. They are measures of the geographic and recreational amenities of a city. An index for climate, a dummy for location on a coast, an index for recreational facilities, and an index for art per capita in a city[10] are characteristics that should attract workers, without affecting productivity other than via the effect of larger population (and density). Using these variables as instruments, we still have a significant effect of employment on α in 1990, while the effect in 1980 is weakened, but the point estimate is still positive and larger than with WLS, but the std error of the estimates is significantly larger (see Table 7). The other estimates are left basically unchanged.

[9] Remember that there is am high correlation between MSA's density and their population. Glaeser (1998) estimates it around 0.5.

Table 7

236 cities, 1990, Method of Estimation:I V

all regressions include an intercept. Std Errors in parenthesis

Year	*1980*			*1990*		
Dependent Variable	α	β	γ	α	β	γ
Education	-0.06	0.005**	0.05***	-0.07	0.007***	0.04**
City	(0.04)	(0.0025)	(0.016)	(0.04)	(0.002)	(0.021)
Experience	-0.028*	0.003***	-0.003	0.025***	-0.0005	-0.024***
City	(0.16)	(0.0009)	(0.005)	(0.006)	(0.001)	(0.0006)
log(Empl.)	0.027	0.0002	-0.003	0.09***	-0.002	-0.01
city	(0.022)	(0.0001)	(0.01)	(0.03)	(0.0015)	(0.01)
R^2	0.02	0.03	0.10	0.07	0.03	0.10

4.3 Refining the Econometric Analysis: selection bias and city fixed-effects

In his work, Rauch (1994) argues that the average education and average experience in a city are exogenous variables, so that the regression reported in table 7, where we have corrected for employment endogeneity, are the correct ones. This assumption seem to us implausibly strong and there are certainly at least three problems with the results obtained so far. We will try to address them in the present and following sections. The first problem is that the effect that we capture could be due to “selection bias”. For example more “educated” cities may attract workers who are better

[10] The index of Climate, art per capita and recreation per capita for our 236 cities are taken from the State and

in some unobservable characteristics. If this "attractive power" is stronger on more educated people, the effect on parameter β could just be due to the selection of people with better qualities in the high education range in cities with high average education[11]. To address this problem we re-estimate the coefficients considering only those workers who have never changed city[12] during their working life, and therefore are not part of the sample of "attracted" workers[13]. On these people the characteristics of the city have not operated as elements of attraction, but only as characteristics shaping the local environment. These people are about one sixth of the total workers in 1980 and one seventh in 1990. Table 8 reports the estimates, including the state-dummies in the regressions.

Table 8

Only non-movers, 236 cities, Method of Estimation WLS

Std Error in Parenthesis

year	*1980*			*1990*		
Dependent Variable	α	β	γ	α	β	γ
Education	-0.09*	0.008***	0.037*	0.104	0.010	0.027
city	(0.05)	(0.002)	(0.019)	(0.09)	(0.007)	(0.065)
Experience	-0.01	0.002*	-0.01	0.001	0.001	0.01
city	(0.01)	(0.0011)	(0.007)	(0.03)	(0.002)	(0.02)
Log(Empl.)	0.024*	0.0006	0.0007	0.08***	-0.002	-0.02
city	(0.014)	(0.0009)	(0.006)	(0.034)	(0.002)	(0.02)
State-Dummies	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.32	0.26	0.31	0.24	0.19	0.20

Metropolitan area Data Book (1991).

[11] What we are testing here is that people who have always worked in the city are not different from people attracted into the city as far as unobservable characteristics are concerned. Our proposed explanation in section 5 relies on attracting workers, but what makes them more productive at high educational levels is the physical capital with which they work. This will have the same effect also on people already in the city.

[12] Actually these workers have always remained at the same address in their working life

[13] These are workers whose potential experience is shorter than the period of time passed since they moved at the current address.

The effects on people who have always resided in the city is encouragingly similar to those on the whole population. In particular the beneficial effect of human capital on the productivity of education skills and of total employment on productivity of raw labor, seem confirmed. Also, notice that the experience premium is now positively affected or non affected by the average level of education and experience in the city. As the non-movers are people who have been exposed for the longest time to the city- characteristics we expect the strongest effect of learning externalities on these people. It is reasonable, therefore, that for those people, the benefit of having more experienced and educated co-workers in the city, who generates strong learning externalities, balances the negative effect of increased supply of experience on the prices of experience skills, found for the population as a whole.

The second important issue is to distinguish between the effect of average human capital in a city and the effect on productivity of a host of local factors that may be correlated with the average level of human capital. City infrastructures, city traditions, city natural resources could affect productivity of skills and be related with the level of human capital. The best way I know to take care of city-specific fixed effects is to consider differences, rather than levels in the variables. In this way any fixed (or highly persistent) local characteristics that affects productivity of labor is removed. The problem in so doing is that we might be eliminating also "good variation" of the dependent variable. It may be the case that part of the city fixed effects in productivity of workers that we eliminate is genuinely due to differences in average human capital. Moreover, if the level of human capital of a city has an effect only with some lag on the productivity of factors we may miss such an effect. This procedure therefore can be regarded as extremely conservative against the hypothesis of local effects of average human capital.

It is therefore a very strong result that even the differences between the estimates of β in 1990 and in 1980, after including regional dummies[14] are very strongly positively affected by the differences in average education at the city level. The effect of average education on productivity

[14] I include four dummies: Mid-West, South, Mountain, West, leaving East out.

of education skills is the only one which remain significant in the regression in differences, the effect of employment on the return of raw labor is still positive but not significant any more.

Table 9

Regression in Differences. Method of estimation WLS,

weights = averages of std deviation of the estimates of α, β, γ.

Std Errors in Parenthesis

Dependent Variable	$a_{90} - a_{80}$	$b_{90} - b_{80}$	$g_{90} - g_{80}$
$(\text{Education-City})_{90}$-	-0.14	0.017***	-0.05
$(\text{Education-City})_{80}$	(0.09)	(0.005)	(0.03)
$(\text{Experience-City})_{90}$-	-0.24	0.007	0.03
$(\text{Experience-City})_{80}$	(0.49)	(0.03)	(0.14)
$(\log(\text{Empl.-City})_{90}$-	0.038	0.003	-0.04
$(\log(\text{Empl-City})_{80}$	(0.08)	(0.005)	(0.06)
Regional Dummies	Yes	Yes	Yes
R^2	0.14	0.08	0.09

The point estimate of the effect of education on β has strongly increased. This shows that the positive effect of average human capital on the productivity of skills operates within a relatively short period of time. Already in a 10 years span the beneficial effect of increased average education on productivity of educational skills is very strong. In a period as the 80's in which technological progress is deeply changing the productive structure, local environment in which average education increases are those in which education premium increases most. Again this may be the sign of directed endogenous technological change, which is more complementary to education where education increases most.

4.4 A Closer Look at Learning Externalities

In the previous section we have tried to capture the learning "dynamic" externalities using a measure that can be considered as a "projection" in an instant of time of that dynamic process. The experience premium captures the difference in wage between workers with different experience, mirroring the process of dynamic accumulation[15]. In this section we want to exploit the time component of our data to analyze learning externalities. From the previous analysis we have not found strong evidence of such externalities, or better we have not found that learning is affected by the average level of human capital in a city. If some externalities are present they merely counterbalance the effect of larger supply of skills and leave no significant positive effect on the compensation of experience skills. Another way of measuring the accumulation of experience skills is by taking a cohort in a city in 1980 and the same cohort 10 years later, and see how the logarithm of its real wage has changed. As most of the increase in wage due to experience is realized in the first 10 years of work we consider the cohort with 0-10 years of experience in 1980 and the same cohort, with 10-20 years of experience in 1990. To make the comparison cleaner we only include in our sample, for 1990, the workers who did not move in or out of the city during the last 10 years. The 10-years experience premium calculated is the difference between the wage of the city-cohort in 1990, after we have controlled for the characteristics of the workers (education, race, sex and marital status) and the average wage of the city-cohort in 1980, always after having controlled for the same observables. In order to see if local environment affects learning we have regressed this measure on the average education, average experience, the industrial, ethnic and linguistic diversity of the city in 1980. The indices of non-diversity used are Herfindal concentration indices, of sector composition, ethnic composition and linguistic composition[16]. The reason we have included

[15] See Peri (1998b) for a model that analyzes the effects of local learning on experience premium.

[16] These indices are calculated as $\sum (sh_i)^2$ where (sh_i) is the share of employment in an industry, in an ethnic group or in a linguistic group. As linguistic groups we have used the indication of language spoken at home and we have identified 20 linguistic groups.

economic diversity indices is because a more diversified local environment may enrich learning from on the job experience. On the other hand a less culturally uniform environment may harm communication and reduce learning.

The regression also includes the initial level of wage of the city-cohort, as mobility across cities in 10 years may generate convergence of wages. Table 9 reports the results. As we can see there is no strong evidence of positive local learning externalities of human capital, although now the coefficient on average experience and average education are positive. Similarly non-diversity do not seem to harm significantly the accumulation of skills[17], although economic diversity has a positive coefficient, while ethnic and linguistic diversity have negative coefficients.

Table 9

Experience Premium of the youngest 10 years cohort

Std. errors in parenthesis

Dependent Variable	D*wage(city-cohort)*
Education- City 1980	0.06
	(0.06)
Experience - City 1980	0.018
	(0.018)
Wage Cohort 1980	-0.93***
	(0.08)
Non-Diversity, Industries 1980	-0.02
	(0.04)
Non-Diversity, Race 1980	0.06
	(0.2)
Non-Diversity, Language 1980	0.16
	(0.26)

[17] It may be the case that non-diversity has an effect on growth of employment rather than on growth of productivity. Due to long-run mobility of labor the advantages of "Jacobs' tipe" externalities are shown in employment rather than productivity growth (as in Glaeser et al, 1992 and Henderson, Kuncoro, Turner, 1995)

4.5 Are Exogenous human capital shock driving the correlation?

We have strongly documented both in levels and changes, controlling for geographical determinants and industry-characteristics the positive and strong correlation between the average level of education in a city and the return to educational skills. Even quantitatively the effect is very significant. Taking a median value in the range of the estimates, we may say that an increase in one year in average education in a city increases by 0.6% a year the experience premium. This means that comparing two otherwise identical cities, in the one with one more year of average education, assuming that labor without any skills is paid the same wage in both cities, high school graduate will earn 8.4% more and college graduate 10.8% more than in the other city. We have not established with this, though, any channel of causation as any econometrician will tell us. In this section we will see that, at least with the instruments we have, there is no support to the idea that is an exogenous change in education in a city, which will trigger higher productivity of more educated. We will tell our story, in which we try to reconcile all the pieces of evidence, in the next section.

Here, we just want to prove that, taking an instrument that will predict the change of average education and experience in cities, but is exogenous to other city-shocks that may have affected productivity in the period 1980-1990, we do not find any correlation between the change of average education and the change in productivity of skills. The instrument we use are the demographic and ethnic structure of a city in 1980. In particular the share of labor force in each 5-years experience cohort, and the share of each of six races (White, Hispanic, Black, Asian, Native, Pacific) in the labor force. Without inter-city mobility experience cohort in 1980 should be a very good predictor of average experience in 1990 (the oldest cohort will disappear and two new cohort will enter, but the rest will just have 10 more years of experience) and similarly for education. Also the ethnic structure of a city is a predictor of its level of education and experience as different ethnic groups display differences in average age and education. These variables, in fact, explain around 35% of the change in education and 40% of the variation in experience across cities. Moreover, as they are based on values in 1980 they are not affected by other shocks that may have affected productivity in the decade 1980-1990. We continue to use the geographic and recreational indices as instruments for the employment growth.

As shown in Table 10, the effect of average education on β has completely vanished. The hypothesis that an exogenous change in average education is the cause of the increased productivity of educated does not hold to the test of the data.

Table 10

Method of Estimation: Instrumental Variables

Std Error in Parenthesis

Dependent Variable	a_{90} - a_{80}	b_{90} - b_{80}	g_{90} - g_{80}
(Education-City)$_{90}$-(Education-City)$_{80}$	0.08	0.0004	-0.065
	(0.18)	(0.012)	(0.076)
(Experience-City)$_{90}$-(Experience-City)$_{80}$	0.006	-0.0003	-0.007
	(0.01)	(0.001)	(0.007)
(log(Empl.-City)$_{90}$-(log(Empl-City)$_{80}$	0.0005	-0.0003	-0.08
	(0.20)	(0.018)	(0.11)
Regional Dummies	Yes	Yes	Yes
R^2	0.11	0.04	0.09

5. A proposed Explanation

Most of the regressions presented have shown a significant correlation between average level of education in a city and the return to educational skills. The other effects seem to be less significant or only occasionally so. We will concentrate on this effect therefore, aware that the test to establish a causation direction, from human capital to productivity has not produced positive results. In order to understand our results I apply to space an idea developed by Acemoglu (1998) and supported by stylized facts. As Katz and Murphy (1992) document for the U.S. market as a whole in the period 1963-87 "the group with largest increase in relative supplies tended to have the largest increase in relative wages". As technologies and physical capital incorporating it, are not complementary to skills by “nature, but by “design”, Acemoglou (1998) argues that in periods of high supply of some skills research has been directed towards skill-complementary techniques. This has generated an increased productivity of those workers. The results that I obtain may suggest that cities whose workers have higher education may induce (or attract) firms to invest in skill-complementary technologies. This may increase the premium for skills and in turn attract more educated people. Borjas, Bronars and Trejo (1992) document that high skilled workers tend to migrate to areas where skills are abundant and skill premia are higher.

In particular in the 80’s some cities may have been hit differentially by the technological shock and in cities with good perspective for having or attracting a large pool of educated people, the innovation might have been directed towards skill-complementary technologies which have increased both the education premium and the average level of human capital in the city. If cities are the dynamic centers of innovation (Jacobs, 1969, Jaffe, Trajtemberg, Henderson, 1993) and innovation and investment are also determined by local pressures, we may expect interesting interactions (and therefore endogeneity) between the qualities of local workers and the technology chosen or developed.

The bottom-line of this story is that the effect that we have detected in the data does not necessarily call for the operating of an externality. Nevertheless the self-reinforcing linkage between human capital, skill-complementary technologies and returns to human capital (arising from increasing returns in accumulation of physical and human capital in the Acemoglou, 1996 model) may generate a positive effect on productivity of local workers and an “attraction effect” on skilled workers.

6. Conclusions

Recent theoretical models (Martin and Ottaviano, 1996, Baldwin, Martin and Ottaviano, 1997) relate geography to innovation and growth, claiming local externalities as the prime engine to phenomena of agglomeration and innovation. Acemoglou (1996) and (1998) investigates in two theoretical models the self-reinforcing role of investment and innovation on accumulation of human capital. Under imperfect matching between workers and firms this generates increasing return for physical and human capital. The present empirical paper offers evidence that can be rationalized by a simple idea, contained in those models. Local conditions, and in particular the characteristics of the local pool of workers, into which a firm will draw, may affect the type of machines bought as investments and the technology adopted. As there are some machines that complement skills while other substitute them, in cities which are abundant of skills, investment in skill-complementary capital will prevail, and it will increase the productivity of the highly educated workers. This will stimulate more investment in human capital and/or attract the more educated from other cities. In the 80's some cities seem to have experienced high growth in productivity of skills and in their supply, in a self reinforcing mechanism, probably generated by technological innovation.

Our story implies that cities may benefit greatly from an educated labor force as it will direct investment and innovation towards complementing high skills, attracting other educated people with all the social benefits that this implies. On the other hand, if the story is true this mechanism may generate a spatial sorting of skill that may increase disparities. The spatial analysis may add an extremely interesting and enriching dimension to the analysis of skill-biased technological progress.

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Appendix

Industries Identified in the data-set:

Construction, Mining, Food Processing, Textiles, Paper, Chemicals, Petroleum, Rubber, Leather, Lumber, Stone, Metal, Machinery, Electric Machinery, Equipment, Precision Instruments, Other Manufacturing, Utilities, Wholesale Trade, Retail Trade, FIRE, Repair Services, Personal Services, Entertainment Services, Health services, Legal Services, Teaching, Social Services, Other services, Public Sector.