AGGLOMERATION ECONOMIES AND URBAN PRODUCTIVITY: THE CASE OF THE HIGH-TECH INDUSTRY IN THE MILAN METROPOLITAN AREA

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1. Introduction

A large consensus exists among urban and regional economists on the importance of agglomeration economies in defining urban productivity and growth. Uneven urban growth is interpreted as the result of different factor productivity levels which, on their turn, are mostly influenced by city size, i.e. by the size of the market. Born within the original contributions of Marshall (1919) and Weber (1929), who were the first to signal the existence of location economies and external advantages in spatially clustered production, the theoretical debate has expanded around the reasons for the existence of production agglomerations, directly and indirectly embedded in the works of geographers like Christaller (1933), economists like Lösch (1954), Hotelling (1929), Isard (1956) Myrdal (1957), Kaldor (1970) and more recently Mills (1970 and 1993), Henderson (1985), just to quote some of them. However, the emerging limits in the explanation of production agglomeration in these theories have moved the debate towards the concept of urbanisation economies, mentioned for the first time in the work of Hoover (1937).

Adam Smith proposed for the first time the idea that productivity increases with the scale of production because increased scale allows firms and workers to specialise in specific tasks, and specialisation and division of labour increases productivity. The ability to exploit these economies of scale depends on the size of the market. The use of this well known concept to urban economies is quite simple: to the extent that the size of the market depends on population density, and is limited by transport costs, the ability to exploit economies of scale depends on city size.

The existence of agglomeration economies explains why larger cities are characterised by higher rents and higher wages. Firms located in larger cities can pay for higher rents and higher wages because of higher factor productivity, and individuals accept to live in larger cities because they are compensated for the negative external costs of a large city and for the higher rents by higher wages. In the mainstream of the neoclassical location theory, the intra and inter urban residential location is determined by an equilibrium solution, when both firms and individuals achieve a location indifference by having negative location costs compensated for by positive advantages of that location, and equal to any other possible location.

Alternatively, the ability to pay higher rents and wages by firms located in larger cities may depend on externalities associated with agglomeration of specific activities in one place: in this case, the industry size, and not the city size, is the explanation for higher factor productivity. Industrial specialisation allows for greater input and output markets, and for more efficient local input-output relationships. This idea dates back to Marshall, who was the first to signal the presence of an "industrial atmosphere" in highly specialised areas; by this term he was underlining the existence of positive externalities stemming from the presence in a specific place of a high number of firms belonging to the same industry. This concept has been developed by other economists, like Weber (1929) and Hoover (1937), who signalled the importance of industry scale in production agglomeration.

A large debate exists on whether the advantages of scale relate primarily to increases in the scale of activity in a particular industry, with all benefits accruing primarily to that industry (location economies), or whether they relate more generally to the overall scale of activity in an area, thereby affecting the productivity of all firms (urbanisation economies). In dynamic terms, this question has been put forward by a recent stream of literature related to industrial economists, who debate over the question whether specialised or diversified knowledge spillovers can better explain innovation activities and technological change in spatially concentrated production systems (Feldman and Audretch, 1999).

It has been argued that industry scale effects are not fundamentally different from city size effects; they are just more specialised and confer benefits primarily on firms within a single industry (Satterthwaite, 1992). The issue of whether urban productivity is associated with city size or industry size has instead important implications: as suggested by Sveikauskas et al. (1988), if productivity is associated with city size, efficiency in production suggests that most production should be concentrated in the largest cities. On the other hand, if greater productivity stems from industry size, then a process of decentralisation, in which particular industries agglomerate in particular locations, is feasible.

The interest in this debate stems from the spatial development patterns witnessed by the high-tech industry in the metropolitan area of Milan. Despite the common idea of the eighties that the high-tech industry is a footloose industry with respect to traditional location factors, the empirical analysis run on census data shows specific location trends of this industry which can be summarised as: a) a tendency towards central locations; b) a tendency towards the reinforcement of previous location choices. This behavioural pattern can be explained by two different logics: a) the interest of firms in exploiting location economies, provided by physical proximity to firms of the same sector, by an industrial atmosphere, and by knowledge externalities stemming from a cluster of specialised small and medium sized firms; b) the interest in exploiting urbanisation economies, which are typical advantages of a central and metropolitan location.

The purpose of this paper is to measure the extent to which location economies rather than urbanisation economies influence factor productivity in the case of the high-tech industry in the metropolitan area of Milan. The empirical exercise is not new in the literature. A number of studies examining the relationship between productivity levels and the scale of production in cities conclude that localisation economies tend to dominate. This conclusion is supported by the tendency for cities to specialise in the production of specific goods (Henderson, 1985) and by evidence from studies of the relationship between industrial clustering and employment growth (Satterthwaite, 1992; hUallacháin, 1992; McDonald, 1992). Our results from the Milan case do not support the "specialisation" hypothesis, and on the contrary show an important role played by a more diversified industrial structure on factor productivity of firms.

In Section 2 we introduce the main theories alternatively favoring location or urbanisation economies in influencing urban productivity. Section 3 presents the spatial development patterns of the high-tech industry in the metropolitan area of Milan. Issues concerning the measurement of urbanisation and location economies are examined in Section 4. Our empirical analysis aims at testing whether these location factors have an impact on the productivity of firms. In doing so, it is first necessary to estimate factor productivity in our firms. This is accomplished in Section 5. These estimates are then employed in the second part of the empirical analysis (Section 6), as dependent variables in multiple cross-section regression models designed to capture whether location or urbanisation economies can explain factor productivity more. Some concluding remarks are presented in Section 7.

2. Urbanisation versus Location Economies

Agglomeration economies have always been interpreted as the economic explanation of efficiency in urban production. The idea that productivity and growth are related to the scale of production is not new - it dates back at least since the time of Adam Smith - nor it is specific to the study of urban economies. In particular, the concept of location economies, i.e. the external advantages associated to a single industry, dates back to the work of Weber (1929), and its refinements and improvements in the field of location theory to the works of Hoover (1937 and 1948), Lösch (1954), Isard (1956), Koopmans (1957) Jacobs (1969) and Bos (1965), just to quote some of them.

According to these theories, the existence of production agglomeration stems from the existence of economies of scale in large scale production within the same production unit (economies of scale) or among different production units (location economies). Efficiency of production agglomeration is thus justified within a logic of production indivisibilities.

Some authors have given a different interpretation to the existence of location economies, which stem from market indivisibilities rather than from production indivisibilities (Christaller, 1933; Lösch, 1954). The central place theory of Christaller and Lösch's refinements are directly concerned with urban hierarchy, interpreted through a spatial division of labour between small and large cities. In their theory, an industry oriented towards a local market will not appear in the market until the maximum distance at which the good can be sold (its "range"), is greater than the distance (or area) which corresponds to the minimum quantity of good produced under efficiency rules (its "threshold"). The concept of threshold is that of market (or goods distribution) indivisibility: a good is produced within a local market if its distribution costs, expressed in terms of transportation costs, do not exceed its efficiency production levels. According to Lausén (1973), market indivisibilities are, under certain circumstances, more useful than production indivisibilities in the explaination of location economies and production agglomeration.

In both cases of production and market indivisibilities, the economic efficiency of production agglomeration is interpreted in an intra-industry logic. Increasing returns to scale in firms' activities belonging to the same industry dates back to Weber's work. This approach has extensively been developed in the keynesian theoretical approach of Myrdal (1959) and Kaldor (1970). In their works, increasing returns to scale explain the process of cumulative and self-reinforcing development, due to a strong positive relationship between production scale and productivity growth. Kaldor defines agglomeration economies as:

"....... nothing else but the existence of increasing returns to scale - using that term in the broadest sense - in processing activities. These are not just the economies of large-scale production, commonly considered, but the cumulative advantages accruing from the growth of the industry itself - the development of skill and know-how; ...." (Kaldor, 1970, quoted in Beeson, 1992).

A vast empirical evidence exists on the role played by industry size on firms' productivity[1]. In the work of Shefer (1973), economies of scale are measured through the estimate of a CES production function in 10 manufacturing industries located in urban areas. Carlino (1980) has divided the same index used by Shefer into three components: economies of scale at the firm level, at the industry level and at the urban level, and his findings reveal the importance of external economies of agglomeration - especially urbanisation economies - as a contributor to total economies of scale in metropolitan manufacturing.

As mentioned already, one of the main explanation for the existence of location economies is production indivisibility at the industry level: input-output relationships explain spatial agglomeration since they act on production costs (in the form of lower input prices) and on transaction costs (in the form of lower commercial risks). However, this is true only if these theories demonstrate that the greater efficiency of input-output relationships takes place only in limited geographical distances (Costa, 1978). Relatively non mobile input suppliers or output buyers are necessary to transform inter-firms linkages into an agglomerative factor. If this may be true for specific (ricardian) goods, it is less valid for services and information exchange, which usually characterise an urban agglomeration.

One of the main critics to location economies in the explanation of urban agglomeration is that restricting external advantages to occur only within the industry may ignore an important source of externality, typical of urban areas: the diversity of industries present in the urban area, which can become an important source of knowledge spillover (Jacobs, 1969), and in general of external advantages. The industrial mix and the possible inter-industry relationships are the primary source of urban productivity. In this respect, Chinitz (1961) argues that external economies are greater in cities which are industrially diversified, such as New York, than in cities which are dominated by a single oligopolistic industry, such as Pittsburgh. Cities specialised in a few industries and dominated by large plants are likely to be deficient in various auxiliary business services. These are needed mostly by small and new firms since the dominant firms are large enough to internalise them. Chinitz refers to the importance of industrial organisation, rather than to scale effects, for the definition of external advantages.

Hoover (1937) was the first to distinguish between location and urbanisation economies: the former stem from economies external to the firm and internal to the industry, the latter by economies external to the industry and internal to the city. If location economies are economies of scale emerging from the size of the industry, the latter emerge from the size of the market in which the firm operates, i.e. the size of the city.

A large consensus exists on the idea that larger cities are more productive. There is also considerable empirical evidence that productivity levels increase with city size[2]. Sveikauskas (1975) ha estimated that manufacturing labour productivity increases by 6.4% every time the city doubles in size. Moomaw (1983) achieves the same conclusions: every time a city doubles in size, labour productivity increases by 6% in manufacturing industries. Many are the reasons for this phenomenon, and in particular many are the elements which characterise urbanisation economies: a) economies of scale stemming from production and use of public goods and services, b) economies of scale stemming from the size of the urban market: quality of the labour market, a large market for final goods, existence of different possibilities of market niches; c) economies stemming from the role of the city as incubator of production factors and input market: large and diversified labour market,

[1] For a review, see Capello, 1998.

[2] See, for example, Henderson, 1974; Kamashima, 1975; Segal, 1976; Marelli, 1981; Ladd, 1992; Catin, 1992; Rousseaux and Proud'homme, 1992; Rousseaux, 1995; Capello, 1998.

accessibility to highly specialised and qualified urban functions (i.e. qualified production services), accessibility to information and communication.

It is easy to understand that urbanisation economies depend to a large extent on the possibility to overcome indivisibilities: indivisibilities in the production of public goods, in the supply of advanced and qualified production services, in the achievement of a market for differenciated goods. As in the case of location economies, urbanisation economies also stem from the important role that urbanisation economies play in reducing transaction costs (Cappellin, 1988): accessibility to information, to qualified services, to advanced urban functions, which reduce the costs of market transactions.

In the recent neoclassical location theory, the general equilibrium model of residential and industrial activities among cities requires the introduction of urbanisation economies in an explicit way. In the model, individuals are compensated for the higher rents paid in large cities by higher wages and firms can pay for higher rents and higher wages only if greater advantages are provided by a location in a large city, which compensate firms for the disamenities and for higher factor costs (rents and labour) of large cities. Without the explicit admission of the existence of urban external economies, the model would not achieve an equilibrium solution: firms and individuals would change their location choice in favour of less costly locations (Fujita, 1985).

These models represent a very stimulating and advanced theoretical framework, enriched by rather solid mathematical modeling. However, an unrealistic result emerges from this analysis, stemming from the necessary hypotheses imposed to the model: under the hypotheses of equal level of utility for all individuals and equal production functions for all cities, the model determines a system of cities, all of the same size (Camagni, 1993). A way of overcoming this result is the introduction of the hypothesis of different urban specialisation patterns, reflected in different urban production functions. In this case, each good would be produced in a number of specialised cities, the number depending on the final demand; the size of cities would be determined by the importance of scale effects in production (Henderson, 1974, 1985 and 1996). Interestingly enough, this approach requires to go back to industrial specialisation and thus to location economies to explain urban productivity.

This short overview of the reasons in favour of urbanisation and location economies shows that a valid and strong support exists for both concepts and for their possible effects. This work provides an additional attempt to measure their importance on factor productivity, through an empirical analysis carried out in the metropolitan area of Milan.

3. Spatial Development Patterns of the High-Tech Industry in the Metropolitan Area of Milan

The analysis on the industrial specialisation of the region Lombardy and of the metropolitan area of Milan highlights the presence of a high share of high-tech industry with respect to the national level. This phenomenon characterises the Lombardy region, and is more emphasised in the metropolitan area of Milan. The spatial development patterns of the high-tech industry are presented on the basis of census data in 1981 and 1991, highlighting the differences which emerge in these two periods.

The problem of the definition of the high-tech industry is not new. Many studies have already tried to identify objective criteria to isolate high-tech sectors from the other traditional industrial sectors. Some of the approaches present in the literature use, as a proxy for high-tech capacity, some indicators as:

- high R&D expenditure;
- considerable share of highly qualified labour forces, such as researchers, engineers, technicians;
- rapid growth in sales, output and employment (Glasmeier, Hall and Markusen 1983).

However, none of these indicators is fully satisfactory for the definition of high-tech industries and all have the problem of being hardly measurable.

Another method to define high-tech sectors, more subjective in its nature, but at the same time more operative, is to analyse the nature of firms output. Following this criterion, it is possible to assume that high-tech sectors are those sectors whose products are "core products inside the dominant technological paradigm, that of information technologies" (Camagni and Rabellotti, 1988). This criterion is the one applied in this study to define the high-tech industry. In Table 1 we present the categories of industries as they appear in the Industrial Census, which we included in the high-tech industry, divided between manufacturing and service industry.

Table 1: Detailed Census classes forming High-Tech Sector

High-Tech Industry
Office machines, computers and data-processing production
Communications equipments and radio-TV appliances production
Medical, precision, optical instruments and watches production
High-Tech Services
Computers and data-processing services
R & D activities

The analysis on the location patterns of the high-tech industry is run for three different levels of territorial aggregation, namely (Capello and Faggian, 1998):

- *a macro level*, i.e. the region Lombardy. At this level the study presents the spatial development patterns of the high-tech industry in the eleven provinces of the region Lombardy;
- *a meso level*, i.e. the province of Milan which represents the statistical basis for the analysis on the metropolitan area of Milan. At this level, the study shows the location patterns in the different municipalities representing the metropolitan area;
- *a micro level*, i.e. the municipality of Milan. At this level, the location patterns of the high-tech industries are studied for the twenty different areas in which the national statistical office divides the municipality.

3.1 The macro level: location patterns of high-tech in the provinces of the region Lombardy

Within the region Lombardy, great difference exists in the location of high-tech industries among provinces. As Figure 1 shows, in 1992 the highest share of high-tech industry is located in the area of Milan, followed by the South-Eastern part of the region and the Como area. On the contrary, the Eastern part of the region has a very limited concentration of high-tech firms. If this data is compared with the 1981 data, an interesting result emerges: the province of Milan shows the most pronounced decrease in the share of high-tech. However, even with this decrease, it still remains the area with the highest share of high tech firms (Figure 2).

A high regional diversification exists in the location patterns of high-tech industry, which may suggest a tendency of high-tech industry to locate in metropolitan areas. For this reason, the share of high-tech industry has been calculated for the 14 most important metropolitan areas in Italy. As Figure 3 shows, however, also at the metropolitan level there is a great difference in the location patterns of high-tech industries, Milan playing the leading role also in this respect.

Among the 14 metropolitan areas, common spatial patterns can be identified regarding:

- the largest metropolitan areas, like Milan, Turin and Rome, showing a decrease in the share of high-tech;
- metropolitan areas located in "local district regions", or Third Italy regions, like Bologna, Trieste, Florenz, witnessing an increase in the share of high-tech;
- a contrasting development pattern in the Southern metropolitan areas: Cagliari, Messina, Naples and Bari show an increase, while Palermo and Messina register a decrease.

3.2. The meso level: location patterns of high-tech in the municipalities of the metropolitan area of Milan

Even from this analysis, the metropolitan area of Milan emerges as the most attracting location for high-tech industry. Within its metropolitan area, there is a clear tendency towards central locations, which reinforces during the decade 1981-1992, as witnessed by Figures 4 and 5. In particular, by analysing in details the two figures, the following tendencies in the location patterns of high-tech firms between 1981 and 1992 emerge:

- a concentration in the core areas, witnessed by an increase of the share of high-tech firms located in the core of Milan and by the constant presence near Monza (the first most important city after Milan in the area) of a high share of high-tech firms;
- an edge-city development around Milan, especially in the North and North-Eastern part of the town, in line with the decentralisation tendency of the residential and industrial activities in the area (Camagni, 1995);
- an increasing location pattern along the main North-Eastern axis, characterised by the presence of motorways, a ring motorway connecting them, and two underground lines connecting the area with the city centre of Milan.

3.3. The micro level: location patterns of high-tech in the municipality of Milan

Figure 6 shows the location of high-tech firms within the core area of Milan, divided into twenty different "statistical areas". At this spatial level of analysis, the main result is the location of high-tech firms in the North-Western and North-Eastern part of Milan, this latter being the starting point of the North-Eastern axis at the metropolitan level. These results support a qualitative analysis run ten years ago in the same area (Camagni and Rabellotti, 1988), which was envisaging the existence of a "Milan Innovation Field (MIF)" in the North-Eastern part of the town thanks to the high density of high-tech firms. Also the South-Western part of the town seems to be an interesting location for high-tech firms, more than central or Southern parts of the town, the former being the natural location of advanced tertiary activities, the latter being traditionally a more agricultural area (Table 2).

Table 2. The metropolitan area of Milan

	Metropolitan area of Milan	Metropolitan area/ Lombardy	Metropolitan area/ Italy	Lombardy/ Italy
Population	3922710	44,12	6,94	15,72
Square km	2762,89	11,58	0,92	7,92
Agriculture	**1305**	**14,43**	**1,29**	**8,95**
High tech industry:	**64376**	**72,91**	**22,73**	**31,17**
* Computer and office equipments	8241	82,42	32,24	39,11
* Radio and TLC equipments	35720	81,23	25,53	31,43
* Medical, measur. and optical equip.	20415	59,48	17,34	29,14
Traditional manufacturing industry	**633347**	**40,10**	**9,74**	**24,29**
Advanced services:	**409656**	**62,20**	**12,84**	**20,64**
* Transport sector	98022	56,91	8,75	15,37
* Monetary and financial services	90500	66,17	15,89	24,01
* Real estate	12394	52,12	14,90	28,58
* Computer services	31910	70,67	17,63	24,95
* Legal services	46610	63,60	14,83	23,32
* Services to firms	125699	62,48	14,31	22,90
* R&D activities	4521	73,07	10,40	14,24

Source: National Census, 1991

The spatial location of R&D activities, available at the metropolitan level, witnesses again a tendency towards concentration. The core area of Milan emerges as the main location of R&D activities in both 1981 and 1992, apart from some small areas where the presence of a high share of high-tech firms and the low employment level may explain the high intensity of R&D activities (Figures 7 and 8). In 1992 the choice of the core of Milan is confirmed, with a greater presence of R&D activity towards the axis between Milan and Monza (Figure 8), the same axis which emerges as one of the most preferred location area of high-tech firms.

4. Measurement Issues: the Sample Choice and the Indices

In the literature different econometric studies have been carried out with the aim to estimate changes in factor productivity due to industry or city size. In this paper, we start from a rather different perspective; we accept the idea that urbanisation and location economies exist, and we rely on the possibility to create a direct measure of them in terms of indicators. Once these indicators are built, they are used to estimate their interpretative power on factor productivity.

The unit of analysis is the firm, rather then the industry of the city as a whole. In particular, we collected information for a sample of 66 firms, belonging to the high-tech industry, and located in a specific area of the city of Milan, the North-Eastern part.

Table 3. A Taxonomy of Location and Urbanisation Economies

	Location economies	Urbanisation economies

Static elements	Accessibility to: - a highly specialised labour market - a high number of firms of the same industry - specialised suppliers	Accessibility to: - a diversified and large market for the final good - a diversified and large market of inputs - a diversified and qualified labour market - a scientific environment (universities and research centres) - a wide range of information
Dynamic elements	Accessibility to specialised knowledge spillovers	Accessibility to diversified knowledge spillovers

A random sample has been selected, with the aim to collect information on the importance of particular location factors, related either to industry or to city size. Table 3 presents a taxonomy of these location factors, and divides them between static and dynamic elements. The former are the traditional agglomeration advantages, stemming from accessibility to specialised suppliers and customers, to a specialised and qualified labour market, to an industrial atmosphere à la Marshall; the latter stem from the existence of a diversified industrial structure, which provides access to a diversified and qualified labour market, to a large and qualified input market, and to a wide and articulated market for final goods.

In dynamic terms, agglomeration advantages are represented by the accessibility to local knowledge which cumulates over time in the area; R&D and knowledge spillovers not only generate externalities, but the evidence also suggests that such knowledge spillovers tend to be geographically bounded within the region where the new economic knowledge was created. Lucas (1993) argues that the only compelling reason for the existence of cities would be the presence of increasing returns to agglomeration of resources which make these locations more productive. The increasing returns to agglomeration of resources can be the result of Marshall - Arrow - Romer externalities, i.e. the results of increased concentration of a particular industry within a specific geographic location which facilitates knowledge spillovers across firms (Glaeser et al., 1992). However, increasing returns to agglomeration of resources can stem from the exchange of complementary knowledge across diverse firms and economic agents, and the diversity of these knowledge sources is greatest in cities (Jacobs, 1969).

In order to build indices of the existence of these externalities and of their importance for local firms, a direct questionnaire has been submitted to firms, with the aim to understand the degree of importance attributed to each possible source of agglomeration advantages in the location choice of local firms. Appendix 1 describes how data on location and urbanisation advantages, estimated by using multiple scales in the questionnaire, are transformed into indicators. The indicators available in the analysis are summarised in Table 3.

Table 3. Indices of Location and Urbanisation Economies

	Location economies	**Urbanisation economies**
Static elements	• Importance attributed to a *highly specialised labour market* in their location choice. • Importance attributed to a *high number of firms of the same industry* in their location	• Importance attributed to a *diversified and large market for the final good* in their location choice. • Importance attributed to *a diversified and large market of inputs* in their location

	choice. • Importance attributed to *specialised suppliers* in their location choice. • Importance of cooperation with other local firms (suppliers and customers) based on non-market rules (i.e. informal contracts).	choice. • Importance attributed to *a scientific environment* in their location choice. • Importance attributed to the presence of transport infrastructures (airport and highways) to their location choice. • Importance of cooperation with other local firms (suppliers and customers) based on market rules (i.e. formal contracts).
Dynamic elements	• Importance attributed to *a high turnover of the labour force* in their location choice. • Importance attributed to *spill-over mechanisms* in their location choice.	• Importance attributed to *an increasing qualified and diversified labour market, highly mobile within the area.*

Once these indices have been built, they are introduced as explanatory variables in the multiple regression models. The first step of the empirical exercise is thus to measure factor productivity for the firms' sample, and this is the subject matter of the next Section.

4. Factor Productivity Estimates: the Model and the Results

Factor productivity is measured in this paper by estimating a trans-log production function, which contrary to the Cobb-Douglas production function, allows to estimate second order variables and cross-variable effects[3] (Christensen et al., 1973). Our firm production function thus becomes:

$$\ln Y = \ln h + a \ln K + b \ln L + c\,\frac{1}{2}\ln K^{2} + d\,\frac{1}{2}\ln L^{2} + f\,\ln K \ln L \qquad (1)$$

where Y is the firms' outcome, K and L are respectively capital and labour. This kind of function allows the direct estimate of outcome elasticity with respect to all input variables, capital and labour, that is the percentage outcome changes due to a 1 percent change of a specific determinant, being other things equal. In order to test whether the change in the capital has increased or decreased firms' outcome (*coeteris paribus*) it is enough to calculate the following expression and to test the sign of e_K:

$$e_K = a + c \ln K + f \ln L \qquad (2)$$

[3] A large debate exists around the necessity to impose restrictions on parameters of production functions, so that they are able to approximate the stylised facts of economic behaviour that neoclassical economists generally agree characterise the real world (Chambers, 1988). On the production function, these restrictions regard:

- monotonicity (and strict monotonicity) of the production function;
- quasi-concavity (and concavity) of the production function;
- weak essentiality (strict essentiality);
- closed and non-empty input requirement set for all outputs;
- the production function is finite, non-negative, real valued for all non-negative and finite inputs;
- the production function is everywhere twice-continounsly differentiable.

It has been underlined, however, that these restrictions have generally been rejected in econometric analyses (Evans and Heckman, 1984). The choice to impose these restrictions even if they have been rejected by empirical data, as is often the case, is not required by any direct comparison between our analysis and other studies where the restrictions have been imposed. Moreover, in our particular case the economic reasoning behind these analytical restrictions is difficult to be accepted a priori. Our production function is in fact a quasi-production function (where inputs are more than the conventional capital and labour inputs), representing an aggregate economic behaviour which may not immediately follow the same economic rules imposed by the neclassical individual firm's behaviour.

where e_K represents the outcome elasticity with respect to capital. At the same time, outcome elasticity with respect to labour is easy to be obtained, by calculating the following expression and test the sign of e_L:

$$e_L = b + d \ln L + f \ln K \qquad (3)$$

Moreover, thanks to equation 2 we can estimate how outcome elasticity with respect to capital changes in the presence of different quantities of capital, by simply calculating:

$$e_{KK} = c \qquad (4)$$

The same reasoning can be applied to outcome elasticity with respect to labour, and measures how outcome elasticity with respect to labour changes in the presence of different quantities of labour available, by calculating:

$$e_{LL} = d \qquad (5)$$

This methodology has been applied to our firms' sample. In particular, for the cross-section estimate of the production function all variables needed to be standardised for a scale element, in order to:

- eliminate the collinearity between capital and labour;
- eliminate the size effects due to the presence of variables in absolute terms.

In the literature, the most common variable chosen for such an exercise is labour. In our case, we decided to standardise all variables by the physical capital stock indicator, which represented, as expected, a high correlation with labour[4], and thus could easily be interpreted as a firm size variable.

With such a choice, we were able to keep both non-material capital stock and labour as independent variables, and measure factor productivities. In fact, the output level, measured in terms of turnover, is in this case a function of:

- *labour*, easily obtainable with the number of employees in each firm;
- *non-material capital stock* of firms, measured by the value of R&D expenses, licences, industrial awards and patents of each firm, available from the balance of sheets of firms[5].

Before presenting the results obtained, some cautious has to be reminded when data comes from the balance of sheet of firms. First, as company accounts are the only basis for company taxation in Italy, their contents partly dictated by tax rules and by fiscal "optimisation" (Signorini, 1994). Profitable firms will try to underestimate sales and over report expenses in order to reduce their tax burden. They may do so legally (by exploiting loopholes in the tax law) or otherwise. In any case, productivity and profits rates will be biased downwards. However, in the context of this paper, the only relevant distortion is one that would have different effects depending on firms' size or specialisation (industry or services). It is unclear why such a relative bias should exist, but the reader should be aware that tax avoidance will partly add noise to the data. Second, the accounting measure

[4] The Pearson correlation coefficient between the two variables assumes a value of 0.85. The physical capital stock is measured interms of monetary assessment of plants, mashines, industrial instruments, and in general all mashines used within the firm (like computers), obtained from the official balance of sheets available from the Chamber of Commerce.

[5] The author is greatful to the Chamber of Commerce in Milan for providing access to the official balance of sheets registered in 1996.

of capital sock (i.e. the monetary book value of fixed assets net of depreciation) is probably unreliable for any single firm, influenced as it is by tax rules (again) and possibly distorting accounting practices. This point is especially important for global productivity measures where capital is an input. Two remarks in this respect are needed: a) capital stock is not used as an input factor in our analysis, and instead applied in the process of eliminating the size effects; b) again, some distortions are irrelevant as long as they aply to all firms in the sample in a similar way. However, one cannot be sure that no large oscillations occur or that no systematic bias is present.

Despite these necessary attention while using such data, the results of the estimates obtained are interesting. They are first of all satisfactory from a statistical point of view. No restrictions are made on the parameters, and the good fitness of the estimate is witnessed by an R square equal to 0.47 and by an acceptable Durbin-Watson[6]. Table 4 contains the statistical results of the model. Interestingly enough, our firms show a decreasing marginal productivity for what concerns labour, and an increasing one for what concerns non-material capital. Our main aim in the analysis is in reality to understand the role of external advantages of firms' location on their productivity, and this is the subject matter of the next section.

Table 4. Results of the Econometric Estimation

	Coefficient	T-student
Labour productivity		
- in firms having the lowest level of labour	0.74	1.97
- in firms having an average level of labour	-0.002	-2.23
- in firms having the highest level of labour	-0.29	-2.00
	Coefficient	T-student
Non-material capital productivity		
- in firms having the lowest level of non-material capital	-0.40	-0.71
- in firms having an average level of non-material capital	0.26	2.17
- in firms having the highest level of non-material capital	0.54	1.65

R-square = 0.47
Durbin-Watson = 2.18
Total observations = 66
Usable observations = 60

5. The Evidence: the Role of Location and Urbanisation Economies on Factor Productivity

The estimates of factor productivity are in this part used as dependent variables in the multiple regression models presented here. In particular, the aim of this section is to measure the role that urbanisation and location economies play in the definition of labour and capital productivity. Table 5 presents the results for what concerns labour productivity. Interesting results emerge, namely:

- an important role played by the access to highways and international airoports in location choice, which represents a traditional urbanisation externality, is positively correlated with labour productivity, although, as expected, it has not the interpretative power to explain it (1' model);
- an important role played by the access to highways and international airoports in location choice, is positively correlated with labour productivity also when an indicator of location economies is

[6] All the results, as well as the programme, are available from the author upon request.

introduced. This latter, measured in terms of knowledge obtained by other firms via spin-off mechanisms, show, on the contrary, a negative correlation with labour productivity (2' model);

- in order to increase the interpretative power of the model, other variables are introduced, namely process innovations in the form of production process automation and externalisation of some functions (3' model). While the automation of some phases of the production is positively correlated with labour productivity, as logically expected, externalisation of some functions seems to provide a negative impulse to labour productivity, probably by imposing a requalification of employees previously responsible for different works. In any case, also this more interpretative model provides prima facie evidence that urbanisation and location economies are correlated with labour productivity, the former in a positive sense, the latter in a negative one.

Table 5. Role of location and urbanisation economies on labour productivity: results of regression estimates

	1' model	2' model	3' model
Constant	0.36 (6.79)	0.40 (8.9)	0.36 (5.14)
Importance of access to highways and international airoports for their location choice	0.11 (1.80)	0.10 (1.92)	0.11 (1.8)
Spin-off mechanisms		-0.17 (-1.95)	-0.33 (-3.39)
Process automation in the firm			0.11 (2.12)
Externalisation of some functions			-0.10 (-1.9)
R-square	0.05	0.12	0.41

Dependent variable: labour productivity

The same kind of analysis is run for non-material capital productivity, and again some interesting results emerge (Table 6):

- traditional urbanisation economies, measured in terms of importance of access to a wide and diversified output market for the location choice, are positively correlated with non-material capital productivity (1' model), although, as expected, they do not have any interpretative power;
- interestingly enough, also dynamic urbanisation economies, like the importance of the access to an increasingly qualified and diversified labour market in the location choice, plays a role in the definition of urbanisation economies, and is positively correlated;
- on the contrary, all indices representing location economies, do not enter the analysis, witnessing no correlation with capital productivity. Moreover, an explicative role is given by the traditional market cooperation, which enters the regression model with a positive sign, in contrast with the unsignificant role played by the variable representing cooperation based on informal and non-market relationships.

Table 6. Role of location and urbanisation economies on capital productivity: results of regression estimates

	1' model	2' model

Constant	-0.16 (-4.8)	-0.42 (-3.33)
Importance of access to a wide and diversified output market for the location choice	0.13 (2.94)	0.12 (2.87)
Importance of access to a increasingly qualified and diversified labour market for the location choice		0.05 (1.92)
Role of cooperation with customers based on traditional market conditions		0.04 (2.0)
R-square	0.12	0.22

Dependent variable: capital productivity

6. Conclusions

The main aim of the paper was to test whether factor productivity of firms located in urban areas is influenced by urbanisation rather than by location economies. A good case for the empirical analysis is the North-Eastern part of Milan, because of the presence of a high density of high-tech firms. In this area, a spontaneous question arises: do firms locate in this area to take advantage of urbanisation rather than location economies?

Our empirical analysis replies empirically to this question. The methodology used is a two step procedures; the first step provides a measurement of factor productivity, through the estimate of a trans-log production function. The second step presents regression models estimating the role of location and urbanisation economies on factor productivity at the firms' level. The analysis is based on a sample of 66 firms in the high-tech industry located in the North-Eastern part of Milan.

The results definitively support the idea that, at least for what concerns the high-tech sector, characterised by a decisive tendency towards urban location patterns, urbanisation economies prevail in influencing factor productivity rather than location economies. Interestingly enough, these results are in line with the evidence provided by Feldman and Audretch (1999) that diversified knowledge spillovers rather than specialised knowledge spill-overs constitute the main reason for innovative activities and technological change in urban areas.

Appendix 1

The table below provides the list of indicators used for location and urbanisation economies.

	Indicator	Question asked in the questionnaire	Nature of the question
Location economies	• Importance attributed to a *highly specialised labour market* in their innovative activity.	• Was the access to a highly specialised labour market important in your innovative activity?	• Binary
	• Importance attributed to the presence of transport infrastructures (airport and highways) to their innovative activity.	• Was the access to highways and international airports important in your innovative activity?	• Binary
	• Importance attributed to *specialised suppliers* in their innovative activity.	• Was the proximity to specialised suppliers important in your innovative activity?	• Binary
	• Importance of cooperation with local customers (suppliers) based on non-market rules (i.e. informal contracts).	• Which share of your local customers (suppliers) is based on the following types of contracts: contractual agreements based on technical standards decided by you; cooperation with a cooperation with innovative content beyond the terms of the contract	• Discrete (four different categories). Trasformed into continous as presented below.
	• Importance of cooperation with other local firms based on non-market rules (i.e. informal contracts).	• Which share of your cooperation with other local firms is based on the following types of contracts: contractual agreements based on technical standards decided by you; cooperation with a cooperation with innovative content beyond the terms of the contract	• Discrete (four different categories). Trasformed into continous as presented below.
	• Importance attributed to *spill-over mechanisms* in their location choice.	• Were spin-off mechanisms in the area important for your innovative activity?	• Binary
	• Importance attributed to *a high turnover of the labour force* in their innovative activity.	• Was the turnover of the labour force in the area a important in your innovative activity?	• Binary
Urbanisation economies	• Importance attributed to *a diversified and large market of inputs* in their innovative activity.	• Was the access to a diversified and large market for inputs important in your innovative activity?	• Binary
	• Importance attributed to a *diversified and large market for the final good* in their location choice.	• Was the access to a diversified and large market for final goods important in your innovative activity?	• Binary

• Importance attributed to *a scientific environment* in their innovative activity.	• Was the presence of university and research centres important in your innovative activity?	• Binary
• Importance of cooperation with local customers (suppliers) based on market rules (i.e. formal contracts).	• Which share of your local customers (suppliers) is based on the following types of contracts: standard supply contract; cooperation with merging of technical teams; equity participation; venture capital.	• Discrete (four different categories). Trasformed into continous as presented below.
• Importance of cooperation with other local firms based on market rules (i.e. formal contracts).	• Which share of your relationships with other local firms is based on the following types of contracts: standard supply contract; cooperation with merging of technical teams; equity participation; venture capital.	• Discrete (four different categories). Trasformed into continous as presented below.
• Importance attributed to *an increasing qualified and diversified labour market.*	• Was the presence of a diversified and qualified labour market important in your innovative activity?	• Binary

Discrete variables have been transformed into continous variables by aggregating different possible replies into one indicator as follows:

$$Ind = \sum_{j=1}^{n} W_j I_{ji}$$

where:
j = the type of contract
i = the firm
I = the answer of firm i for each type of contract
W = the weight attributed to each type of contract.
D = discrete variable representing four intervals of shares of local customers (suppliers and other firms).

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