Deciphering the effects of agglomeration economies on firms' productive efficiency

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Abstract

The present work assess the effects of MAR and Jacob's type agglomeration economies on a sample of firms in the machineries and textiles industries in Greece for the periods 1989-91 and 1999-01. The analysis employs a stochastic production frontier function and allows agglomeration economies to enter as inputs and/or as factors reducing inefficiency. Results re-confirm that the effects of agglomeration economies are industry specific. In our study, the machineries industry benefits from MAR type agglomeration economies and the textiles industry benefits from Jacob's type agglomeration economies. Agglomeration economies may exercise a twin effect on firms' productive efficiency. First, as in the case of the machineries industry in our study, MAR agglomeration economies may act as a new input and affect the kernel of the production frontier. Second, agglomeration economies may act as a factor reducing technical inefficiency with non-neutral effects with labour and capital as in the case of both the machineries and the textiles industries in our study. Finally, it is indicated that agglomeration economies establish a type of "path dependence" for firms. Firms that make significant use of agglomeration economies survive to the next period at higher percentages in comparison to other firms in the same industry. At the same time, entrants are favoured by MAR type agglomeration economies while incumbents are favoured by Jacob's type agglomeration economies.

Introduction

Geographers and economists alike have developed a long interest on the location of economic activity and its effects on local and regional development. Rosenthal and Strange (2004) provide the most complete review of strategies for evaluating the scope of agglomeration economies. They argue that, following Henderson (1986), external economies are by definition shifters of an establishment's production function causing Hicks neutral effects. Rosenthal and Strange (2004) argue that interdependencies of the establishments' operation should take account of distance in three ways; first, in its physical nature as geographic distance; second, in its economic activity nature as industrial activity; third, in its time nature as temporal effects. Direct approaches for measuring the influence of agglomeration on productivity is to estimate a production function at plant level as in Henderson (2003) which is a model paper of the productivity based study of agglomeration. The wide range of works following Henderson's (2003) work assumes an underlying Cobb-Douglas production function. Another approach is through estimating cost functions that allow the separate identification of the impacts of agglomeration externalities on short- and long-run scale economies and input substitution patterns (Paul-Morrison and Siegel, 1999; Cohen and Paul-Morrison, 2005).

Another prominent and influential approach to firms' productive performance measurement relies on the estimation of a parametric or non-parametric production or cost frontier, which directly links productive efficiency to the notion of productive inefficiency as it was introduced, by Farell's (1957) seminal work. The popularity of using production or cost frontiers to measuring productive performance is mainly due to their ability to decompose the overall productive efficiency in components. These components are either due to the production mix itself, or due to exogenous factors which are accounted as productive inefficiency factors. To the best of our knowledge there were two works which attempted to make use of production frontiers in the study of agglomeration economies effects on productivity. Mitra (1999) used a stochastic frontier to analyze the effects of city size on technical efficiency. He obtained technical efficiency measures, treated them as dependent variables and regressed a number of independent variables (including city size) on these technical efficiency measures. He found that city size (scale or urbanization economies) has a U-shaped effect on technical efficiency, increasing up to a threshold of city size and after that decreasing making city size a diseconomy. Tveteras and Battese (2006) examined the influence of regional agglomeration externalities on the productivity in Norwegian salmon aquaculture. The authors construct two external agglomeration economy indices, namely regional industry size and regional salmon farm density. By using a production frontier methodology they distinguish between the effects on the production possibility frontier and technical inefficiency due to "errors" in optimization by farms. Their results support the presence of externalities to both the frontier and technical inefficiency. Thus, agglomeration externalities influence both the best-practice productivity and technical inefficiency in salmon farming.

The two most important estimation issues concern with omitted variables and simultaneity. Absence of data on certain inputs raises issues related to the estimation of production functions with omitted variables. Lack of data on one of the major inputs, for example capital, may result to inflated effects of city size as in Sveikauskas (1975) pointed out by Moomaw (1983). However, most often, available data are far from ideal, and either major inputs such as capital, labour or land, are missing or other inputs such as materials purchased or materials produced internally are not available (Ciccone and Hall, 1996; Henderson, 2003). If successful entrepreneurs choose to locate in areas where agglomeration economies enhance plant productivity, then agglomeration economies simultaneously affect the decision to locate and the production decisions. This type of simultaneity, raises challenging endogeneity estimation issues (for a more elaborate discussion the interested reader is directed to Combes et al., 2008 and Martin et al., 2008).

Data and Case Study Industries

Data

Data for this work come from two distinct sources. Firstly, data on business characteristics come from a business database maintained by a Greek private financial and business information service company called ICAP. The annual ICAP directories provide key elements from the published balance sheets of almost all Plc. and Ltd. firms operating in all sectors of economic activity in Greece. For this work we choose two manufacturing industries, namely machineries and textiles, at the two digit level of industrial disaggregation. Previous work has been conducted mainly at the two-digit level and evidence shows that estimating agglomeration economies at this level does not exaggerate their importance (Moomaw, 1998). The specific industries are chosen because the machineries industry is a typical medium to high tech industry that has been extensively studied in other works and countries and thus, comparisons may be drawn more easily. The textiles industry was chosen as a medium to low tech industry that is very significant for the Greek economy and undergone significant re-structuring during the time period under consideration. From the annual directories of ICAP we devised a database of firms operating in these two industries of the manufacturing sector, and for two distinct time periods. The first time period covers the years 1989-1991 and the other one the years 1999-2001. In order to avoid the well recorded fluctuations of financial data due to business cycles, the mean of each financial and economic variable for the period 1989 to 1991 and 1999 to 2001 was constructed. Thus, we ended up with an unbalanced panel of businesses in two periods, one averaging the years 1989-1991 and one averaging the years 1999-2001.

Secondly, data on agglomeration economies are derived from the censuses of population, the most complete source of information as regards levels of spatial and industrial disaggregation of employment provided for by the National Statistical Service of Greece (NSSG). The two time periods for which business data are collected coincide with the 1991 and 2001 censuses of population. In constructing appropriate proxies for agglomeration economies we considered two issues. Firstly, we considered the level of spatial disaggregation for which indices capturing agglomeration economies may be constructed. We choose the prefectures as the spatial unit of analysis that correspond to the NUTS 3 European regions. In most cases the Greek NUTS 3 areas contain one large city which is the main urban agglomeration and a few smaller towns connected to it. Spillover effects do not travel large distances either in Europe (Crescenzi et al., 2007; Moreno et al., 2005; Rodriguez-Pose and Crescenzi, 2008; Soest et al., 2006) or the US (Anselin et al., 1997; Sonn and Storper, 2008; Varga, 2000). Following previous works we constructed indices aiming to capture inter-sectoral, MAR effects and intra-sectoral Jacobian like effects. Nakamura and Paul (2009) provide an extensive overview of approaches for measuring agglomeration. Inter-sectoral indices are constructed following a location quotient:

$$\frac{E_{ir}/E_r}{E_{in}/E_n} \qquad (1)$$

where E_{ir} is the employment in sector i in region r, E_r is the total employment in region r, E_{in} is employment in sector i in the whole country (all regions) and E_n is employment in the whole country (all regions all sectors). The total employment was defined as the set of industries for which the sectors show significant input-output relationships, all manufacturing industries or the total economy. Not surprisingly, the estimated indices had a very high and statistically significant correlation coefficient indicating that whichever index is used does not really matter. Thus, in this work we use the aforementioned index estimated over the whole of manufacturing industries. Intra-sectoral indices are constructed following a simple index:

$$s_r = \sum_i \left(\frac{E_{ir}}{E_r} - \frac{E_{in}}{E_n} \right)^2 \quad (2)$$

where notation is the same as in the above index. This index, the squared difference between the nominator and denominator of equation (1), is the Ellison-Glaeser (1997) index used by Henderson (2003) to capture diversity. Other indices such as a modified Helfindhal index, as well as an index measuring the fraction of the region's employment in the five largest industries other than the industry in question (Glaeser et al., 1992) were constructed. Again total employment was defined as the set of industries for which the sectors show significant input-output relationships, all manufacturing industries or the total economy. Due to the fact that all estimated indices have very high correlation coefficients and our case study industries have links with firms from industries outside the manufacturing sector, we use the aforementioned index estimated over the whole industries and not only the manufacturing industries.

The Machineries Industry

In our study the machineries sector is represented by NACE 29 excluding NACE 29.6, manufacture of weapons and ammunition and 29.7, manufacture of domestic appliances because these two sub-sectors serve different markets, experience different business cycles and demand dynamics and apply different innovation processes than the rest of the NACE 29 sub-sectors. This exclusion does not cause any significant distortion due to the fact that these two sub-sectors are extremely small. What is left is a rather homogenous of businesses producing capital equipment and supplying technology and services to a large number of other industries mainly within the manufacturing and primary sectors and especially to the food processing and spirits industry. The largest sub-sectors are manufacture of agricultural and forestry machinery (NACE 29.3), manufacture of machine tools (NACE 29.4), and manufacture of pumps and compressors (NACE 29.12).

In 2005 the NSSG reports for the sector 6,376 establishments, around 7% of all manufacturing establishments in Greece, of which 97% are entrepreneurial micro businesses of less than 10 employees. However, larger (> 10 employees) and smaller establishments share almost equal proportions of the industry's total employment. The industry's gross value of production, value added and sales account for 3% of the respective totals for the whole manufacturing sector in Greece. The machineries industry employs more people with higher education qualifications than the manufacturing sector. The major clients of the industry are the construction sector, the industry itself and public administration and its major suppliers are manufacturers of metal products and of electrical machinery, the industry itself and the recycling industry. Thus, there is a high proliferation of linkages between different producers in the sector and of producers and clients in very few and specific industries. The industry's innovation pattern is strongly demand based frequently customized to the specific needs of clients whose specifications trigger innovation. Monopolistic competition dominates the industry and firms differentiate from potential competitors by looking for different quality characteristics of their products and specializing in certain niches. This technological cooperation with clients implies that products are produced in small quantities making it difficult to gain scale economies advantage and justifying the dominance of micro entrepreneurial firms. Radical innovations are rare in the industry and technological developments rest on existing specific knowledge that is improved in certain parameters such as accuracy, flexibility and speed of processing. In recent years, many producers have found that the provision of services including maintenance, emergency services, adjustment of machinery to new regulations or specifications, training and leasing can provide a significant fraction of their turnover. To conclude the discussion so far we note that the sector depends highly on its clients, existing knowledge and other producers in the sector, skilled labour, and is dominated by very small firms.

The Textiles Industry

In our study the textiles industry is represented by NACE 17 including the treatment of raw materials (NACE 17.1), the production of woven and knitted fabrics (NACE 17.2 and 17.6), and finishing activities (NACE 17.3) and excluding the transformation of fabrics into products (NACE 17.4, 17.5, 17.7) and the clothing industry (NACE 18). The textiles industry is misleadingly referred to as a "low-tech", or "traditional" industry of the old economy, implying that there is little innovation efforts or R&D expenditures. In 2005 the NSSG reports for the sector 3,673 establishments, around 4% of all manufacturing establishments in Greece, of which 90% are entrepreneurial micro businesses of less than 10 employees. However, larger (> 10 employees) establishments account for 63% of the industry's total employment and are very important. The industry's gross value of production, value added and sales account for less than 2% of the respective totals for the whole manufacturing sector in Greece. The industry has undergone significant restructuring, a process that was driven by a liberalization boost following the abolition of import quota agreed in the WTO Agreement on Textiles and Clothing in 1993. In the EU and especially in Greece, which is a prime producer of cotton natural fabrics and cotton textiles, this liberalization triggered the abandonment of low cost production strategies towards a quest of competitive strength through innovation, creativity, design and fashion. In the decade 1995-2005 for which data exist for establishments of over 10 employees, the number of businesses and total employment fell by more than half, while the gross value of production and total sales fell by less than 25%. From the most recent 2005 input-output tables for the Greek economy we see that the major clients of the industry are the clothing industry and the industry itself while its major suppliers are the primary sector and especially the cotton growing sector and the industry itself.

Innovation in the textiles industry is characterized by a complex structure of the knowledge base where technological innovations constitute the visible and the smaller part of total innovations. Technology transfer and non-technological innovations, the other two components of total innovation, remain below the surface of perception and are not recorded in official statistics. Technological innovations have been triggered by the sophisticated and specialized markets in the car industry, house construction, environmental technologies and sports. Technology transfer refers to the use of innovations generated mainly in the chemicals and machinery industries and depends on the geographic proximity with manufacturers from such industries. Non-technological innovations refer mainly to the ability to synthesize novelty by synthesizing competence by organization and design. Synthesizing competence is the ability to tap into distributed knowledge from totally different areas and to recombine it creatively. Organization is the ability to link players who possess relevant knowledge, technology and competence. Design is the ability to achieve fitness between the form and its context by configuring and modifying artifacts to meet certain needs and expectations. All the above point that firms in the textiles industry need to bridge with a wider diversified economy.

Table 1 below shows the population, area and employment in the Greek prefectures for 1991 and 2001 as well as the estimated indices capturing MAR and Jacobs effects. Tables 2 and 3 provide descriptive statistics of the firms and their dynamics in the machineries and textiles industries between 1989 and 2001.

Table 1. Population, employment and indices for the Greek prefectures, 1991-2001.

	1991	2001
Total employment in:		
Machineries	16,624	19,331
Textiles	42,307	28,278
All manufacturing industries	534,663	530,501
All sectors	3,885,623	4,615,085
Average Area (Km^2)	2,531	2,531
Average Population	197,305	208,972
Index for MAR Effects		
Machineries	0.682	0.719
Textiles	1.064	0.902
Index for Jacob's Effects	0.036	0.030
Number of prefectures	51	51

Table 2. Descriptive Statistics of Firms and Their Dynamics in the Machineries Industry, 1989-2001.

The Machineries Industry								
	Firms in 1989-1991		Firms Exiting in 1992-1998		Firms Entering in 1992-1998		Firms in 1999-2001	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Personnel	27	37	20	21	21	20	30	44
Capital	377.970	853.379	266.901	396.624	659.617	1.247.768	774.662	1.327.742
Own Capital	508.498	1.115.337	308.048	480.240	1.035.675	1.736.243	1.356.809	2.997.461
Total Liabilities	1.003.245	2.545.582	773.110	1.169.124	1.240.519	2.008.762	1.743.946	3.382.657
Net Fixed Assets	526.349	1.672.452	337.578	742.659	820.166	1.809.371	1.068.968	2.438.881
Total Assets	1.513.600	3.555.061	1.080.901	1.494.487	2.266.079	3.562.164	3.112.144	5.811.262
Turnover	1.630.461	2.736.054	1.220.454	1.698.820	1.735.449	2.033.658	2.433.268	4.363.333
Net Profits	48.290	239.003	22.770	207.433	164.567	623.262	282.303	1.278.505
Number of Firms	215		130		110		195	

Table 3. Descriptive Statistics of Firms and Their Dynamics in the Textiles Industry, 1989-2001.

The Textiles Industry								
	Firms in 1989-1991		Firms Exiting in 1992-1998		Firms Entering in 1992-1998		Firms in 1999-2001	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Personnel	116	764	125	911	37	52	60	110
Capital	1.702.604	8.869.788	1.802.243	10.389.292	1.710.049	3.156.285	2.391.465	5.886.648
Own Capital	1.741.717	4.542.938	1.093.911	3.338.802	2.641.764	7.202.496	4.656.761	16.440.206
Total Liabilities	3.957.819	21.076.554	4.229.161	25.005.377	3.630.853	5.225.967	4.522.536	8.149.165
Net Fixed Assets	2.163.698	7.531.374	1.961.644	8.400.782	2.821.989	7.187.797	4.291.320	14.924.941
Total Assets	5.700.824	21.733.879	5.323.594	25.001.245	6.202.156	11.304.125	9.143.822	22.828.815
Turnover	4.924.004	11.138.720	4.155.521	11.243.991	4.206.076	5.901.589	5.585.441	9.557.412
Net Profits	-217.660	3.884.014	-440.730	4.587.205	172.573	605.186	307.233	797.930
Number of Firms		594		414		180		360

The Model

The proposed model

The parametric stochastic production and cost frontiers allow us to test two hypotheses: first, agglomeration economies affect the kernel of the frontier and thus are treated, in econometric terms, as an "additional input" in the production process; second, agglomeration economies are simply exogenous factors that may affect, in every possible direction, the firms' productive efficiency. If none of the aforementioned hypotheses are accepted, agglomeration economies have no impact on firms' productive performance. Following Kumbhakar and Lovell (2000, p.262) let $\left(x_1,...,x_N\right)\geq 0$ be an input vector used to produce scalar output $y \geq 0$. The stochastic production frontier may be written as:

$$\ln y_{it} = \ln f\left(\mathbf{x_{it}};\boldsymbol{\beta}\right)+v_{it}-u_{it}, \quad i=1,...,I, \quad t=1,...,T \qquad (3)$$

where i stands for firms and t for time, $\ln f\left(\mathbf{x_{it}};\boldsymbol{\beta}\right)$ is the deterministic kernel of the stochastic production frontier $\left[\ln f\left(\mathbf{x_{it}};\boldsymbol{\beta}\right)+v_{it}\right]$, $v_i \sim iid\ N\left(0,\sigma_v^2\right)$ captures the effect of random noise on the production process, $u_i \sim N\left(0,\sigma_u^2\right)$ captures the effect of technical inefficiency and $\boldsymbol{\beta}$ is the parameter vector to be estimated. Hereafter the subscript t is suppressed and fixed effects panel data models are employed for simplicity. Battese and Coelli (1992) show that the best predictor of the technical efficiency of each firm is $TE_i = \exp(-\hat{u}_i)$, where $\hat{u}_i = E\left(u_i \left|\left(v_i - u_i\right)\right.\right)$. In the above described model, the so called Error Component Model (ECM), agglomeration economies may influence the productive performance through their inclusion in the input mix. As such, agglomeration economies proxies are treated as additional inputs, and the corresponding stochastic production frontier can be written as:

$$\ln y_i = \ln f\left(\mathbf{x_i}, x_E;\boldsymbol{\beta},\boldsymbol{\beta_E}\right)+v_i-u_i, \quad i=1,...,I \qquad (4)$$

where x_E is the employed agglomeration economy proxy which operates as a shifter of the deterministic part of the production frontier, $\boldsymbol{\beta_E}$ is the vector of the additional parameters to be estimated and captures the alteration of the position and shape of the production frontier due to the inclusion of x_E.

Next, we consider the case where a vector of exogenous variables $\left(z_1,...,z_Q\right)$ affects the structure of the production process by which inputs $\mathbf{x}$ are converted to output y. The elements of $\mathbf{z}$ reflect features of the environment within which the production takes place. They are, generally, considered to be conditioning variables beyond the control of those who manage the production process. In this case, as Huang and Liu (1994) proposed, the stochastic production frontier of equation (3) is accompanied by the technical inefficiency relationship

$$u_i = g\left(\mathbf{z_i};\boldsymbol{\delta}\right)+\varepsilon_i \qquad (5)$$

where $\boldsymbol{\delta}$ is a vector of parameters which are associated to inefficiency factors, to be estimated. The requirement that $u_i = \left[g\left(\mathbf{z_i};\boldsymbol{\delta}\right)+\varepsilon_i\right] \geq 0$ is met by truncating ε_i from below such that $\varepsilon_i \geq -g\left(\mathrm{z_i};\delta\right)$, and by assigning a distribution to ε_i such that $\varepsilon_i \sim N\left(0,\sigma_\varepsilon^2\right)$. This allows $\varepsilon_i < 0$ but enforces $u_i > 0$. In the case in which the g function is linear, the above model is the so-called Technical Efficiency Effects Model (TEEM) introduced by Batesee and Coelli (1995). The technical efficiency of the $i-$th firm is given by $TE = \exp\left\{-u_i\right\} = \exp\left\{-\boldsymbol{\delta}'\mathbf{z_i} - \varepsilon_i\right\}$. In this work we test the hypothesis that agglomeration economies may behave as a variable affecting inefficiency, a z variable, which we name it $z_{\mathbf{E}}$, and thus relationship (5) becomes:

$$u_i = g\left(\mathbf{z_i};\mathbf{z_E};\boldsymbol{\delta};\boldsymbol{\delta}_\mathbf{E}\right)+\varepsilon_i \qquad (6)$$

where $\boldsymbol{\delta}_\mathbf{E}$ are the additional parameters which have to be estimated since the agglomeration economies proxies have been included among the inefficiency factors. According to equation (6) agglomeration economies do not influence the structure of the production frontier, but they do influence the technical efficiency with which producers approach the production frontier.

Thus, in order to test the hypothesis that agglomeration economies affect the production process through both the position and shape of the production frontier and the inefficiency term, equations (4) and (6) should be combined as following:

$$\begin{gathered}\ln y_i = \ln f\left(\mathbf{x_i};\mathbf{x_{E;}}\boldsymbol{\beta};\boldsymbol{\beta}_\mathbf{E}\right)+v_i - u_i \\ u_i = g\left(\mathbf{z_i};\mathbf{z_E};\boldsymbol{\delta};\boldsymbol{\delta}_\mathbf{E}\right)+\varepsilon_i\end{gathered} \qquad (7)$$

At this point it is better to use an example which will help us understand the economic intuition of the ECM and TEEM models presented in equations 4, 6 and 7. Agglomeration economies create externalities due to the local concentration of firms in the same industry (MAR spillover effects) or the degree of diversification of the local economy (Jacobs' type spillover effects). Knowledge spillovers may be one of the externalities of agglomeration economies. When knowledge spillovers transmit existing knowledge, and assuming that existing knowledge is already embodied in the frontier as a best-practice production technology, then knowledge spillovers may lead to the reduction in the technical inefficiency of firms relative to the production frontier. However, knowledge spillovers also may create new knowledge that is not already embodied in the frontier production technology. This new knowledge may take the form of an incremental innovation. This new knowledge shifts the production frontier in a positive direction, leading to an increase in maximum output conditional on the given level of inputs. Furthermore, the local concentration of firms in a sector may result to the local concentration of specialist suppliers that has an effect on the timely and less costly repair of a firm's machinery, may attract more specialized public infrastructure, may create dense commodity networks or may make the search for specialized labour easier all of which will be recorded as reduced inefficiency. This implies that measures of externalities may influence either the frontier function (equation 4) or the technical inefficiencies (equation 6) that are deviations of realized production from the frontier production, or both. In the Huang and Liu (1994) contribution, the function $g\left(\mathbf{z_i};\boldsymbol{\delta}\right)$ is allowed to include interactions between exogenous factors $\mathbf{z_i}$ and production inputs $\mathbf{x_i}$ (Batesse and Broca, 1997). The incorporation of non neutral effects of agglomeration economies in the production performance can be realized by considering agglomeration economies either as a factor that affects the production frontier itself, or as a technical efficiency factor. In the former case, the $g\left(\mathbf{z_i};\boldsymbol{\delta}\right)$ function for the $i-$th firm can be written as:

$$g\left(\mathbf{z_i},\mathbf{x_{ni}},x_{Ei};\boldsymbol{\delta},\boldsymbol{\delta_{Eqi}}\right)=\sum_{q}^{Q}\delta_q z_{qi}+\sum_{q}^{Q}\sum_{n}^{N}\delta_{qn}z_{qi}\ln x_i+\sum_{q}^{Q}\delta_{Eq}z_q\ln x_E \quad (8)$$

The last term of the right hand part of equation (8) depicts the non neutral effects of agglomeration economies on the inefficiency terms when agglomeration economies affect productive performance through the kernel of the stochastic production frontier. When agglomeration economies are considered an inefficiency factor exhibiting non neutral effects, the $g\left(\mathbf{z_i};\boldsymbol{\delta}\right)$ function for the $i-$th firm can be written as:

$$g\left(\mathbf{z_i},\mathbf{z_{Ei}},\mathbf{x_i};\boldsymbol{\delta},\boldsymbol{\delta_E}\right)=\sum_{q}^{Q}\delta_q z_{qi}+\delta_E z_E+\sum_{q}^{Q}\sum_{n}^{N}\delta_{qn}z_{qi}\ln x_{ni}+\sum_{n}^{N}\delta_{nE}z_{Ei}\ln x_{ni} \quad (9)$$

The last term of the right hand part of the above equation depicts the non neutral effects of agglomeration economies on the inefficiency terms when agglomeration economies are a factor affecting inefficiency. The total effect of agglomeration economies on the technical inefficiency of the $i-$th firm is the sum of the second and fourth term of the right hand part of the above equation. By combining equations (8) and (9) we can explore the case where non-neutral effects arise from considering agglomeration economies as a factor that affects the production frontier and inefficiency.

Figure 1 shows the process of deciphering the effects of agglomeration economies on firms' productive performance in four vertical flowcharts. Each of the first three charts from the left shows each of the three hypotheses regarding the possible neutral impacts of agglomeration economies on a firm's productive performance. The chart on the far left shows the process testing the hypothesis that agglomeration economies affect the deterministic part of the frontier, and operate as an "additional, new-input"; the chart second from left shows the process where agglomeration economies affect the inefficiency term, and the chart third from left combines the two process and tests the hypothesis that agglomeration economies act both as a new input and as a factor reducing inefficiency. The far right chart examines the hypothesis of no effects at all.

In the appendix of this work we elaborate further the processes presented in figure 1. If we consider that agglomeration economies are a new input, the first vertical flow chart in figure 1 denotes that this may be approximated by an ECM specification (model B in appendix) or under a TEEM specification. The TEEM specification may be modeled with neutral effects (model D in appendix) or with non-neutral effects (model G in appendix). The flow chart second from left assumes that agglomeration economies act only as an inefficiency factor that can be approached by a TEEM model specification with neutral (model E in appendix) or non-neutral (model F in appendix) effects. Accordingly, the third from left vertical flow chart reveals that the impact of agglomeration economies can be approximated only by a TEEM model with neutral (model H in appendix) or non-neutral (model I in appendix) effects of the inefficiency terms. Finally, the far right flow chart assumes that agglomeration economies have nothing to do with firms' productive efficiency. In that case, the ECM (model A in appendix) and the TEEM (models C and J in appendix) are the two specification to be estimated[1]. The models above are nested and their differences are in the number of restrictions employed in their estimation. Thus, we can use the generalized likelihood ratio to decide which identification is the most appropriate and reveal the role of agglomeration economies on firms' productive efficiency. The proposed approach allows us to test for the functional form of the production function, to test the alternative hypotheses that agglomeration economies may operate as an input to the production function or as a term affecting inefficiency or both and to test whether agglomeration economies exert non-neutral effects. Technical inefficiency from a sample of individual firms can be predicted on the basis of cross-sections or panel data sets. However, when cross-sections are employed, the estimation procedure must assume that inefficiency is independent of regressors. This might be incorrect since input and output quantities are together determined at the equilibrium and since firms have a prior knowledge (even incomplete) of their level of inefficiency when they choose inputs quantities. This assumption is potentially avoidable following two strategies. First using panel data sets (Cornwell et al., 1990) or models where inefficiency varies over time (Ivaldi et al., 1994). Second, allowing for time varying inefficiencies (Gagnepain and Ivaldi, 2002). In the present paper both strategies are used.

Results

Table 4 provides an overview of the sample and basic descriptive statistics for the variables used in estimating alternative frontiers for the machineries and textiles industries. Using the base model of each column (as shown in figure 1) we have performed a series of tests regarding the functional form of the frontier and the distributional assumptions regarding the inefficiency term for each one of the two industries under consideration. More specifically with respect to the functional form of the frontier we have tested the hypotheses (i) of Constant Returns to Scale vs. Variable Returns to Scale, (ii) of Cobb-Douglas vs. Translog functional Form, (iii) of no technical change and (iv) of neutral vs. non-neutral technical change. Regarding the distribution of the inefficiency term we have tested the hypothesis (i) of half normal vs. a truncated normal distribution and (ii) of time varying vs. time –invariant technical efficiency. The hypothesis that the total deviation from the frontier is entirely due to noise is tested in each one of the estimated models. Results of the above tests are not presented here due to space limitations but are available from the authors upon request.

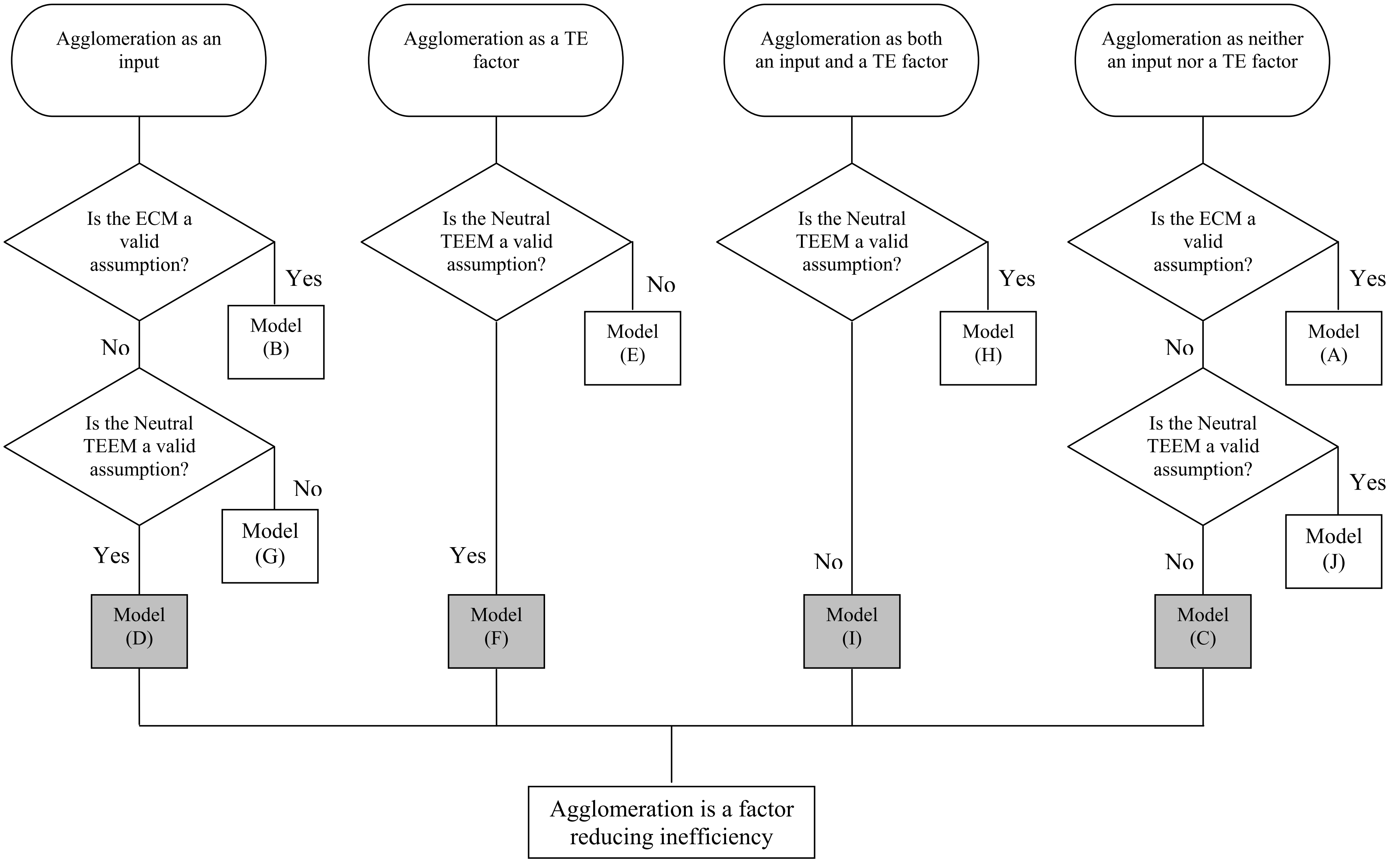

Figure 1. Model selection decision process

Table 4. Sample Description, and Mean and Standard Deviation of the Variables Used in the Analysis

	Machineries			**Textiles**		
Sample	1989-1991	1999-2001	Pooled Sample	1989-1991	1999-2001	Pooled Sample
No of Firms	215	195	325	594	361	774
No of Used Observations	189	194	383	572	355	927
Descriptive Statistics of the Used Variables						
Kernel of the Frontier						
Output (Q)	1,630,461	2,433,268	2,037,105	4,931,835	5,634,852	5,201,059
	(2,736,054)	(4,363,333)	(3,669,433)	(11,146,891)	(9,599,656)	(10,581,328)
Capital (K)	1,644,337	3,125,897	2,394,788	5,891,473	9,250,164	7,177,703
	(3,754,537)	(5,823,115)	(4,961,807)	(22,125,937)	(22,971,360)	(22,500,494)
Labor (L)	28.0185	29.8780	28.9604	119.5293	59.8761	96.6847
	(38.5692)	(44.5619)	(41.6684)	(777.6863)	(109.8296)	(615.1332)
Agglomeration Variables						
MAR Agglomeration Index (MAR)	1.1410	1.0542	1.0970	1.0672	1.2500	1.1372
	(0.3118)	(0.2904)	(0.3079)	(0.5270)	(0.6657)	(0.5904)
Jacobs Agglomeration Index (JAC)	0.0283	0.0207	0.0245	0.0189	0.0214	0.0197
	(0.0169)	(0.0191)	(0.0184)	(0.0186)	(0.0187)	(0.0188)
Inefficiency Factors						
$z_1 = \frac{\text{Fixed Assets}}{\text{Total Assets}}$	0.3027	0.2906	0.2966	0.3351	0.3379	0.3361
	(0.1931)	(0.1961)	(0.1945)	(0.2073)	(0.2079)	(0.2074)
$z_2 = \frac{\text{Net Profits}}{\text{Turnovers}}$	0.0357	0.0621	0.0491	-0.0295	0.0438	-0.0014
	(0.4131)	(0.2806)	(0.3521)	(0.3587)	(0.1965)	(0.3088)
$z_3 = \frac{\text{Debt}}{\text{Total Assets}}$	0.6521	0.5733	0.6122	0.6153	0.5655	0.5962
	(0.3007)	(0.2226)	(0.2667)	(0.3028)	(0.2322)	(0.2788)
$z_4 = Age$	19.6508	18.0825	18.8564	20.7937	21.8000	21.1791
	(17.1739)	(13.7078	(15.5152)	(18.0695)	(15.8466)	(17.2503)
$z_5 = \text{Market Share}$	0.0053	0.0052	0.0052	0.0017	0.0020	0.0018
	(0.0089)	(0.0092)	(0.0091)	(0.0040)	(0.0034)	(0.0037)

The Machineries industry

For the machineries industry only the MAR type agglomeration economies have a significant impact. The Jacob's type of agglomeration economies was not significant in any of the models, either as a standalone agglomeration economy variable or in relation to the MAR type agglomeration economy variable. Table 5 below shows the most important models estimated for the machineries industry. Models 1 and 2 treat the MAR type of agglomeration economies variable as a factor reducing inefficiency without and with non-neutral effects correspondingly and not as an input to the production function. Model 3 treats the MAR type of agglomeration economies as an input to the production function and not as a factor reducing inefficiency. Model 4 encapsulates models 2 and 3 and treats the MAR type of agglomeration variable as both an input and as a factor reducing inefficiency allowing for non-neutral effects. Due to the fact that certain of the interaction terms in the inefficiency part of model 4 were highly correlated, model 5 re-estimates model 4 by excluding these variables. Almost all statistically significant interaction terms in the inefficiency part of model 4 remain significant in model 5 and with the same sign. Model 4 is nested with models 2 and 3 and likelihood ratio tests reveal that is preferable to both models 2 and 3. For non-nested models the calculated AIC indicates again that model 4 or model 5, its condensed version, is the most preferable models.

In general the kernel of the frontier is well behaved and according to production theory. The γ-parameter value indicates that our model sufficiently disentangles inefficiency from white noise. The MAR variable is well behaved as an input. Its marginal product is positive and declining (parameters a_{MAR} and a_{MARMAR}). Technical regress (parameter a_t) is negative but its statistical significance is marginal. Significant and positive interactions between the capital input and the MAR agglomeration economies variable arise from the estimated coefficients of the kernel of the frontier (parameter a_{KMAR}). The marginal product of the MAR agglomeration economies variable is monotonically increasing with respect to the capital input and the same applies for the marginal product of the capital input with respect to the MAR agglomeration economies. The opposite effects are observed with respect to the labour input in model 4 but no significant interactions between the labor input and the MAR agglomeration economies variables are identified in the kernel of the frontier in model 5.

The effects of the MAR agglomeration economies variable when this acts as a factor affecting inefficiency are very interesting. Coefficient δ_6 is negative indicating that the direct effect of MAR agglomeration on technical efficiency is positive, i.e., reduces inefficiency. However, the interaction terms capturing non-neutral effects of the MAR agglomeration variable with capital (δ_{13}) and labour (δ_{20}), provide contradicting effects. The effect arising from the interaction of the labor input and MAR agglomeration economies when the latter is included in the inefficiency model is positive (parameter δ_{20} is negative). On the contrary, the interaction between the capital input and the MAR agglomeration economies on firms' technical efficiency is negative (parameter δ_{13} is positive). That is, the positive influence of the MAR agglomeration economies on firms' technical efficiency is biased in favor of the firms with less capital assets.

The Textiles industry

For the textiles industry only the Jacobs type agglomeration economies have a significant impact. The MAR type of agglomeration economies was not significant in any of the models, either as a standalone agglomeration economy variable or in relation to the Jacobs type agglomeration economy variable. Table 6 below shows the most important models estimated for the machineries industry. Model 1 is the base model which does not include the Jacobs type of agglomeration economies either as a factor reducing inefficiency or as an input. Model 2 treats the Jacobs type of agglomeration economies variable as a factor reducing inefficiency with non-neutral effects and not as an input to the production function. Model 3 treats the Jacobs type of agglomeration economies as an input to the production function and not as a factor reducing inefficiency. Model 4 encapsulates models 2 and 3 and treats the Jacobs type of agglomeration variable as both an input and as a factor reducing inefficiency allowing for non-neutral effects. However, due to the fact that certain of the interaction terms in the inefficiency part of model 4 were highly correlated, the provided estimates exclude these variables. Based on the AIC, model 2 is the most preferred model indicating that the Jacobs type of agglomeration economies do not behave as a factor of production but as a mere inefficiency reduction factor that has non-neutral effects with inputs.

In general the kernel of the frontier behaves according to what is expected from production theory, as this is revealed by the negative semi-definite Heesian matrix. The γ-parameter value indicates that only a small part of the total deviation from the production frontier is due to noise as, approximately, more than 80% of it is due to inefficiency. Technical change has a dual effect. Hicks neutral and capital biased technological progress have been identified. This finding is the opposite of the corresponding finding for the machineries industry, and is a vivid example of industry-specific patterns due different technological regimes. At this point we should recall the different patterns of evolution of the two industries as these were presented in part 3 of this work.

The most preferred model assumes that the Jacobs type of agglomeration economies affect only the inefficiency part of the frontier and not the kernel. As such, the Jacobs type of agglomeration economies significantly reduces the technical inefficiency of Greek textile firms'. Three sources of this beneficial effect are identified. The first is the direct effect of the Jacobs type of agglomeration economies on firms' technical efficiency (parameter δ_7 is negative). The other two sources are related to the non-neutral effects, that operate through the interactions of the Jacobs agglomeration economies with the capital and labour inputs (parameters δ_{14} and δ_{21} are both negative and statistically significant). Taking into account that both inputs capture the size characteristics of the firms, one could reasonably argue that Jacobs type of agglomeration economies are suitable to firms at the right hand side of the skew of the size distribution.

Table 5. Alternative estimations of the machineries industry production frontier.

Parameter	Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Production Frontier						
a_0	constant	0.1968 (0.7006)	0.1787 (0.6359)	1.1641 (4.1141)*	1.8800 (6.5142)*	1.1508 (3.6380)*
a_K	$(\ln K)$	0.9708 (8.1214)*	0.9152 (7.6268)*	0.5255 (6.0459)*	0.4901 (5.5307)*	0.8136 (5.1582)*
a_L	$(\ln L)$	0.0865 (0.5650)	0.0036 (0.0229)	-0.0072 (-0.0629)	0.0340 (0.3171)	-0.1782 (-0.8645)
a_{MAR}	$(\ln MAR)$	-	-	0.17930 (0.1131)	1.1384 (5.6292)*	0.0908 (1.5355)**
a_{KK}	$(\ln K)^2$	0.1373 (5.2962)*	0.1228 (4.0315)*	0.0862 (4.9862)*	0.0777 (4.9820)*	0.1276 (4.5121)*

a_{LL}	$(\ln L)^2$	0.0995 (2.2065)*	0.0963 (1.7142)*	0.0728 (2.4268)*	0.2508 (6.0045)*	0.0101 (0.2193)
a_{MARMAR}	$(\ln MAR)^2$	-	-	0.01917 (0.2176)	0.4690 (5.2883)*	-0.0151 (-0.1123)
a_{KL}	$(\ln K)(\ln L)$	-0.2242 (-0.3599)	-0.2195 (-2.9401)*	-0.2450 (-5.834)*	-0.4195 (-9.3566)*	-0.1903 (-2.8780)*
a_{KMAR}	$(\ln K)(\ln MAR)$	-	-	0.0134 (0.2098)	0.3227 (5.7987)*	0.1077 (1.9962)*
a_{LMAR}	$(\ln L)(\ln MAR)$	-	-	0.3302 (3.8646)*	-0.2782 (-3.4989)*	0.0831 (0.5668)
a_t	t	1.6386 (2.0427)*	1.6495 (2.0562)*	-0.8166 (-1.0179)	-0.5816 (-0.7250)	-1.0379 (-1.2921)**
a_{tt}	t^2	-1.2816 (-2.3740)*	-1.2562 (-2.3298)*	0.8343 (1.545)**	0.8289 (1.535)**	0.5092 (0.9191)
a_{tK}	$t(\ln K)$	-0.2788 (-2.0364)*	-0.2170 (1.6661)*	-0.08579 (-1.1084)	0.0635 (0.8576)	-0.0725 (-0.4898)
a_{tL}	$t(\ln L)$	0.1405 (0.7535)	0.1311 (0.7233)	0.11703 (1.0762)	0.0001 (0.0013)	0.0882 (0.4499)
a_{tMAR}	$t(\ln MAR)$	-	-	-0.1956 (-1.1419)	-0.2329 (-1.344)**	0.1875 (0.5434)
Inefficiency Model						
δ_0	*constant*	-7.4638 (-2.9402)*	-2.3488 (-3.7589)*	1.5973 (21.4664)*	3.8063 (19.9301)*	0.5918 (2.6655)*
δ_1	$z_1 = FIXTOTOT$	10.9565 (4.1857)*	5.2573 (6.4387)*	0.2602 (4.0629)*	0.1783 (2.6186)*	0.9637 (4.4395)*
δ_2	$z_2 = PRFMARGN$	0.6684 (3.1819)*	0.3700 (2.3725)*	-0.2977 (-8.2482)*	-0.2086 (-4.4271)*	-0.6577 (-4.6781)*
δ_3	$z_3 = DEBT$	1.0475 (2.4790)*	0.4187 (1.8049)*	-0.2153 (-3.8433)*	-0.1151 (-2.1749)*	-0.5520 (-3.2433)*
δ_4	$z_4 = AGE$	1.1554 (1.9790)*	0.5483 (1.320)**	0.2535 (2.3433)*	-0.1154 (-1.1248)	-0.1907 (-0.4774)
δ_5	$z_5 = MRKTSHR$	-63.7980 -(1.817)*	-44.6368 (-2.6984)*	-84.9343 (-20.800)*	-108.8776 (-30.922)*	-17.2624 (-10.4718)*
δ_6	$z_6 = MAR$	-1.0473 (-4.6543)*	-1.3570 (-4.5887)*	-	-1.8752 (-9.8008)*	-1.6271 (-2.0057)*
δ_7	$z_7 = JAC$	-	-	-	-	-
δ_8	$z_8 = K * z_1$	-	-	-0.0439 (-4.8834)*	0.1040 (5.9541)*	-0.1264 (-10.2127)*
δ_9	$z_9 = K * z_2$	-	-	-0.0947 (-4.5659)*	0.3643 (7.4400)*	×
δ_{10}	$z_{10} = K * z_3$	-	-	-0.1739 (-17.010)*	-0.2759 (-15.692)*	×
δ_{11}	$z_{11} = K * z_4$	-	-	0.2625 (2.3246)*	0.1316 (1.4122)**	×
δ_{12}	$z_{12} = K * z_5$	-	-	31.6321 (17.7110)*	45.2265 (23.3778)*	×
δ_{13}	$z_{13} = K * z_6$	-	0.0185 (0.1397)	-	0.2967 (7.7056)*	0.2237 (4.0626)*

δ_{14}	$z_{14} = K * z_7$	-	-	-	-	-
δ_{15}	$z_{15} = L * z_1$	-	-	-0.0548 (-3.7707)*	-0.1025 (-0.8685)	×
δ_{16}	$z_{16} = L * z_2$	-	-	-0.3948 (-10.866)*	-0.5089 (-11.448)*	×
δ_{17}	$z_{17} = L * z_3$	-	-	-0.0808 (-8.0736)*	-0.0868 (-9.9107)*	-0.1041 (-9.6827)*
δ_{18}	$z_{18} = L * z_4$	-	-	-0.2555 (-1.7956)*	-0.2438 (-1.8786)*	-0.2423 (-0.6643)
δ_{19}	$z_{19} = L * z_5$	-	-	26.6680 (20.6879)*	16.4541 (12.7542)*	×
δ_{20}	$z_{20} = L * z_6$	-	-0.6011 (-3.6270)*	-	-0.2779 (-5.3199)*	-0.3104 (-3.7025)*
$Log - L$		-219.4883	-217.1360	-209.7461	-145.8776	-168.0226
κ		17	19	31	34	27
AIC		472,9766	472,2720	481,4922	359,7552	390,0452
γ		0.9532 (62.6305)*	0.9131 (4.5177)*	0.6227 (3.9891)*	0.7129 (14.1456)*	0.8395 (108.7716)*
σ^2		1.8512 (3.5366)*	0.8991 (6.3837)*	0.0447 (16.4426)*	0.0354 (15.9772)*	0.1972 (10.8894)*
$\overline{EFF}$		0.7233	0.6969	0.4729	0.5496	0.5882

Numbers in parentheses are t-ratios.
* Statistical significant at 5% significance level
** Statistical significant at 10% significance level
× Excluded due to multicollinearity

Table 6. Alternative estimations of the textiles industry production frontier.

Parameter	Variable	Model I	Model II	Model III	Model IV
Production Frontier					
a_0	constant	0.7328 (11.9281)*	0.6793 (10.2247) *	0.5785 (10.0898)*	0.4557 (7.0982)*
a_K	$(\ln K)$	0.7440 (10.7160)*	0.6716 (9.5571)	0.3507 (5.9835)*	0.2131 (3.0988)*
a_L	$(\ln L)$	0.0829 (1.1752)	0.1572 (2.2159)*	0.5715 (21.9306)*	0.2361 (12.0988)*
a_{JAC}	$(\ln JAC)$	-	-	-0.0028 (-0.4395)	0.0231 (1.3441)**
a_{KK}	$(\ln K)^2$	-0.0012 (-0.0076)	-0.0012 (-0.0670)	0.2578 (8.5942)*	-0.0290 (-0.8530)
a_{LL}	$(\ln L)^2$	-0.0059 (-0.4522)	0.0017 (0.1009)	-0.0002 (-3.8900)*	-0.0088 (-2.1931)*
a_{JACJAC}	$(\ln JAC)^2$	-	-	-0.0167 (-0.1888)	-0.0221 (-0.2335)
a_{KL}	$(\ln K)(\ln L)$	0.0121 (0.4433)	0.0072 (0.2247)	-0.0003 (-3.5571)*	-0.0012 (-2.1321)*

a_{KJAC}	$(\ln K)(\ln JAC)$	-	-	-0.0002 (-0.0006)	-0.0018 (-0.0321)
a_{LJAC}	$(\ln L)(\ln JAC)$	-	-	-0.0004 (-0.5414)	-0.0046 (-0.6772)
a_t	t	0.1776 (3.1038)*	0.1422 (2.4141)*	-0.0007 (-2.4396)*	0.0017 (2.0122)*
a_{tt}	t^2	0.0087 (0.1452)	0.0063 (0.1049)	0.0005 (1.5122)**	0.0035 (1.1072)
a_{tK}	$t(\ln K)$	0.0363 (2.5510)*	0.0117 (1.7672)*	-0.0090 (-0.3723)	0.0213 (1.9821)*
a_{tL}	$t(\ln L)$	-0.0018 (0.7620)	0.0021 (0.4552)	(0.0033) (2.8593)*	-0.0044 (0.6570)
a_{tJAC}	$t(\ln JAC)$	-	-	0.0192 (1.8876)*	0.0218 (1.6992)*
Inefficiency Model					
δ_0	constant	-0.0971 (-0.4145)	-0.6596 (2.2098)	-1.9449 (-4.2169)*	-0.2312 (-3.0811)*
δ_1	$z_1 = FIXTOTOT$	1.3762 (3.9205)*	2.2788 (4.8597)*	-0.1733 (-3.2390)*	1.0989 (2.1277)*
δ_2	$z_2 = PRFMARGN$	-1.0217 (-7.8783)*	-0.9876 (-7.5851)*	0.2434 (1.4053)**	0.1888 (0.7743)
δ_3	$z_3 = DEBT$	-1.2740 (-3.7316)*	-1.0792 (-2.9464)*	-0.0014 (-3.5836)*	-1.0325 (-1.7663)
δ_4	$z_4 = AGE$	-0.0057 (-2.6213)*	-0.0007 (-0.2470)	0.0099 (0.0500)	0.0034 (0.0632)
δ_5	$z_5 = MRKTSHR$	-19.0783 (-1.9776)*	-24.8203 (-2.1775)*	-12.0004 (-1.2134)	-11.3221 (-1.4554)**
δ_6	$z_6 = MAR$	-	-	-	-
δ_7	$z_7 = JAC$		-0.0014 (-3.1453)*	-	-0.0211 (-2.2294)*
δ_8	$z_8 = K * z_1$	0.2471 (1.2842)**	0.7678 (3.3879)*	-	×
δ_9	$z_9 = K * z_2$	0.0033 (0.0178)	-0.0298 (-0.1555)	-	-0.0162 (-0.0762)
δ_{10}	$z_{10} = K * z_3$	0.0912 (0.4810)	0.3103 (1.4766)**	-	×
δ_{11}	$z_{11} = K * z_4$	-0.0066 (-2.1989)*	-0.0117 (-3.3048)*	-	-0.0321 (-2.8775)
δ_{12}	$z_{12} = K * z_5$	3.2802 (1.7003)*	4.0819 (2.0381)*	-	2.0878 (3.1221)*
δ_{13}	$z_{13} = K * MAR$	-	-	-	-
δ_{14}	$z_{14} = K * JAC$	-	-16.6506 (-3.6451)*	-	-4.3212 (-2.0908)*
δ_{15}	$z_{15} = L * z_1$	-0.3665 (-1.5675)**	-0.6322 (-2.6643)*	-	×

δ_{16}	$z_{16} = L * z_2$	-0.2638 (-1.1287)	-0.2145 (-0.9106)	-	×
δ_{17}	$z_{17} = L * z_3$	-0.5378 (-3.0953)*	-0.6188 (-2.9187)*	-	×
δ_{18}	$z_{18} = L * z_4$	-0.0034 (-0.9356)	0.0043 (1.0271)	-	0.0353 (0.9144)
δ_{19}	$z_{19} = L * z_5$	7.7861 (1.9312)*	9.4226 (2.1955)*	-	×
δ_{20}	$z_{20} = L * MAR$	-	-	-	-
δ_{21}	$z_{21} = L * JAC$	-	-6.7237 (-2.5259)*	-	-3.1998 (-1.7731)*
δ_{22}	$z_{22} = JAC * z_1$	-	-	-0.6702 (-1.0315)	×
δ_{23}	$z_{23} = JAC * z_2$	-	-	-0.0003 (-0.6678)	×
δ_{24}	$z_{24} = JAC * z_3$	-	-	0.1540 (0.6253)	×
δ_{25}	$z_{25} = JAC * z_4$	-	-	-0.0004 (- 1.4474)**	-0.0018 (-1.8552)*
δ_{26}	$z_{26} = JAC * z_5$	-	-	-0.0006 (-0.2176)	×
δ_{27}	$z_{27} = JAC * z_6$	-	-	-	-
δ_{28}	$z_{28} = JAC * z_7$	-	-	-	-
$Log - L$		-786.6735	-698.9198	-763.9198	-752.8791
k		26	29	26	29
AIC		1625.347	1455.84	1579.84	1563.757
γ		0.6709 (20.0109)*	0.8085 (19.3258) *		
σ^2		0.4596 (9.9640)*	0.5367 (9.0452)*		
$\overline{EFF}$		0.6462	0.6737		

Numbers in parentheses are t-ratios.
* Statistical significant in 5% significance level
** Statistical significant in 10% significance level
× Excluded due to multicollinearity

The overall impact of agglomeration economies on firms' productive performance

From all the empirical results presented and discussed above agglomeration economies in the form of MAR economies act both as inputs and inefficiency factors in the case of the machineries industry while Jacobs agglomeration economies act only as a factor reducing inefficiency in the case of the textiles industry. In order to determine the overall influence of the agglomeration economies proxies on firms' productive performance we use a composite measure which takes account of the several piecemeal and segmented influences. Following Battese and Broca (1997), we estimate the output elasticity with respect to the agglomeration economies proxies $\left(\varepsilon_E^q\right)$, taking into account that in our case the MAR agglomeration economies affect both the deterministic part of the frontier and the inefficiency model. Thus, the output elasticity is defined as the sum of the frontier elasticity $\left(\varepsilon_E^f\right)$ and the technical inefficiency elasticity $\left(\varepsilon_E^u\right)$ with respect to the MAR agglomeration proxy. Hence, in the case of the translog non-neutral stochastic frontier, the output elasticity with respect to agglomeration economies is:

$$\frac{\partial \ln E(q_i)}{\partial \ln \tilde{x}_E} = \beta_E + 2\beta_{EE} \ln \tilde{x}_E + \sum_{j=K,L} \beta_{jE} \ln x_{ji} + \beta_{ET} T - C_i \left(\frac{\partial \mu_i}{\partial \ln \tilde{x}_E} \right) \qquad (10)$$

The term $\varepsilon_E^f = \left(\beta_E + 2\beta_{EE} \ln \tilde{x}_E + \sum_{j=K,L} \beta_{jE} \ln x_j + \beta_{ET} T \right)$ represents the elasticity of the frontier output with respect to MAR agglomeration economies. In other words, the specific term is a measure of the effect exercised by MAR agglomeration economies on the position and the shape of the firms' production frontier. On the other hand the term $\varepsilon_E^u = C_i \left(\partial \mu_i / \partial \ln \tilde{x}_E \right)$, is the elasticity of technical inefficiency and captures the influence exercised by MAR agglomeration economies on a firm's technical efficiency, where μ_{it} is the mean of the distribution of the inefficiency model. That is,

$$\mu_i = \delta_0 + \sum_q^Q \delta_q z_{qi} + \sum_q^Q \delta_{eq} z_q \ln x_e$$

Following Battese and Broca (1997), it can be shown that:

$$C_{it} = 1 - \frac{1}{\sigma} \left\{ \frac{\phi\left(\frac{\mu_{it}}{\sigma} - \sigma \right)}{\Phi\left(\frac{\mu_{it}}{\sigma} - \sigma \right)} - \frac{\phi\left(\frac{\mu_{it}}{\sigma} \right)}{\Phi\left(\frac{\mu_{it}}{\sigma} \right)} \right\}$$

where ϕ and Φ represent the density and distribution functions of the standard normal random variable, respectively. Essentially, the term C_i disentangles the influence of MAR agglomeration economies change in two parts. The first is the inefficiency term and the second is the white noise of the stochastic frontier of firms in the machineries industry.

Figure 2 shows a smoothed frequency diagram of the firms in our machineries sample according to their attained frontier elasticity with respect to the MAR agglomeration variable as an input. In the period 1989-91, of the 189 observations, 82 firms achieved elasticities in the range 0.5-1.0 due to the operation of the MAR agglomeration variable as an input and 92 firms in the range 1.0-1.5. In the period 1999-01, the respective frequencies are 67 and 112 out of the 193 observations. Figure 3 shows the smoothed frequency diagram of the elasticities achieved by the same firms with respect to the MAR agglomeration variable as a factor reducing inefficiency. In the period 1989-91, of the 189 observations, 121 firms achieved elasticities in the range -1.5 to -1.0 due to the operation of the MAR agglomeration variable as a factor reducing inefficiency.

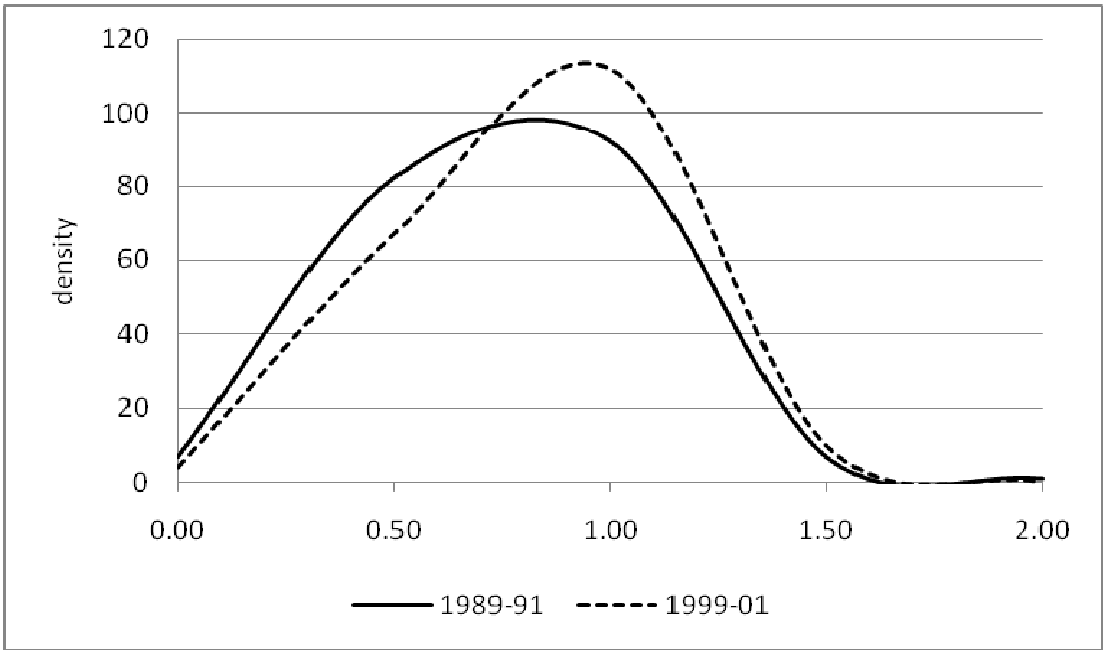

Figure 2. Frontier elasticity with respect to the MAR agglomeration as an input among firms in the machineries industry.

The total effect of the MAR agglomeration variable on output is shown in figure 4 where 144 and 124 firms reached elasticities of more than 2 in the periods 1989-91 and 1999-01 respectively. Figure 5 shows the smoothed frequency diagram of the elasticities achieved by the firms in the textiles industry with respect to the JAC agglomeration variable as a factor reducing inefficiency. In the period 1989-91, of the 572 observations, 457 firms achieved elasticities in the range -2.0 to -1.0 due to the operation of the JAC agglomeration variable as a factor reducing inefficiency.

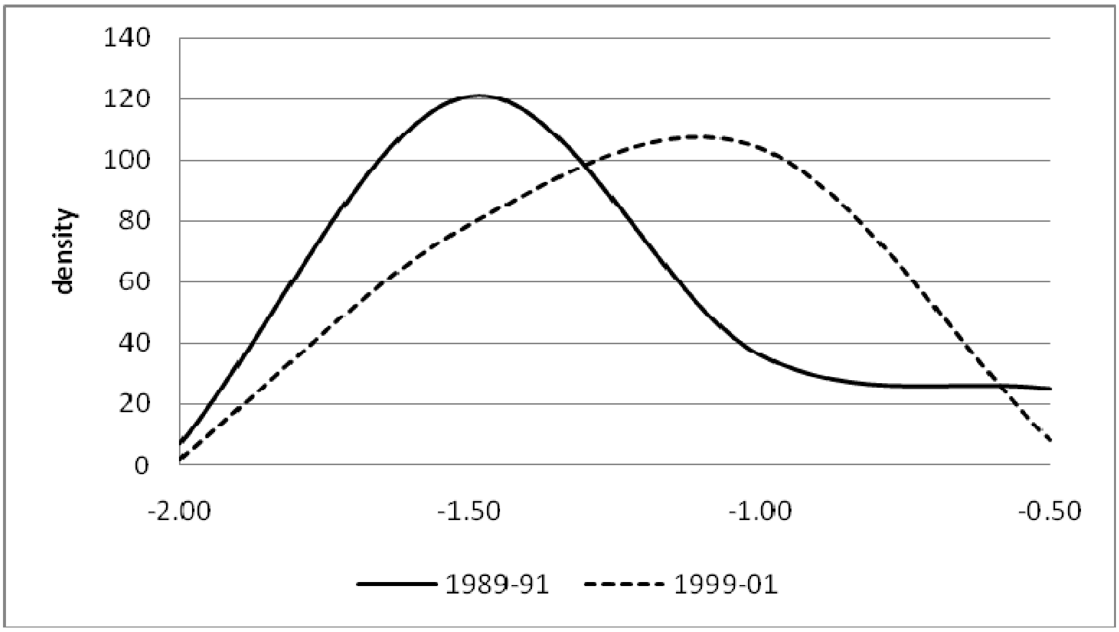

Figure 3. Inefficiency elasticity with respect to the MAR agglomeration as a factor affecting inefficiency among firms in the machineries industry.

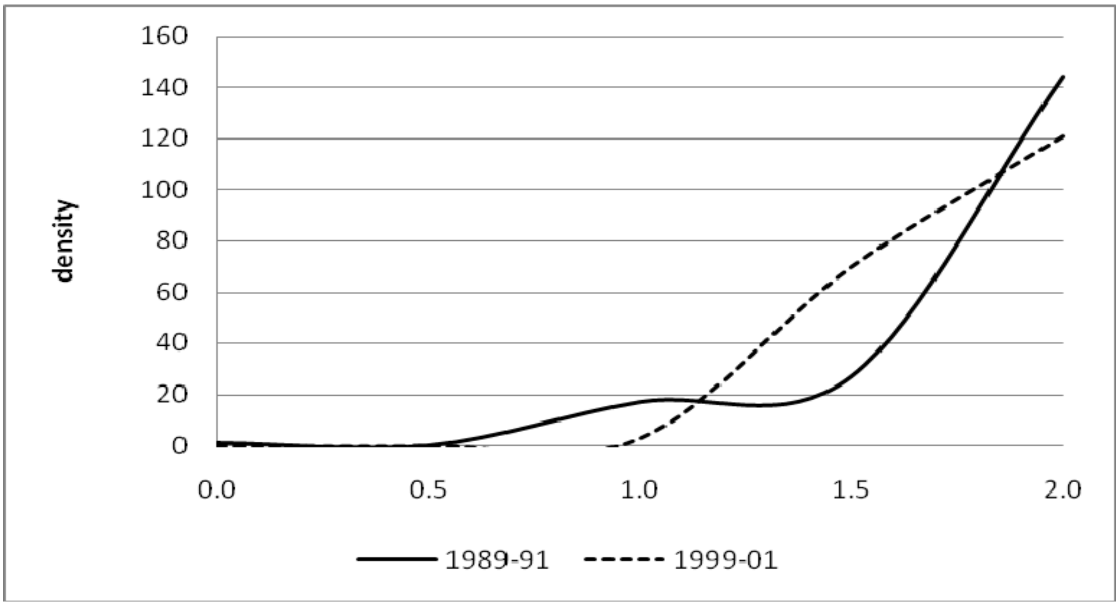

Figure 4. Total elasticity with respect to the MAR agglomeration as both an input and a factor affecting inefficiency among firms in the machineries industry.

Figure 5. Inefficiency elasticity with respect to the JAC agglomeration as a factor affecting inefficiency in the textiles industry.

Business characteristics and MAR type agglomeration economies

It is worth searching a little further the characteristics of the firms that have made the most out of the MAR economies in terms of the elasticity attained through the MAR's variable effect on the frontier, the inefficiency model and their additive effect as total elasticity. For this reason, we constructed three sub-samples from the original sample and for each time period, each sub-sample containing 30% of the firms which score the highest in the respective elasticity, i.e. the elasticity due to the MAR variable's effect on the frontier, the inefficiency and the total. From now on we will refer to these three categories of firms as FREL (FRontier ELasticity, TEEL (Technical Efficiency Elasticity) and TOTEL (TOTal ELasticity) following with the number 1 if the firms are in the first cohort of 1989-91 and the number 2 if they are from the second cohort of 1999-01. The top 30% in the first cohort comprise of 57 firms and in the second cohort of 58 firms in each category.

The first surprise comes from the fact that there is not even one common firm between the sub-sample of FREL and TEEL (i.e., the firms scoring the top 30% in the frontier and inefficiency elasticities). The two sub-sample in both periods are comprised of totally different firms. Furthermore, those firms scoring the top 30% of the total elasticity (i.e, the TEEL sub-sample), are comprised in the first period by 26 firms (46%) which also belong to the FREL category, 18 firms (32%) which also belong to the TEEL category and 13 firms (22%) which do not belong to any of the two categories but score at the top 30% of the total elasticity. In the second period the respective shares of the TOTEL category are 69%, 12% and 19%.

Table 7 reveals some sharp differences. In both cohorts, the first difference is between those firms scoring at the top 30% in the three categories and the rest of the firms in the category and the second difference is among the firms which score at the top 30% among the three categories. Firms in the FREL category in both cohorts are significantly larger than the rest of the firms in the sample and the firms in the TEEL and TOTEL categories as concerns their output, capital, employed labour, and invested capital per employee. Firms in the TEEL category are significantly smaller than the rest of the firms and the firms in the FREL and TOTEL categories as concerns all the above variables. Firms in the TOTEL category approach the sample average in the first cohort, are more like firms in the FREL category in the second cohort and are significantly larger than firms in the TEEL category. From all the above we may assume, very safely, that the utilization of the MAR agglomeration economies segregates their population in two distinct clusters. First, large firms make use of MAR agglomeration economies as an input contributing to the creation of new knowledge and the elasticity of the MAR variable with respect to the frontier's kernel is high. Second, small firms make use of MAR agglomeration economies as existing knowledge that reduces their productive inefficiency and thus the elasticity of the MAR variable with respect to the technical efficiency is high.

Table 7. Basic Descriptive Statistics of Firms in Terms of MAR Utilization.

	1989-1991							1999-2001						
	FREL		TEEL		TOTEL		ALL	FREL		TEEL		TOTEL		ALL
	Top30%	All Others	Top30%	All Others	Top30%	All Others		Top30%	All Others	Top30%	All Others	Top30%	All Others	
Q	2,968,069	1,052,857	653,210	2,052,455	1,206,203	1,813,663	1,630,461	5,092,724	1,299,088	1,095,001	3,003,999	4,663,308	1,482,221	2,433,268
K	3,433,806	871,612	446,202	2,161,713	1,859,046	1,551,622	1,644,337	7,041,026	1,456,210	858,187	4,093,009	6,642,418	1,626,205	3,125,897
L	36.8	24.2	18.5	32.1	25.3	29.2	28.0	49.7	21.4	22.3	33.1	52.0	20.4	29.9
z5	26,253	11,729	6,958	20,061	19,857	14,491	16,110	58,679	24,258	8,498	45,659	47,965	28,828	34,549
FREL	1.325	0.902	0.790	1.133	1.156	0.975	1.030	1.386	0.960	0.865	1.182	1.298	0.997	1.087
TEEL	-0.692	-1.147	-1.357	-0.859	-1.129	-0.958	-1.010	-0.748	-1.048	-1.223	-0.845	-0.891	-0.987	-0.958
TOTEL	2.017	2.049	2.148	1.993	2.285	1.933	2.039	2.133	2.008	2.088	2.027	2.189	1.984	2.045
MAR	1.335	1.057	1.051	1.180	1.296	1.074	1.141	1.213	0.986	1.111	1.030	1.244	0.973	1.054
JAC	0.024	0.030	0.031	0.027	0.030	0.027	0.028	0.018	0.022	0.019	0.022	0.018	0.022	0.021
N	57	132	57	132	57	132	189	58	136	58	136	58	136	194

Furthermore, it is very important to follow the pathway of development of the firms in the first period and the historical trajectory of the firms in the second period with respect to the utilization of the MAR agglomeration variable. Table 8 shows what happened to the MAR champions of the 1989-91 cohort and where from the MAR champions of the 1999-01 cohort come. Table 8 shows across a row what happened to the 1989-91 MAR champions and down a column where did they come from the 1999-01 MAR champions. From those 57 firms in 1989-91 that scored the top 30% MAR elasticities with respect to the frontier (FREL), 7 of them (12.3%) remained FREL champions, 8 of them (14.0%) became TEEL champions and 7 of them (12.3%) became TOTEL champions in 1999-01. Furthermore, 5 of them (8.8%) did not score at the top 30% of any of the above categories in 1999-01, while 18 of them (31.6%) ceased operation and 12 of them (21.0%) changed their operation from manufacturing to trading companies. From those 57 firms in 1989-91 that scored the top 30% MAR elasticities with respect to technical efficiency (TEEL), 8 of them (14.0%) remained TEEL champions, but 25 of them (43.9%) ceased operation and 13 of them (22.8%) changed their operation from manufacturing to trading companies.

Table 8. Where do they come from and what happens to the MAR champions?

1989-91	1999-01					
	Top 30% FREL	Top 30% TEEL	Top 30% TOTEL	None	Exits	
					Ceased	Changed
Top 30% FREL	7 (12.3)* (12.1)**	8 (14.0) (13.8)	7 (12.3) (12.1)	5 (8.8) (8.6)	18 (31.6)	12 (21.0)
Top 30% TEEL	5 (8.8) (8.6)	8 (14.0) (13.8)	4 (7.0) (6.9)	2 (3.5) (3.4)	25 (43.9)	13 (22.8)
Top 30% TOTEL	7 (12.3) (12.1)	4 (7.0) (6.9)	4 (7.0) (6.9)	7 (12.3)	20 (35.1)	15 (26.3)
None	6 (10.3)	3 (5.2)	9 (15.5)	———	———	———
Entry	27 (46.6)	19 (32.7)	28 (48.3)	———	———	———
Appeared	6 (10.3)	16 (27.6)	6 (10.3)	———	———	———

*=row percentage, **=column percentage

Reading down the first column, from those 58 firms in 1999-01 that scored the top 30% MAR elasticities with respect to the frontier (FREL), 7 of them (12.1%) came from the 1989-91 FREL champions, 5 of them (8.6%) came from the 1989-91 TEEL champions and 7 of them (12.1%) came from the 1989-91 TOTEL champions. Furthermore, 6 of them (10.3%) did not score at the top 30% of any of the above categories in 1989-91, while 27 of them (46.6%) are new entries and 6 of them (10.3%) are existing companies which were not recorded in 1989-91 database but appear in 1999-01. The 1999-01 TEEL champions present the lowest entry rate. In general, one may argue that there is a very significant mobility among categories and firms do not hold on the advantage derived by their large MAR elasticities in one time period to the consecutive time period. Firms in the FREL category face the lowest exit risk and the highest entry rates. Firms in the TEEL category face the highest exit risk and the smallest entry rates.

Business characteristics and Jacob's type agglomeration economies

In order to search the characteristics of the firms that have made the most out of the JAC economies in terms of the elasticity attained through the JAC's variable effect on the inefficiency model we constructed one sub-samples from the original sample of firms in the textiles industry and for each cohort. Each sub-sample contains 30% of the firms which score the highest in the respective elasticity in each period. The top 30% in the first cohort comprise of 172 firms and in the second cohort of 107 firms.

Table 9. Basic Descriptive Statistics of Firms in Terms of JAC Utilization.

	1989-91			1999-01		
	Top30%	All Others	All	Top30%	All Others	All
Q	12,923,939	1,495,230	4,931,835	14,078,466	1,991,840	5,634,852
K	16,626,531	1,275,398	5,891,473	25,177,413	2,378,327	9,250,164
L	332.28	28.05	119.53	141.82	24.52	59.88
K/L	74,213.7	59,538.0	63,950.9	207,465.3	118,832.9	145,547.5
TEEL	-0.533	-0.044	-0.191	-0.609	-0.064	-0.229
MAR	1.199	1.010	1.067	1.395	1.187	1.250
JAC	0.031	0.030	0.030	0.030	0.019	0.022
N	172	400	572	107	248	355

Table 9 reveals some sharp differences among the firms that utilized JAC agglomeration economies to reduce inefficiency and all others in both cohorts. The top 30% in terms of JAC utilization are really large firms in terms of production, invested capital and employed labour. This makes also a sharp difference between MAR and JAC agglomeration economies. When MAR economies operate as a factor reducing inefficiency, the top 30% of firms in the machineries industry in terms of inefficiency reduction are smaller than the rest of the firms in the machineries industry and not the largest as in the textiles industry. Thus we may assume, very safely, that the utilization of the JAC agglomeration economies segregates the population of firms in the textiles industry in two distinct clusters. The cluster of large firms that make use of JAC agglomeration economies as a factor reducing inefficiency and the cluster of small firms that fail to reclaim such benefits. Of the 172 firms in the top 30% in the first period, 77 (44.8%) survived through the next period while the respective figure for those firms not in the top 30% is 100 out of 400 or 25%. Of the 77 cases that survived to the next period, 75% are also in the top 30% of firms of the second period. Thus, firms that utilize JAC agglomeration economies as a factor reducing inefficiency are survivors and hold on their advantage through time.

Conclusions

Our work attempted to decipher the effects of agglomeration economies on firms' productivity. Our first conclusion re-confirms older results that the effects of agglomeration economies are industry specific. Not all industries benefit from the same agglomeration economies in the same way. In our study, the machineries industry benefits from MAR and not from Jacob's type agglomeration economies while the textiles industry benefits from Jacob's and not from MAR type agglomeration economies. Our second conclusion shows that agglomeration economies may exercise a twin effect on firms' productive efficiency. First, as in the case of the machineries industry in our study, MAR agglomeration economies may act as a new input and affect the kernel of the production frontier. Second, agglomeration economies may act as a factor reducing technical inefficiency with non-neutral effects with labour and capital as in the case of both the machineries and the textiles industries in our study. Our third conclusion shows that not all firms make the same use of agglomeration economies either as an input or as a factor reducing inefficiency. In the machineries industry larger firms make a more intense use of agglomeration economies as an input while smaller firms treat agglomeration economies as a factor reducing inefficiency. In the case of the textiles industry the contradicting non-neutral effects, between agglomeration economies and labour and capital respectively, favour the use of agglomeration economies as a factor reducing inefficiency by larger firms. The fourth conclusion shows that the effect of agglomeration economies on firms' productive efficiency establishes a path dependency. Firms that make significant use of agglomeration economies survive to the next period at higher percentages in comparison to other firms in the same industry. At the same time, entrants are favoured by MAR type agglomeration economies while incumbents are favoured by Jacob's type agglomeration economies.

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Appendix – Model Specification and Hypotheses Testing

If we consider that the best approximation of the production frontier is achieved by a translog function, the baseline model of the production frontier without inefficiency factors, i.e. the Error Component Model (ECM), described in equations 3 and 4 may be written as:

$$\ln Q = a_0 + \sum_{i=K,L} a_i \ln x_i + \frac{1}{2}\sum_{i=K,L}\sum_{j=K,L} a_{ij} \ln x_i \ln x_j + v - u \qquad \textbf{model A}$$

In the same way, the Technical Efficiency Effects Model (TEEM) described by equation (6) may be written as:

$$\ln Q = a_0 + \sum_{i=K,L} a_i \ln x_i + \frac{1}{2}\sum_{i=K,L}\sum_{j=K,L} a_{ij} \ln x_i \ln x_j + v - u$$

model C

$$u = \delta_0 + \sum_{j=1} \delta_j z_j + w$$

In their extension of the aforementioned models, Battese and Brocca (1997) introduced non-neutral specifications of the stochastic frontier which nest the technical efficiency effects model (Battese and Coelli, 1995) which, in turn, nests the error components model (Battese and Coelli, 1992). More specifically the inefficiency term, u, may be approximated by:

$$\ln Q = a_0 + \sum_{i=K,L} a_i \ln x_i + \frac{1}{2}\sum_{i=K,L}\sum_{j=K,L} a_{ij} \ln x_i \ln x_j + v - u$$

model J

$$u_i = \delta_o + \sum_{j=1} \delta_j z_{ji} + \sum_{j=1}\sum_{k=1} \gamma_{kj} z_{ji} x_{ki} + w_i$$

which, is called non-neutral technical efficiency effects model. The specific model explicitly adopts the assumption that the inefficiency effects are functions of all the input variables. All interactions between a specific technical inefficiency effect and all inputs show the factor of production that is affected the most by the specific inefficiency factor and the direction (negative or positive) in which this factor of production is affected. If we consider agglomeration economies to be an input to production, this enhances the bundle of inputs such as capital and labour with a 'new' input, the above described baseline models are encompassing this new factor in their production function. The Error Component Model (ECM) becomes:

$$\ln Q = a_0 + \sum_{i=K,L} a_i \ln x_i + \frac{1}{2}\sum_{i=K,L}\sum_{j=K,L} a_{ij} \ln x_i \ln x_j + a_{agg}x_{agg} + u - v$$ **model B**

where x_{agg} is the respective agglomeration variable. Correspondingly, the technical efficiency effects model (TEEM) with agglomeration economies as an input of production becomes:

$$\ln Q = a_0 + \sum_{i=K,L} a_i \ln x_i + \frac{1}{2}\sum_{i=K,L}\sum_{j=K,L} a_{ij} \ln x_i \ln x_j + a_{agg}x_{agg} + u - v$$

model D

$$v = \delta_0 + \sum_{j=1} \delta_j z_j + w$$

and the non-neutral variant of the above model becomes:

$$\ln Q = a_0 + \sum_{i=K,L} a_i \ln x_i + \frac{1}{2}\sum_{i=K,L}\sum_{j=K,L} a_{ij} \ln x_i \ln x_j + a_{agg}x_{agg} + u - v$$

model G

$$v = \delta_0 + \sum_{j=2} \delta_j z_j + \sum_{j=1} \delta_{agg,j} x_{agg} z_j + w$$

If agglomeration economies is not considered to be an input of production but is considered simply as a process that may assist firms to reduce production inefficiencies or as a factor that aggravates inefficiencies by creating congestion, then the Technical Efficiency Effects Model (TEEM) becomes:

$$\ln Q = a_0 + \sum_{i=K,L} a_i \ln x_i + \frac{1}{2}\sum_{i=K,L}\sum_{j=K,L} a_{ij} \ln x_i \ln x_j + u - v$$

model E

$$v = \delta_0 + \delta_{agg} z_{agg} + \sum_{j=1} \delta_j z_j + w$$

and the non-neutral variant of the same model becomes:

$$\ln Q = a_0 + \sum_{i=K,L} a_i \ln x_i + \frac{1}{2}\sum_{i=K,L}\sum_{j=K,L} a_{ij} \ln x_i \ln x_j + u - v$$

model F

$$v = \delta_0 + \delta_{agg} z_{agg} + \sum_{j=2} \delta_j z_j + \sum_{j=K,L} \delta_{agg,j} x_j z_{agg} + w$$

If agglomeration economies act as both a new input of production and a factor affecting production inefficiency, the Technical Efficiency Effects model (TEEM) becomes:

$$\ln Q = a_0 + \sum_{i=K,L} a_i \ln x_i + \frac{1}{2}\sum_{i=K,L}\sum_{j=K,L} a_{ij} \ln x_i \ln x_j + a_{agg} x_{agg} + u - v$$

model H

$$v = \delta_0 + \delta_{agg} x_{agg} + \sum_{j=2} \delta_j z_j + w$$

and its non-neutral variant becomes:

$$\ln Q = a_0 + \sum_{i=K,L} a_i \ln x_i + \frac{1}{2}\sum_{i=K,L}\sum_{j=K,L} a_{ij} \ln x_i \ln x_j + a_{agg} x_{agg} + u - v$$

model I

$$v = \delta_0 + \delta_{agg} z_{agg} + \sum_{j=2} \delta_j z_j + \sum_{j=1} \delta_{agg,j} x_{agg} z_j + \sum_{j=K,L} \delta_{agg,j} z_{agg} x_j + w$$

Within each one of the four vertical flow charts of figure 1, all possible model formulations are explored. More specifically, agglomeration economies are considered to be an input, the first vertical flow chart on the far left of Figure 1 shows that this may be approximated under an Error Components Model (ECM) specification (model B) or under a Technical Efficiency Effects Model (TEEM) specification. The latter may be modelled with neutral (model D) or non-neutral (model G) effects of the inefficiency terms. Accordingly, if agglomeration economies are considered as a simple inefficiency factor, the second from the left vertical flow chart of Figure 1 shows that this may be approximated only by a TEEM specification with neutral (model E) or non-neutral (model F) effects of the inefficiency terms. If agglomeration economies act both as an input and an inefficiency factor, the third from the left vertical flow chart of Figure 1 shows that this may be approximated only by a TEEM specification with neutral (model H) or non-neutral (model I) effects of the inefficiency terms. Finally, if agglomeration economies are not considered either as an input or as an inefficiency term of the production process, the ECM specification (model A) and the TEEM specification (model C) without non-neutral effects are estimated.

All the above models are nested and their differences are in the number of restrictions employed in their estimation. Thus, hypotheses about the nature of technical inefficiencies can be tested using the generalised likelihood ratio statistic,

λ, as $\lambda = -2\left[\ln L\left(H_0\right) - \ln L\left(H_1\right)\right]$ where $L\left(H_0\right)$ and $L\left(H_1\right)$ denote the values of the likelihood function under the null equation. However, the possible combinations of the large number of models estimated in this work, complicates the testing of hypotheses. For this reason, we identified the best four models, one for each of the four vertical flow charts presented in Figure 1. In other words, we find the best model under each one of the four major assumptions concerning the effects of agglomeration on productive efficiency of firms. Then we compare these four models with each other in order to find the model that best describes the effects of agglomeration on productive efficiency of firms and also shows the exact nature of the effects exercised by agglomeration on productive efficiency of firms.

Endnotes

[1] In the context of the non-neutral TEEM modeling procedure, two alternatives arise. The first alternative is the one which incorporates the non-neutral effects which are generated by the interaction of all the inputs with all the inefficiency factors. The second alternative is the one which is restricted to the inclusion in the inefficiency model only of those terms which are generated by the interaction of only a subset of inputs with the inefficiency factors. In the context of the present paper we have followed the second approach since the full version of the non-neutral TEEM approach incorporates thirty-two inefficiency factors and serious multicollinearity problems arise. Specifically, in all the cases where the modeling procedure considers agglomeration economies as an additional factor, the inefficiency model encompasses the non neutral-effects of the $\tilde{x}_E$ input with all the inefficiency factors.