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Spatial Agglomeration of Manufacturing in Greece

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Spatial Agglomeration of Manufacturing in Greece

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Abstract

The agglomeration economies play an important role in the location decisions and development of industries and, hence, the evaluation of regional policies and investment strategies. This paper addresses several intricate issues related to the measurement of localization economies and the estimation of their main determinants in manufacturing sectors. The original empirical analysis employs annual industrial data during the period 1993-2006 in Greece at the prefecture level. The data exploration reveals the temporal persistence of localization economies in Greek manufacturing and the high level of agglomeration associated with the high-technology industries, compared to the medium and low technology industries. The findings obtained from the use of alternative geographic concentration indices and panel data models signify the importance of industry characteristics associated with knowledge externalities, labor skills and productivity, and scale economies on spatial agglomeration. Thus, policies that affect these industry-specific factors can have a significant impact on the regional manufacturing activity. Amongst others, policies which aim at promoting the regional convergence should focus on reducing the transport costs for firms or sectors, including improvements in infrastructure and taxation measures.

Ανάλυση της Χωρικής Συγκέντρωσης της Μεταποιητικής Βιομηχανίας στην Ελλάδα

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Περίληψη

Οι οικονομίες συγκέντρωσης διαδραματίζουν διεθνώς καθοριστικό ρόλο στις αποφάσεις χωροθέτησης, το μέγεθος και την παραγωγικότητα των βιομηχανιών στους κλάδους της μεταποίησης. Συνεπώς, πρέπει να λαμβάνονται υπόψη κατά τον σχεδιασμό και την αξιολόγηση κλαδικών περιφερειακών πολιτικών και επενδυτικών προγραμμάτων. Η εργασία αυτή απευθύνει μια σειρά από ζητήματα που αφορούν στην μέτρηση των οικονομιών τοπικής συγκέντρωσης (ή τοπικοποίησης) και τον καθορισμό των προσδιοριστικών τους παραγόντων στους κλάδους της μεταποίησης στην Ελλάδα. Η πρωτότυπη εμπειρική ανάλυση βασίζεται στην επεξεργασία δεδομένων από τις Ετήσιες Βιομηχανικές Έρευνες την περίοδο 1993-2006 σε επίπεδο Νομού. Η επεξεργασία αυτή δείχνει τη διατήρηση των οικονομιών τοπικοποίησης στους κλάδους της μεταποίησης κατά την διάρκεια της περιόδου μελέτης. Οι βιομηχανίες υψηλής τεχνολογίας συνδέονται με τα μεγαλύτερα επίπεδα χωρικής συγκέντρωσης, σε σύγκριση με τις βιομηχανίες μεσαίας και χαμηλής τεχνολογίας. Τα αποτελέσματα της οικονομετρικής ανάλυσης με τη χρήση εναλλακτικών μεθόδων εκτίμησης δεδομένων ομάδος (τύπου panel) και δεικτών συγκέντρωσης δείχνουν τη στατιστικά σημαντική θετική επίδραση στις οικονομίες βιομηχανικής τοπικοποίησης των ακόλουθων παραγόντων: (i) οικονομίες κλίμακας, (ii) εξωτερικεύσεις λόγω διάθεσης εργατικού δυναμικού, (iii) εξωτερικεύσεις γνώσης, (iv) κάθετες κλαδικές διασυνδέσεις και (v) κόστος μεταφοράς, η αύξηση του οποίου μακροπρόθεσμα ενισχύει τις δυνάμεις χωρικής συγκέντρωσης. Επομένως, πολιτικές οι οποίες επηρεάζουν αυτούς τους παράγοντες, όπως επενδύσεις σε υποδομές, επενδυτικά κίνητρα και χωροταξικές ρυθμίσεις, δύνανται να έχουν σημαντική επίδραση στην βιομηχανική δραστηριότητα, την ανάπτυξη της υπαίθρου και την περιφερειακή σύγκλιση.

1. Introduction

The economies of agglomeration relate to the benefits that firms obtain when locating near each other, mainly due to increasing economies of scale and network effects. The literature refers to *localization* economies in the case where the increasing economies of scale are internal to the industrial sectors, i.e., among the firms belonging to the same sector. The *urbanization* economies are observed in the case where increasing returns of scale arise out of a specific industrial sector, because of clustering of firms belonging to different sectors in the same area. The fact that the geographic concentration of manufacturing firms is ascribed to different sources and the relevant agglomeration economies operate within different scopes (industrial, geographic and temporal) renders their measurement and impact evaluation a complicate task.

This paper aims to discern the patterns and trends of agglomeration and examine the determinants of spatial concentration (localization) of manufacturing industries in Greece in the period spanning 1993-2006. The current approach is initiated by the work of Rosenthal and Strange (2001). It relies on the calculation and comparative investigation of different geographic concentration metrics, such as the raw geographic concentration index and the Krugman spatial concentration index, for each manufacturing industry, and it relates them with important sectoral characteristics. Specifically, the impact of several factors is tested, including labor market pooling externalities, knowledge spillovers, vertical linkages, scale economies, input sharing externalities, and transport costs.

The original empirical analysis can provide useful insight into the microeconomic and market-orientated drivers of localization economies. In accordance with the theoretical framework of new economic geography (NEG), which stresses the importance of those industry-specific and market-driven sources of agglomeration, the study findings can be employed to support the design and evaluation of appropriate economic policies, which can promote the industrial and regional development of the country.

The paper is organized as follows. Section 2 describes the theoretical background and empirical literature regarding agglomeration economies, especially in the manufacturing industries. Section 3 reports alternative metrics for measuring spatial agglomeration. Section 4 provides an exploratory analysis of the observed patterns and trends in spatial agglomeration by industry in Greece. Section 5 presents the determinants of the geographic concentration of manufacturing. Section 6 includes the econometric results of the factors influencing the spatial agglomeration of Greek manufacturing. Section 7 summarizes and provides conclusions.

2. Theoretical and Empirical Literature

Each manufacturing industry can be considered to perform two distinct types of behavior. First, the spatial behavior determines the spatial pattern of manufacturing activity and the degree of geographic concentration or dispersion of the corresponding sector. Second, the sectoral behavior determines the sectoral pattern of manufacturing activity, in terms of which industries are dominant in the market and whether manufacturing activity is diversified or not. Agglomeration forces are critical in shaping the feedback relationship between these two distinct types of behavior of industries.

The literature typically considers the positive effects of spatial agglomeration on industrial and regional development. The related benefits encompass reduced transport and storage costs, increased returns to scale in intermediate inputs for a product, labor pooling externalities, easier interaction between firm agents (producers, suppliers, carriers, wholesalers, retailers etc.), increased specialization and labor productivity, positive knowledge spillovers and innovation. Hence, the presence of spatial agglomeration in manufacturing increases the probability of firm entry and survival rate and enhances a region's attractiveness and appropriateness as an investment location. Empirically, there have been found significant agglomeration benefits on labor productivity, output, employment and other economic measures of manufacturing as well as other sectors of the economy (e.g., Ciccone and Hall, 1996; Tabuchi and Yoshida, 2000; Glaeser et al., 2001; Ciccone, 2002; Foster and Stehrer, 2009). According to Kanemoto (2011), the benefit estimates could exceed 10 percent after combining production and consumption agglomeration economies.

However, the effects of agglomeration economies and estimates for any particular empirical context may have little relevance elsewhere (Melo at al., 2009). Besides, the literature also refers to diseconomies of agglomeration that adversely influence the location of manufacturing firms. These negative economies can arise because of diminishing returns of scale in the production of accessible land, yielding overcrowding or congestion effects, pollution and regulatory costs. Specifically, it has been found that the spatial agglomeration adversely affects growth rate or convergence between European regions, but the opposite holds for the effect of neighboring regions (Bosker, 2007). By and large, there is a possibility that at some point a critical agglomeration limit is reached, after which further increases cause diseconomies in advanced regions (Alexiadis and Tsagdis, 2010).

In the Greek context, Katochianou (1984) investigated the level, evolution and contribution of each sector and prefecture into the regional and national development (in terms of employment) of manufacturing across 1963-1978. She calculated Gini, inter-sectoral and interregional indices and employed rank-order and shift-share analysis, based on statistical data from domestic Industrial Surveys. Later studies in Greece have focused on the positive impact of spatial concentration on the location, start-up and survival of manufacturing firms, without formally measuring the economies of industrial agglomeration in the country.

Specifically, Louri and Anagnostaki (1994) used a comparative model between Athens and the rest of Greece to verify the positive impact of spatial concentration on regional entry preferences of manufacturing firms. Fotopoulos and Louri (2000) examined the effect of agglomeration economies (proxied by population density) on the location and survival of new firms, and Fotopoulos and Spence (1998, 1999) underlined the role of localization and agglomeration on new firm formation in manufacturing. Filippaios and Kottaridi (2004) confirmed that positive agglomeration externalities play a significant role for the location decisions of manufacturing plants in Greek NUTS-II regions[1]. Kottaridi and Lioukas (2011) demonstrated that the attractive local characteristics of large metropolitan hubs (i.e., the NUTS-II regions of Attica and Central Macedonia), compared to the periphery, are catalysts for the location of firms. Daskalopoulou and Liargovas (2008) indicated the effect of spatial agglomeration on the location of new firms. Daskalopoulou and Liargovas (2010) and Liargovas and Daskalopoulou (2011) showed how agglomeration economies have an impact on the regional concentration of Greek manufacturing start-ups, accounting for the existence of different sources of externalities.

Regarding the factors influencing the spatial agglomeration of manufacturing, the literature has identified a rather wide range of determinants (see Rosenthal and

[1] The NUTS (Nomenclature of Territorial Units for Statistics) classification is used in the Community legislation for the sub-national division of regions into 3 levels: Development Regions at NUTS I, Regions at NUTS II and Prefectures at NUTS III.

Strange, 2001; Duranton and Puga, 2004; Rosenthal and Strange, 2004). Most of these rely on better matching, sharing, gains in variety and learning mechanisms, while particular emphasis has been given to the importance of labor market pooling, input sharing and knowledge spillovers. The current study employs alternative indices for measuring spatial agglomeration (Section 3) as well as alternative specifications for identifying the impact of several determinants (Section 5).

3. The Measurement of Spatial Agglomeration

In general, a given industry is referred to as being 'geographically concentrated', 'agglomerated', 'clustered', or 'localized', if a large part of its total production (or employment) takes place in a few locations (regions). There are several ways to assess the extent of spatial concentration of industries. In order to consistently address measurement issues, alternative absolute and relative metrics (indices) of industrial agglomeration have been suggested and compared in the empirical literature. In particular, Fratesi (2008) performed such an investigation for the localization of manufacturing, correcting both for the agglomeration of the whole economy and for the internal structure of each sector.

In this paper, we calculate two alternative measures of spatial agglomeration, namely, the Krugman's spatial concentration index and the raw geographic concentration index as defined by Ellison and Glaeser (1997). The Krugman index is defined as follows:

$$K_i = \sum_r |x_r - s_r| \quad (1)$$

where $x_r = \frac{\sum_i Q_{ir}}{\sum_i \sum_r Q_{ir}}$ and $s_r = \frac{Q_{ir}}{\sum_r Q_{ir}}$

The variable Q_{ir} denotes the output (or employment) in industry i of region r; hence, x_r is the share of total output (or employment) of region r in the total country output (or employment) and s_r is the share of output (or employment) in the industry i of region r in the total country's industry output (or employment). This index takes values between 0 and 2, with larger values indicating a higher extent of spatial agglomeration of a given industry. We employ this index because it is a relative measure of spatial agglomeration and has been widely used in the literature. It is noted that an absolute measure is affected by the absolute size of regions in the total country's output or employment and, thus, the interpretation of the results of an absolute index could be misleading.

The second agglomeration measure that is used here refers to the raw geographic concentration index, which is defined as:

$$G_i = \sum_r (x_r - s_r)^2 \qquad (2)$$

where x_r and s_r denote the shares mentioned before. This index, which is also relative in nature, is used by Ellison and Glaeser (1997) in their γ-index, which is essentially the difference between the G and the Herfindahl index. The γ-index calculation requires firm-level data to determine the Herfindahl index, which takes into account the market concentration in an industry when evaluating its geographic concentration. However, due to the unavailability of these disaggregate firm data, the γ-index is not used here. Under certain conditions (if the total output or employment is more or less uniformly distributed across regions), the G index takes values exactly in the range [0, 1] and approximates the spatial Gini coefficient. Depending on the baseline distribution, the measure in practice usually takes values between 0 and close to (but less than) 1, with higher values indicating higher geographic concentration.

4. Patterns and Trends in Spatial Agglomeration by Industry in Greece

4.1 Analysis of trends in industrial agglomeration

The aforementioned indices are calculated for each year during the sample period 1993-2006 and for each of the 22 manufacturing sectors, using both output and employment data at the prefecture (NUTS III) level, which corresponds to 51 prefectures. Namely, there are a total of 15,708 raw data observations which are used for calculating the geographic concentration indices. The source for the sectoral and regional data is the Hellenic Statistical Authority (ELSTAT). For demonstration purposes, Tables 1 and 3 present the descriptive patterns and trends in the spatial concentration of each industry for the initial and final year for which we possess data, 1993 and 2006, respectively. In each table, there are four columns of results, which correspond to the two alternative indices calculated with employment and output data.

Table 1: Spatial Agglomeration patterns in year 1993

ISIC	Industry description	***G***		***K***	
		Empl.	Output	Empl.	Output
15	Manufacture of food products & beverages	0.02169	0.01994	0.41169	0.44432
16	Manufacture of tobacco products	0.27253	0.37199	0.99597	1.14356
17	Manufacture of textiles	0.02562	0.02910	0.49400	0.55875
18	Manufacture of wearing apparel	0.06341	0.06299	0.70941	0.68124
19	Manufacture of leather, handbags & footwear	0.09348	0.08671	0.63177	0.67286
20	Manufacture of wood & products thereof	0.12267	0.17514	0.91709	1.04377
21	Manufacture of paper and paper products	0.08105	0.08189	0.66353	0.72961
22	Publishing, printing & recorded media	0.17889	0.25928	0.82700	0.96962
23	Manufacture of coke & refined petroleum prod.	0.19770	0.10667	0.86236	0.77925
24	Manufacture of chemicals and chemical products	0.12813	0.09481	0.69497	0.63310
25	Manufacture of rubber and plastics products	0.01847	0.02272	0.47435	0.45965
26	Manufacture of other non-metallic mineral prod.	0.06559	0.07799	0.65438	0.68811
27	Manufacture of basic metals	0.09701	0.16347	0.81092	0.84198
28	Manufacture of fabricated metal products	0.00756	0.01162	0.32222	0.31955
29	Manufacture of machinery and equipment n.e.c.	0.02064	0.04139	0.41585	0.52114
31	Manufacture of electrical machinery & apparatus	0.05784	0.14683	0.73735	1.07511
32	Manufacture of radio, TV & communication eq.	0.11004	0.09261	0.73827	0.77925
33	Manufacture of medical, & precision instruments	0.15753	0.16097	0.77277	0.77925
34	Manufacture of motor vehicles & trailers	0.18319	0.27333	0.82817	0.99330
35	Manufacture of other transport equipment	0.13509	0.14837	0.89794	0.91708
36	Manufacture of furniture; manufacturing n.e.c.	0.01990	0.03483	0.45323	0.55931

Notes: *G* stands for the raw geographic index in equation (2) and *K* for the Krugman index in equation (1). ***Source:*** Authors' own calculations based on data from ELSTAT.

Table 2: Correlation matrix for spatial agglomeration indices in year 1993

	G (employment)	*G* (output)	*K* (employment)	*K* (output)
G (employment)	1			

G (output)	0.878786	1		
	(0.0000)	-----		
K (employment)	0.875362	0.824931	1	
	(0.0000)	(0.0000)	-----	
K (output)	0.764047	0.877417	0.913891	1
	(0.0001)	(0.0000)	(0.0000)	-----

Notes: Pearson correlation coefficients are shown. The numbers in parentheses are *p*-values.

As it is evident from Table 1, the most geographically concentrated industries (categorized according to the International Standard Industrial Classification or ISIC) in 1993 pertain to the manufacture of tobacco products, manufacture of coke &

refined petroleum products, manufacture of motor vehicles & trailers, publishing, printing & recorded media, and manufacture of medical & precision instruments. The least spatially agglomerated (or most dispersed) industries are manufacture of fabricated metal products, manufacture of rubber and plastics products, manufacture of furniture, and manufacture of food products & beverages.

These concentration patterns are produced with the employment data, which are the most commonly used for such purposes in the literature. However, the picture that emerges from the use of output data is more or less the same regarding the agglomeration of manufacturing industries. This is confirmed by the findings of the correlation analysis of the four indices in the year 1993 (see Table 2). It is found that a very high and statistically significant correlation exists between the G indices calculated from employment and output data, between the K indices calculated from employment and output data, and between the G and K indices.

Table 3: Spatial Agglomeration patterns in year 2006

ISIC	Industry description	***G***		***K***	
		Empl.	Output	Empl.	Output
15	Manufacture of food products & beverages	0.03091	0.05309	0.45875	0.57920
16	Manufacture of tobacco products	0.32286	0.34308	1.07585	1.10181
17	Manufacture of textiles	0.08662	0.12004	0.87396	1.05237
18	Manufacture of wearing apparel	0.06483	0.18449	0.72816	1.03717
19	Manufacture of leather, handbags & footwear	0.20127	0.22209	0.87083	0.89242
20	Manufacture of wood & products thereof	0.10338	0.17371	1.10004	1.30555
21	Manufacture of paper and paper products	0.01692	0.03261	0.50648	0.58934
22	Publishing, printing & recorded media	0.17586	0.25256	0.80979	0.94289
23	Manufacture of coke & refined petroleum prod.	0.32286	0.34308	1.07585	1.10181
24	Manufacture of chemicals and chemical products	0.09846	0.06837	0.61359	0.63486
25	Manufacture of rubber and plastics products	0.03332	0.05032	0.59338	0.68341
26	Manufacture of other non-metallic mineral prod.	0.04122	0.05685	0.53060	0.57913
27	Manufacture of basic metals	0.11428	0.20376	0.86901	0.97675
28	Manufacture of fabricated metal products	0.01162	0.05650	0.37025	0.54129
29	Manufacture of machinery and equipment n.e.c.	0.02334	0.03386	0.47843	0.55092
31	Manufacture of electrical machinery & apparatus	0.04697	0.22899	0.71441	1.04423
32	Manufacture of radio, TV & communication eq.	0.17761	0.16366	0.81568	0.84154
33	Manufacture of medical, & precision instruments	0.32286	0.34308	1.07585	1.10181
34	Manufacture of motor vehicles & trailers	0.20286	0.31090	0.87106	1.05279
35	Manufacture of other transport equipment	0.10033	0.10427	0.81545	0.77943
36	Manufacture of furniture; manufacturing n.e.c.	0.03682	0.04677	0.52102	0.62449

Notes: G stands for the raw geographic index in equation (2) and K for the Krugman index in equation (1). ***Source:*** Authors' own calculations based on data from ELSTAT.

Table 3 shows that, in year 2006, sectors such as manufacture of medical & precision instruments, manufacture of coke & refined petroleum products, manufacture of tobacco products, and manufacture of motor vehicles & trailers exhibit the highest spatial concentration in the country. On the other hand, the lowest geographic agglomeration is found in fabricated metal products, paper and paper products industry, machinery and equipment sector, and in the food products & beverages industry. This pattern is generally evident and reproduced with the use of all the calculated indices. As in year 1993, the correlations among all indices in 2006 are found to be very strong and highly statistically significant (see Table 4).

Table 4: Correlation matrix for spatial agglomeration indices in year 2006

	G (employment)	*G* (output)	*K* (employment)	*K* (output)
G (employment)	1			

G (output)	0.892678	1		
	(0.0000)	-----		
K (employment)	0.831037	0.844278	1	
	(0.0000)	(0.0000)	-----	
K (output)	0.641426	0.821520	0.914872	1
	(0.0017)	(0.0000)	(0.0000)	-----

Notes: Pearson correlation coefficients are shown. The numbers in parentheses indicate *p*-values.

Table 5: Industry agglomeration dynamics between 1993 and 2006

		2006			
		G (employment)	*G* (output)	*K* (employment)	*K* (output)
1993	*G* (employment)	0.864760 (0.0000)			
	G (output)		0.745124 (0.0001)		
	K (employment)			0.778934 (0.0000)	
	K (output)				0.707413 (0.0003)

Notes: Spearman rank correlation coefficients between spatial concentration indices in 1993 and 2006 are shown. The numbers in parentheses indicate *p*-values.

By cross-examining Tables 1 and 3, we note that highly agglomerated industries at the beginning of the period remain to be spatially concentrated at the end of it In order to further examine this observation and the dynamics of industrial agglomeration, that is, whether there has been a significant change in the agglomeration pattern across industries during the sample period, the Spearman rank correlation coefficients are calculated for the geographic concentration indices in

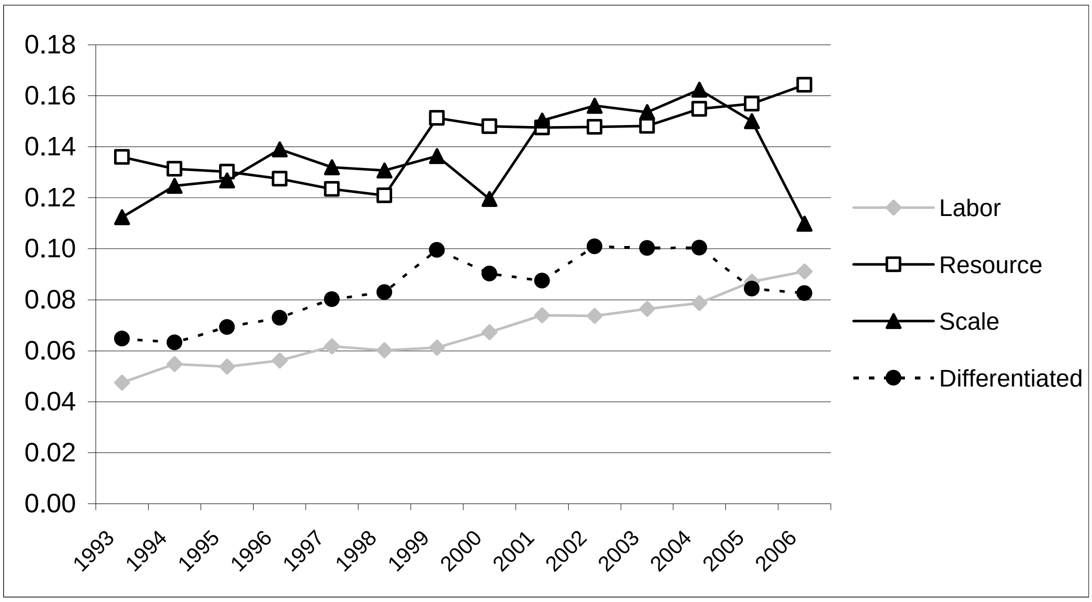
1993 and 2006. If the most (least) concentrated sectors in 1993 remain the most (least) concentrated sectors in 2006, then a statistically significant positive Spearman coefficient would be expected. On the other hand, a significantly negative Spearman coefficient would indicate that there has been a significant change and reordering in the agglomeration pattern in the given period.

As it is evident from Table 5, there is a highly statistically significant positive Spearman rank correlation between the G indexes in 1993 and 2006, as well as between the K indexes in 1993 and 2006, as calculated with both employment and output data. This outcome demonstrates that the agglomeration pattern across the manufacturing industries has not changed significantly over time and that, more or less, the industries that were amongst the most spatially concentrated in 1993 are the same in 2006. This is particularly true for the G index calculated with employment data and relatively less so for the K index calculated with output data.

4.2 Spatial concentration patterns by factor-intensities & technology levels

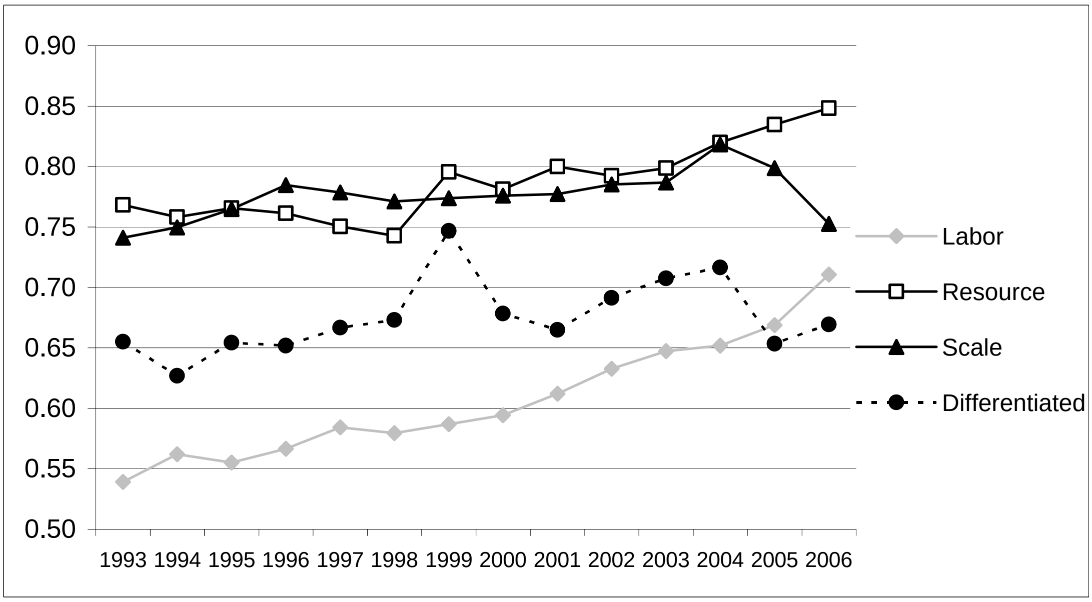
In this subsection, the manufacturing industries are categorized in accordance with two classifications, based on the OECD (1987; 2001), which contain information on factor-intensities and technology levels, in order to examine what characterizes the industries that agglomerate. The first industry classification distinguishes four categories (i.e., labor-intensive, resource-intensive, scale-intensive, and differentiated goods-intensive industries). The differentiated goods industry category reflects the importance of the brand names, design, special features, and unique characteristics of the goods produced within the industry. Thus, this category more or less groups together those industries that exhibit key monopolistic competition aspects. The goods included in this category contain relatively more human capital or skilled and upper management labor, such as design, advertisement and R&D, for purposes of creating a unique and special product and brand awareness. The second classification distinguishes four technology categories (high-technology, medium-high tech, medium-low tech, and low-technology industries). These two classifications are applied into the present industry dataset and the spatial concentration indices are calculated for those categories.

Figure 1: Spatial agglomeration according to factor intensities (*G* indices)



Notes: Raw geographic concentration (*G*) indices calculated with employment data.
Source: Authors' own calculations based on data from ELSTAT.

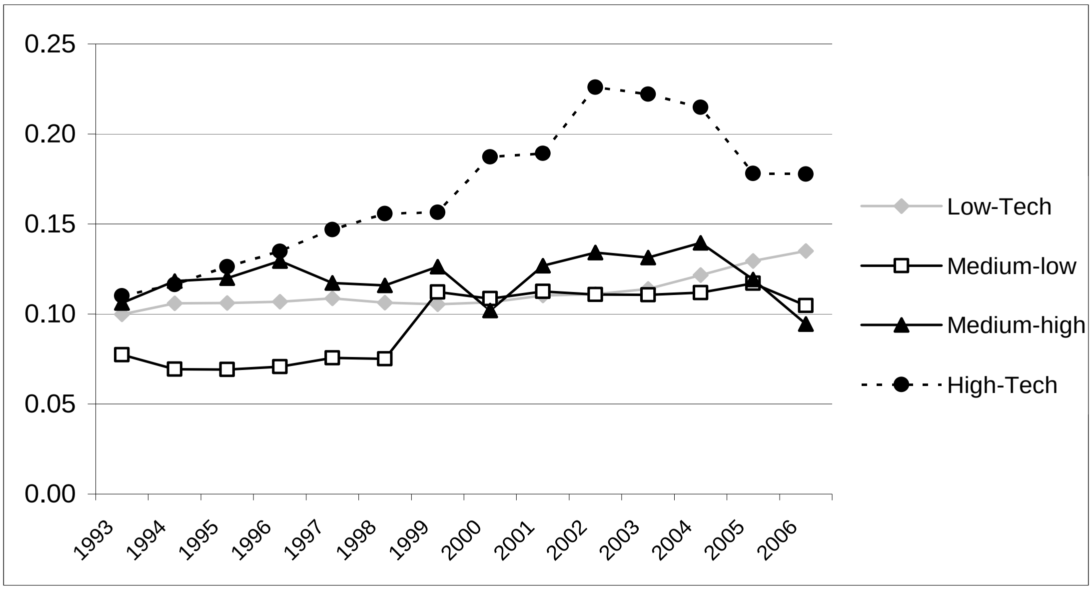
Figure 2: Spatial agglomeration according to factor intensities (*K* indices)



Notes: Krugman (*K*) indices calculated with employment data.
Source: Authors' own calculations based on data from ELSTAT.

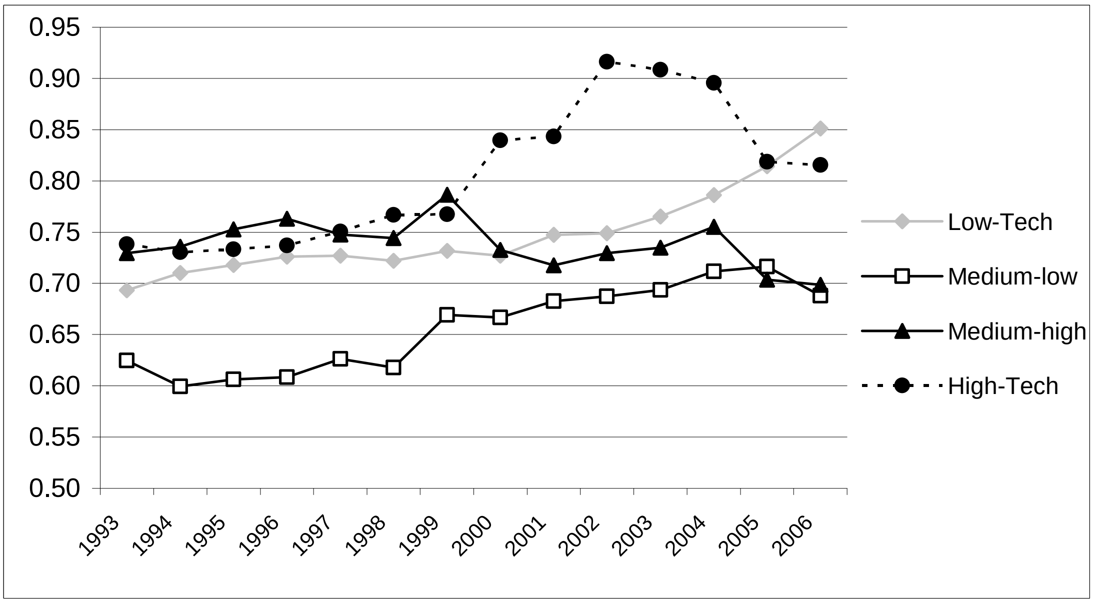
Figures 1 and 2 show the results for the factor-intensity groupings, as obtained from the calculation of G and K indices, respectively, with the use of employment data. The corresponding results obtained from the use of output data are shown in the Appendix (Figures A1 and A2). The analysis reveals that labor-intensive industries exhibit the lowest geographic concentration. However, they present a continuous upward trend, which particularly reflects on the Krugman index calculated from output data. On the other hand, resource-intensive and scale-intensive industries show the highest spatial agglomeration and to some extent an increasing trend over time (especially, the resource-intensive industries). These findings suggest that natural resource externalities and scale economies are important in driving the spatial concentration of manufacturing in Greece.

Figure 3: Spatial agglomeration according to technology levels (*G* indices)



Notes: Raw geographic concentration (*G*) indices calculated with employment data.
Source: Authors' own calculations based on data from ELSTAT.

Figure 4: Spatial agglomeration according to technology levels (*K* indices)



Notes: Krugman (*K*) indices calculated with employment data.
Source: Authors' own calculations based on data from ELSTAT.

Figures 3 and 4 illustrate the geographic concentration patterns and trends with regard to technology levels, as obtained from the calculation of G and K indices, respectively, with the use of employment data. The corresponding results obtained from the use of output data are reported in the Appendix (Figures A3 and A4). It is evident that high-tech industries are the most geographically concentrated ones when we consider the agglomeration indices calculated from employment data (especially the G index). This is not true when we consider the indices calculated from output data. However, the high-tech category still exhibits a high level of agglomeration with an increasing trend. Medium-low technology industries are the most spatially dispersed industries, closely followed by low-tech industries (except for the case of the K index calculated from output data). In general, all technology categories show an increasing trend, except for the high-tech and medium-high-tech industries during the last years of the sample period.

5. Determinants of Spatial Agglomeration of Manufacturing

5.1 Variables and data

The literature on industrial agglomeration and the NEG models identifies several important sources of agglomerative externalities that cause geographic concentration, such as labor market pooling externalities, knowledge spillovers, vertical linkages, scale economies, input sharing externalities, and transport costs. In this paper, several independent variables that proxy for the above agglomeration factors are calculated and included in the econometric analysis.

Regarding the effect of labor market pooling (*LM*), the two proxies that are most commonly used in the literature are the sectoral wage per employee and the labor productivity index. Lu and Tao (2009) also suggested the wage premium index, that is, the regional wage premium of an industry over the average wage in that region, averaged over all regions and weighted by the industry's employment shares in those regions. The rationale for using such proxies is that, according to the NEG theory, the wage levels are higher in activities/industries that show a high spatial concentration, due to the importance of labor market pooling (for skilled and productive workers). Notably, there is no single proxy that captures fully the labor market pooling externalities. The various proxies employed in the literature constitute rather imperfect proxies capturing certain aspects of those externalities. Therefore, we include and test alternatively the three above mentioned proxies.

Knowledge spillovers (*KS*) also constitute a key factor of agglomerative externalities (e.g., Audretsch and Feldman, 1996). Firms, particularly those belonging to the high-tech industries, benefit by clustering together, as there may be geographic boundaries in the flow of transferable information and knowledge. Also, there may exist tacit innovation and knowledge externalities that spillover to nearby firms, which create positive productivity effects. This factor is proxied by the industry's research and development (R&D) intensity, i.e., the ratio of R&D expenditure to the total output of that sector.

Moreover, the existence of vertical linkages (*VL*) among industries can drive spatial agglomeration, as intermediate inputs obtained from within an industrial cluster may be less costly (Venables, 1996). We proxy this factor in the standard way, namely, by the intermediate goods intensity of the sector (i.e., the ratio of expenditure in intermediate goods to total output). Scale economies (*SE*) favor agglomeration through the home-market effect, where firms tend to locate in the large market in order to minimize transport costs from the distribution (sales) of their goods. The literature mostly uses the average firm size to proxy this factor. This measure is expressed here by the total industry value added divided by the number of firms in the sector.

Input and information sharing (*IS*) affects positively industry agglomeration, as some common inputs or facilities (including software) necessary for a firm's production can be shared among many firms in the same location, leading to significant reduction of production costs (Holmes, 1998). Since a direct measure for this factor is not practically available, we proxy it by the export-intensity of the sector, as suggested by Lu and Tao (2009). The rationale for adopting this proxy is that export sectors may have a larger need for input and information sharing (i.e., some common facilities, procedures, and information on international markets relevant for the task of exporting).

The last factor included here is the transport cost (*TC*). A high transport cost in a given sector is likely to cause agglomeration, as firms will try to minimize those costs by agglomerating their activities in particular locations near markets where they can sell their products. The problem faced with handling this variable is that we cannot include those costs observable at a specific year and expect to (simultaneously) observe a high agglomeration at that year. This is because if the industry has high transport costs and then responded by agglomerating in a location, those costs would fall and reach at a relatively low level after an adjustment period of some years. Thus, the proxy used is the total expenditure cost for transport (with own industry vehicles) in a given sector with a time lag of five years. The particular lag length was determined on the basis of data considerations (as there is a dearth of historical data going back for many years) and the time that is likely to be required for an observed relocation pattern to take place with respect to spatial concentration. The decreased transport costs associated with the clustering of firms leads to increasing the likelihood of a core-periphery pattern. The outcome of such a pattern is that more intermediate inputs will be focused at the core (for instance, in metropolitan areas like that of Athens in the Attica Region), which will subsequently attract more firms in related industries.

Table 6: Matrix of correlations between the determinants of industrial agglomeration economies

	LM	*KS*	*VL*	*SE*	*IS*	*TC*
LM	1 -----					
KS	0.0035	1 -----				
VL	-0.0784	0.0158	1 -----			
SE	-0.0583	-0.0227	0.4040*	1 -----		
IS	0.0777	0.4697*	0.0422	-0.001	1 -----	
TC	-0.0071	-0.0019	-0.0376	-0.2237*	-0.2245*	1 -----

Note: (*) denotes coefficients that are statistically significant at the 5% level (2-tailed).

Table 6 shows the matrix of correlations among the determinants of industrial agglomeration economies, as described before. The correlation matrix verifies that the explanatory variables used here are not highly correlated to each other; in all cases, the correlation coefficient is lower than 50%. Hence, the inclusion of these variables is not expected to lead to biased estimates due to multicollinearity problems. It is mentioned that, based on the results of a series of alternative specification runs of the model (Section 5), both the sectoral wage per employee and the labor productivity index were found to significantly positively affect the spatial concentration indices, compared to the wage premium index, whose effect was found to be statistically non-significant. Due to the higher statistical significance of the coefficient related to the labor productivity index (Section 6), the outcomes in Table 6 and all the subsequent reported econometric results for the labor market pooling externalities variable (*LM*) refer to the latter proxy. However, this does not change the results of the other coefficients and the overall model. All the monetary values in the annual industrial data have been deflated by using the producer price indices in the manufacturing industries and converted to constant 2000 base-year euros. The data sources for the variables refer to the ELSTAT and OECD.

5.2 Specification and econometric methodology

Due to the panel structure of the data, the econometric model is specified as a linear panel-data model in the following form:

$$A_{it} = \beta_0 + \beta_1 LM_{it} + \beta_2 KS_{it} + \beta_3 VL_{it} + \beta_4 SE_{it} + \beta_5 IS + \beta_6 TC_{it} + v_i + \mu_t + \varepsilon_{it}\,, \qquad (3)$$

with

$i = 1, 2, \ldots, 21$ (index of industries)[2]

$t = 1993, 1994, \ldots, 2006$ (index of years)

The dependent variable A denotes the spatial agglomeration, which is expressed with either the G index or the K index, β_1 to β_6 are the parameters to be estimated (which all are expected to be positive), v_i captures time-invariant industry-specific fixed effects, μ_t captures industry-invariant time fixed effects and $\varepsilon_{it} \sim N(0, \sigma^2)$ is the stochastic error term. The Hausman tests, which are conducted in order to reveal the appropriate panel specification (with fixed or random effects), clearly indicate that the fixed-effects estimator is the preferred panel-data modeling methodology. Thus, the findings are interpreted and policy implications are drawn on the basis of the fixed-effects models with panel-robust standard errors.

[2] One industry (ISIC 30) is dropped from the analysis due to insufficient data.

Another consideration that must be taken into account in modeling spatial agglomeration is the constraints imposed into the range of indices. Specifically, as the two alternative dependent variables are limited (the G index is bounded between 0 and 1, and the K index ranges between 0 and 2), there is a need to control for possible bias resulting from the censorship of estimated values below and above the corresponding lower and upper limits. In order to address this issue and check for robustness in the results, a fixed-effects panel data model with logistic transformation of the dependent variable (which removes the limited range) is estimated, in addition to the standard fixed-effects models. This procedure is performed only for the G index that takes values in the range [0, 1]. Furthermore, panel tobit estimations (which are widely used for solving limited dependent variable models) are performed for the model with the G index as well as the K index. By adopting the tobit methodology for the panel data models, the dependent variables (concentration indices) can have a latent variable interpretation which denotes that they can only be partially observed by using the current dataset.

6. Econometric Results

The empirical results of the econometric estimation of the models with the G index and the K index as the dependent variable (spatial agglomeration) are reported in the Tables 6 and 7, respectively. In all the cases, the analysis is focused on the results obtained from the use of employment data, as in the empirical literature this is the most preferred measure used to calculate the concentration indices[3]. Turning first to the models with the G index as the dependent variable, Table 7 presents three estimation outputs obtained from a standard fixed-effects (FE) model, a logistic-transformation FE model, and a tobit FE model.

In the standard FE model, all the explanatory variables are found to be statistically significant (at the conventional levels of confidence) and with the correct (expected) coefficient sign, except the information sharing proxy. However, it is noted that this variable is poorly proxied (due to lack of relevant data) and it essentially measures the export-intensity of the sector. Hence, although it is claimed that, in some

[3] It is noted that the results obtained from the use of output data lead to very similar conclusions, although the parameter estimates have somewhat less statistical significance, compared to those obtained from the use of employment data.

cases, it reflects (and is correlated with) information sharing externalities, we cannot really confirm that those externalities are an important factor of spatial agglomeration in Greece. It can only be concluded that a sector's export-intensity does not play a significant role in the localization economies of manufacturing.

Table 7: Determinants of Spatial Agglomeration (Dependent variable: *G* index)

Variables	FE Model	Logistic Transformation	Tobit FE Model
Labor Market Pooling	0.0002398 (0.009)	0.0020672 (0.001)	0.0002398 (0.006)
Knowledge-spillovers	0.0054092 (0.010)	0.0272422 (0.031)	0.0054092 (0.007)
Vertical Linkages	0.0008451 (0.093)	0.0077324 (0.084)	0.0008451 (0.077)
Scale Economies	0.0006354 (0.000)	0.0037252 (0.000)	0.0006354 (0.000)
Information Sharing	-0.0001403 (0.546)	0.0009658 (0.670)	-0.0001403 (0.526)
Transport Cost	0.0274473 (0.001)	0.2387278 (0.000)	0.0274473 (0.000)
Adj. R^2	0.8727	0.9343	
Log likelihood			598.28
NT	294	294	294

Notes: The dependent variable (*G* index) is calculated with employment data. Results for the constant and fixed effects are not shown (available from the authors upon request).

Regarding the other determinants, the scale economies, transport cost, labor market pooling externalities and knowledge spillovers are found to be highly statistically significant at the 1% level of confidence, whilst vertical linkages are significant at the 10% level. The overall fit of the standard FE model is high, indicating that about 87% of the cross-sectoral variance in the extent of spatial agglomeration can be explained by the variability of the included explanatory variables. The model with the logistic transformation of the dependent variable produces similar results. In particular, the estimated coefficients are larger and more statistically significant, as is the overall model fit. The panel-tobit model produces the same coefficients to those of the standard FE model. This fact indicates that none of the observations is hitting the upper or lower limits for the G index. Thus, in the given problem, the FE panel regression model can provide unbiased and efficient coefficient estimates (without sample censorship bias).

Table 8: Determinants of Spatial Agglomeration (Dependent variable: *K* index)

Variables	FE Model	Tobit FE Model	Tobit RE Model
Labor Market Pooling	0.0005045 (0.001)	0.0005045 (0.011)	0.0004298 (0.020)
Knowledge-spillovers	0.006151 (0.079)	0.006151 (0.181)	0.0109737 (0.000)
Vertical Linkages	0.003412 (0.011)	0.003412 (0.002)	0.0034145 (0.000)
Scale Economies	0.0011963 (0.000)	0.0011963 (0.000)	0.0010359 (0.000)
Information Sharing	0.0002484 (0.707)	0.0002484 (0.622)	0.0000348 (0.914)
Transport Cost	0.0797318 (0.000)	0.0797318 (0.000)	0.0440192 (0.001)
Adj. R^2	0.8877		
Log likelihood		356.53	292.76
NT	294	294	294

Notes: The dependent variable (*K* index) is calculated with employment data. Results for the constant and fixed effects are not shown (available from the authors upon request).

As regards the results of the models where the dependent variable is the K index (Table 8), there are three estimation outputs, namely, those of the: (i) standard FE model, (ii) tobit FE model, and (iii) tobit random-effects (RE) model. The output of the latter (tobit RE) model is presented here for comparison purposes with respect to the corresponding FE model, because no logistic transformation model is estimated as the K index ranges between 0 and 2. The results of the standard FE model with the K index are very close to those of the standard FE model with the G index (Table 7), with a similar satisfactory overall fit (89%). Again, the same five variables are found to be statistically significant, while the information sharing proxy has no statistically significant impact on the spatial agglomerative externalities.

In the tobit FE model, identical coefficients are produced and four regressors are found to be statistically significant (knowledge spillovers are statistically non-significant as well as information sharing). By and large, the tobit RE model produces similar results to those of the tobit FE model. Therefore, the general view that emerges from all the empirical results of the econometric analysis is that factors such as scale economies, transport cost, labor market pooling externalities, knowledge spillovers, and vertical linkages exert a statically significant effect on an industry's extent of spatial agglomeration. These effects are positively associated with the economies of industrial agglomeration in the country.

7. Conclusions

The measurement of spatial agglomeration and knowledge about its determinants can provide useful insight into how specific industrial sectors increase their size and production. In turn, this knowledge can support the design and evaluation of development plans in large urban regions and peripheries, as agglomeration provides a planning mechanism for promoting the sustainable urban/regional growth. Based on the processing of employment and output data from the Greek annual industrial surveys, the raw geographic concentration index and Krugman spatial concentration index are calculated for a period spanning 1993-2006. The exploratory analysis of the dataset signifies the persistence of localization economies in Greek manufacturing, in the sense that highly agglomerated (dispersed) industries at the beginning of the period remain to be spatially concentrated (dispersed) at the end of it. The high-technology industries exhibit a high level of agglomeration with an increasing trend. Medium-low technology industries are the most spatially dispersed ones, closely followed by the low-technology industries. The natural resource externalities and scale economies are important in driving the spatial concentration of manufacturing in the country.

Based on sound panel data estimation techniques, the identification of the impacts that several factors have on localization economies of manufacturing can help to formulate and deploy policies focused on industrial and regional development. Specifically, appropriate planning mechanisms, e.g., based on the designation of functional economic areas (Prodromidis, 2010), can be employed to influence the spatial structure of labor markets in a way that promote the positive role of labor market pooling externalities on localization economies. Investments in research and development can be used as a policy tool to enhance knowledge spillovers and, hence, the spatial agglomeration of manufacturing. Besides, the exploitation of scale economies of industries in large market areas and development of regional industrial clusters (including innovation and distribution centres), which can strengthen vertical linkages within industries, will favor the localization economies of Greek manufacturing.

The appropriate selection and (combination of) use of transport modes may play an important role in the location patterns of industries, whose clustering is sensitive to shipping costs. In particular, reduction of transport cost, e.g., through investments for new or improved infrastructure and transport services, reduced fuel prices and increased fuel efficiency, are expected to increase the geographic dispersion of manufacturing industries in the long run. Consequently, policies targeted at regional convergence should utilize such measures that reduce transport cost for firms or sectors, in conjunction with other measures for the local development of each region. The present conclusions could be enriched in the future from the use of further localization measurement techniques and indices for comparison purposes and the spatial agglomeration analysis at different levels of industrial aggregation with narrowly defined subsectors.

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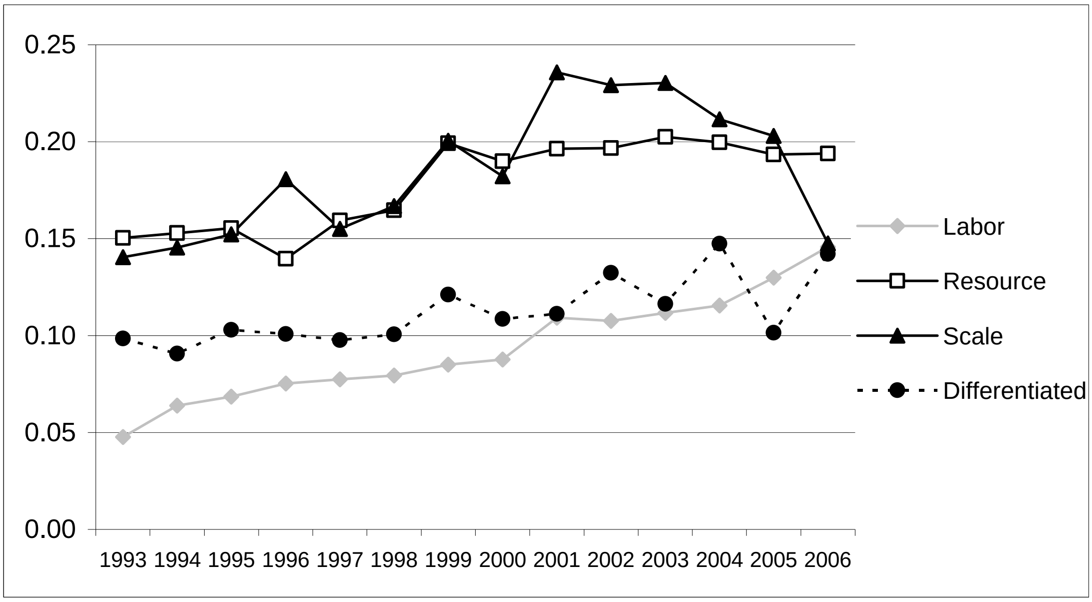
APPENDIX A

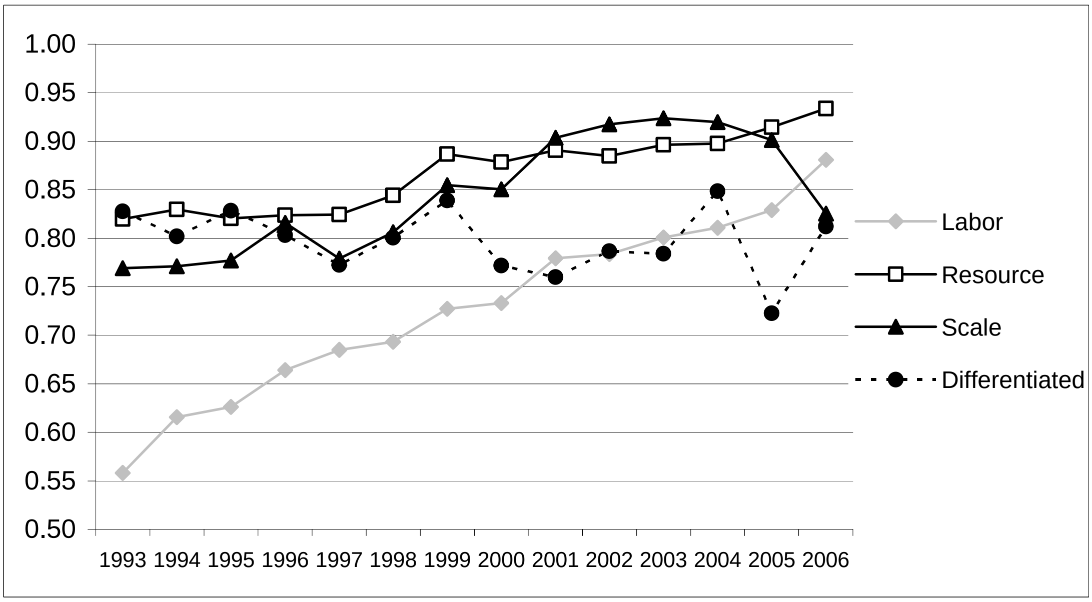
Spatial agglomeration patterns and trends according to factor-intensities calculated with output data

Figure A1: *G* index



Notes: Raw geographic concentration (*G*) indices calculated with output data.
Source: Authors' own calculations based on data from ELSTAT.

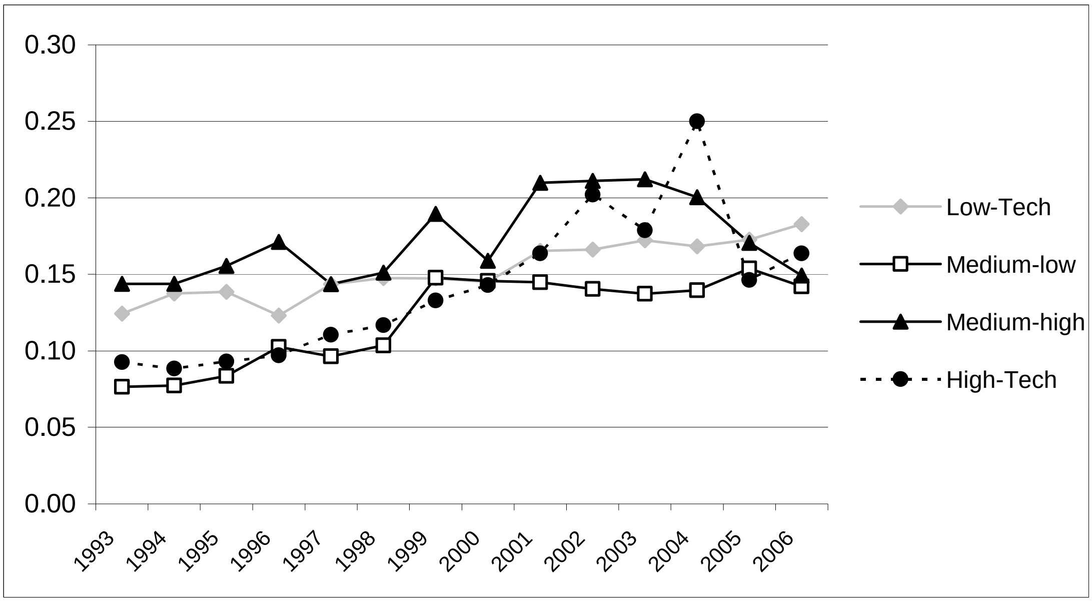
Figure A2: *K* index



Notes: Krugman (*K*) indices calculated with output data.
Source: Authors' own calculations based on data from ELSTAT.

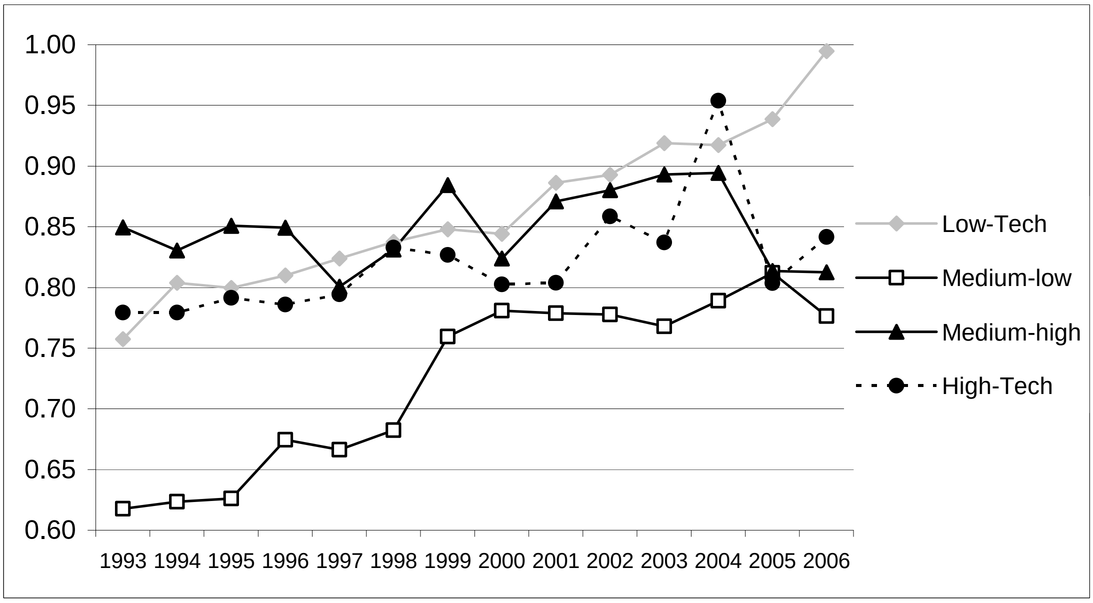
Spatial agglomeration patterns and trends according to technology levels calculated with output data

Figure A3: *G* index



Notes: Raw geographic concentration (*G*) indices calculated with output data.
Source: Authors' own calculations based on data from ELSTAT.

Figure A4: *K* index



Notes: Krugman (*K*) indices calculated with output data.
Source: Authors' own calculations based on data from ELSTAT.

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