Laboratory of Economics and Management
Sant'Anna School of Advanced Studies

Via Carducci, 40 - I-56127 PISA (Italy)
Tel. +39-050-883-341 Fax +39-050-883-344
Email: lem@sssup.it Web Page: http://lem.sssup.it

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On the Ubiquitous Nature of the Agglomeration Economies and their Diverse Determinants: Some Notes

*Giulio Bottazzi**
Giovanni Dosi *
and
*Giorgio Fagiolo**

* *St.Anna School of Advanced Studies, Pisa, Italy*

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Giulio Bottazzi Giovanni Dosi Giorgio Fagiolo

Sant'Anna School of Advanced Studies, Pisa, Italy
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1 Introduction

The embeddedness of economic processes into underlying spatial dimensions ought to be sufficiently straightforward not to require much further elaborations. Indeed, *spatial dimensions* include both literally geographic aspects - related to the physical locations of agents - and more metaphorical metrics - regarding e.g. technological and institutional "distances"; mechanisms of inclusion/exclusion between networks, organizations and, of course, nations; degrees of information and knowledge sharing; etc. .

Having said that, it is equally easy to acknowledge that the economic discipline is far from offering anything resembling robust accounts of spatial localization of economic activities, or, even less so, their underlying generating dynamics. Needless to say, there is no possible claim of any systematic answer here to such tangled questions. Much more modestly, we shall add a few further question marks, together with some hints on hopefully novel interpretative conjectures. (Indeed, in what follows, we shall somewhat indulge on our naivité as newcomers to the field !)

If *space* - however defined - *matters*, it is also because particular "places" in it, persistently affect (i) identities, capabilities and behaviors of individual agents; (ii) interaction patters; and, ultimately, (iii) individual *and collective* performances. In turn, this means that sheer geography, together with institutional and technological specificities, ought to be studied in their long term effects upon economic structures and relative efficiencies.

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Even when going along with many our fellow economists in (the admittedly despicable practice of) blackboxing institutional diversities across nations and regions, one should nonetheless be able to track intersectoral differences in the agglomeration drivers exerted by technological factors. This is the first point that we shall address below (Section 2). Second, an assessment - albeit quite telegraphic - of the state-of-the-art of diverse strands of "economic geography" might help in flagging out achievements, standing shortcomings and challenges ahead (Section 3).

Theories on agglomeration (*and dispersion*) forces urgently demand stronger links with empirical predictions. This is what we begin to explore in Section 4, while in Section 5 we put our techniques to work on three - quite diverse - industrial sectors on Italian data (i.e. primary metals, transport equipment and furniture). Broader conjectures will be put forth in the conclusions (Section 6) of a report - we want to emphasize - which is very much preliminary and "work-in-progress".

2 Empirical Evidence on Agglomeration Phenomena: On Some Facts and Puzzles

A survey of the enormous empirical literature on agglomeration economics in general and industrial districts in particular is well beyond the scope of these notes[1]. Here let we just mention four sets of empirical regularities.

Discrete Types of Agglomeration Structures

The first robust piece of evidence concerns the variety of agglomeration phenomena yielding equally diverse "types" of local structures, including the following broad classes.

1. *Horizontally Diversified Agglomerations.* They comprise a good deal of the "Made-in-Italy" districts, presenting remarkable ever-changing product varieties generally produced by a multiplicity of small and medium firms (e.g. clothing, textiles, jewelries, tiles, etc.).

2. *Agglomerations of Vertically Disintegrated Activities.* Again, largely overlapping with the former, they include a quite few "Made-in-Italy" districts whereby activities previously vertically integrated within individual firms undergo a sort of "Smithian" process of division of labor *cum* branching out of different firms. In some analogy with the old "pin story" of Adam Smith, division of labor and spatial agglomeration rest upon: (a) economies of specialization; (b) input-output links; and (c) user-producers exchanges of knowledge (cf. shoe-making and textile/clothing among others).

3. *Hierarchical Spatially Localized Relations.* They generally involve an "oligopolistic core" and subcontracting networks (although not necessarily mechanisms of technological

[1] On the italian evidence about industrial districts, cf., among the others, Signorini (2000), Brusco and Paba (1997) and Onida *et al.* (1992).

dominance and rent-extraction by such a "core"). In Italy, transport equipment, white goods, etc. are good cases to the point.

4. *Agglomeration Phenomena based on Knowledge Complementarities - at least partly fueled by "exogenous science"*- the 'Silicon Valley' in the U.S. being the most famous example. Incidentally, note that in Italy this type of agglomeration is almost non-existent.

5. *Agglomerations as Sheer Outcomes of Path-Dependence* - for example due to spatial inertia in the birth and death of firms - without however any particular advantage of agglomeration itself[2].

Different types of agglomeration clearly hint at possibly different drivers of agglomeration itself and their different sectoral specificities.

Intersectoral Differences in the Importance of Agglomeration Economies

A second, related, set of empirical regularities concerns the intersectoral differences in the revealed importance of spatial agglomerations.

Figure 1 summarizes the statistical evidence on the contribution of districts production to exports in Italy at quite high degrees of sectoral disaggregation[3], highlighting a characteristic skewed distribution.

Complementary evidence on the contribution of individual districts to the total italian exports of the sectors in which they are specialized (Figure 2) confirms the idea of a significant devide between a group of "districts activities" and the rest of industrial production for which agglomeration economies appear to be much less relevant[4].

The importance of agglomeration maps into diverse sectoral patterns of innovation.

Third, the foregoing intersectoral differences in agglomeration economies interestingly map into taxonomic differences in the sectoral patterns of innovation, as proxied by Pavitt's categorization (cf. Pavitt, 1984)[5].

In particular, as shown in Figure 3, agglomeration economies appear particularly relevant in "scale-intensive sectors" - hinting at forms of *hierarchical agglomeration* discussed above - and in "supplier-dominated sectors" - which tend to include most of the so-called "made-in-Italy" activities[6]. Conversely, they appear the least relevant in "science-based" sectors.

[2] This is indeed the thesis of Klepper (2000) concerning the role of the Detroit area in automobiles.

[3] While the contribution to exports rather than production is admittedly less than perfect, it allows - in Italy - those higher levels of disaggregation often corresponding to "industrial districts".

[4] Table A1 (see Appendix A) provides the complete list of 4-digit sectors accounted in Figure 1 with the respective contributions by districts to the total italian exports.

[5] The italian ATECO 91 classification of sectors into Pavitt's taxonomy is available from the authors upon

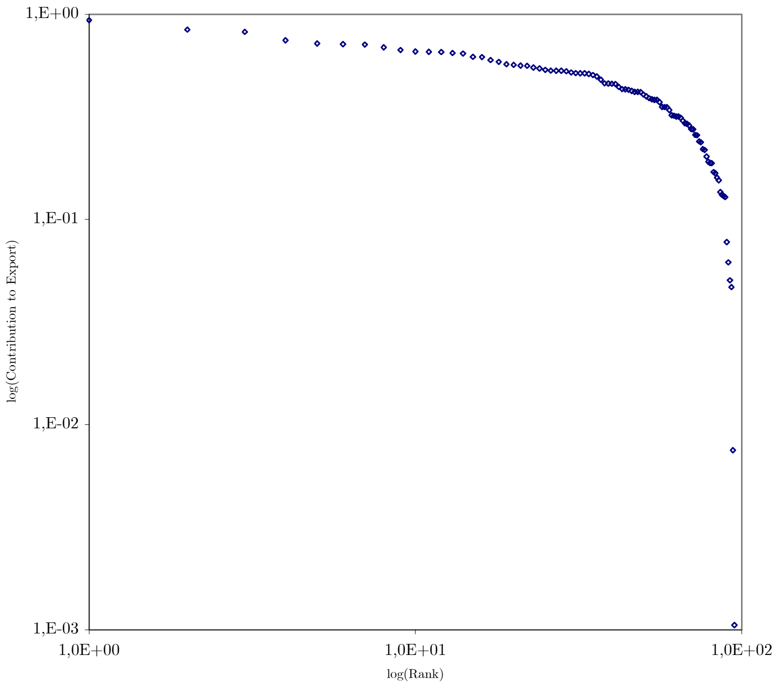

Figure 1: Log of Districts' contribution to Total Italian exports by product category vs. Log of Rank (Ateco 91 Classification). Year: 1996. Source: ISTAT, Censimento Intermedio dell'Industria e dei Servizi. See also App. A, Table A1.

Some form of 'life-cycles' in agglomeration phenomena ?

Widespread evidence support some sort of *metastability* in agglomeration phenomena, in the sense that in quite a few circumstances they persist on time-scales of order of magnitude greater than those of the processes supporting them, even though they tend to vanish on much longer time-scales.

So, for example, Brusco and Paba (1997) report on several industrial districts in Italy (especially but not only in the South) which existed after WWII but disappeared thereafter. At the international level, sectors like steel, automobiles, tires and many others appeared quite spatially concentrated near the time of their birth, but became geographically much more footloose. In fact, it could well be that geographical stickiness fall whenever: (a) specific technological paradigms become fully established; and (b) international oligopolistic firms emerge, incorporating the core knowledge associated with production and innovation[7].

request.

[6] "Supplier-dominated" is an unfortunate and somewhat misleading name for a set of industries which might well be characterized by a lot of product differentiation (e.g. related to fashion) and organizational innovations, but at the same time acquire most of their technological innovations via intermediate and capital inputs produced elsewhere. Textiles, clothing, furniture, toys, etc. are good examples of such a set of industries.

[7] Some related remarks by one of us may already be found in Dosi (1982).

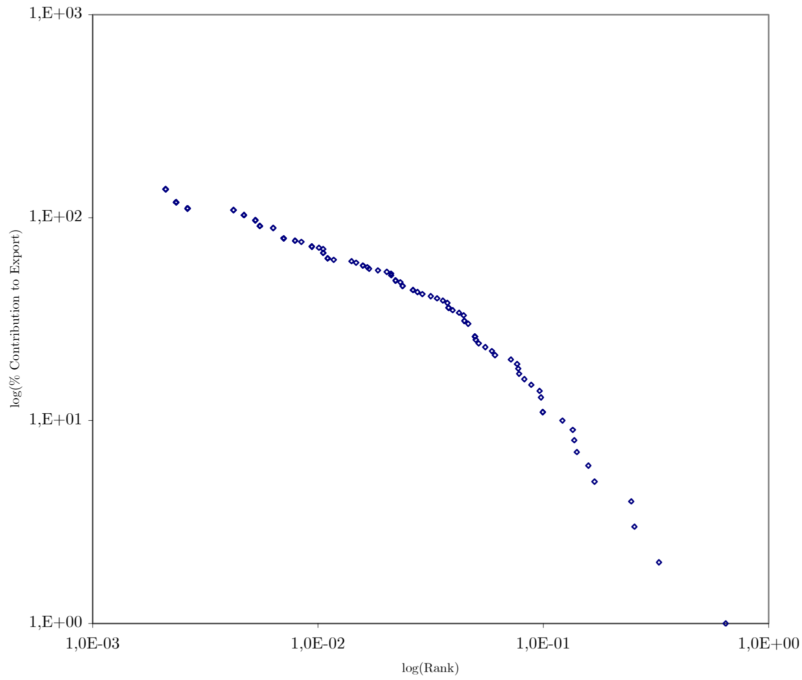

Figure 2: Log of Percentage Contribution to exports of specialized districts by ATECO micro-sector vs. Log of Rank (Total Italian Exports by the micro-sector =100). (Ateco 91 Classification). Source: ISTAT, Censimento Intermedio dell'Industria e dei Servizi.

There are two general conjectures which stem from the foregoing evidence, namely:

1. The drivers of agglomeration economies are often nested in the nature of sector-specific patterns of knowledge accumulation.

2. Relatedly, cross-sectional differences in agglomeration forces ought to be at least partly explained on the grounds of underlying differences in such processes of technological and organizational learning. They affect among others the relative importance of phenomena such as localized knowledge spillovers; inter- vs. intra-organizational learning; knowledge complementarities fueled by localized labor-mobility; innovative explorations undertaken through spin-offs and, more generally, the birth of new firms.

To what extent are such knowledge-related drivers accounted for in the current literature ? This is what we shall briefly discuss in the next section.

3 Space, Geography and Agglomeration: Some Telegraphic Comments on the State-of-the-Art

In a nutshell, one might identify four main questions that scholars concerned about the 'spatial dimension' of economic interactions have been all trying to address, albeit from different

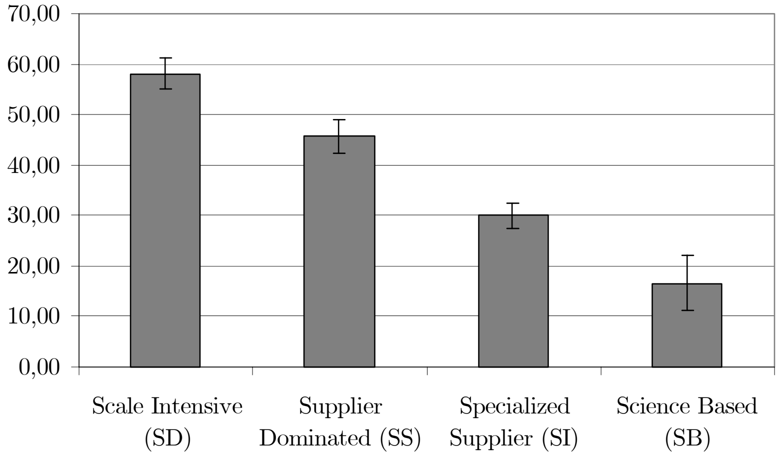

Figure 3: Mean of Percentage Contribution to exports according to Pavitt's Taxonomy.

perspectives, for more than a century, namely: (i) What is the role of mere "chance" in the observed spatial concentration of economic activities ? (ii) Relatedly, why and when could one observe persistent spatial patterns that cannot be explained by resorting to pre-existing heterogeneity in agents and locations (i.e. by some kind of "comparative advantage theory" alone) ? (iii) Could one neatly identify agglomeration (centripetal) and dispersion (centrifugal) forces lying at the heart of the processes generating sustained spatial concentration (and possibly its destabilization) ? And, (iv) How and when emerging spatial structures of production and innovation tend to become self-sustained over time ? (And, conversely, what make them wither away ?)

As well known, pioneering works such as Von Thunen (1826) and Marshall (1890), tried to investigate the main economic forces driving geographical differentiation and agglomeration. For instance, Von Thunen's simple analysis of land use - by stressing the importance of space constraints in decentralized economies - addressed the relationships between micro and macro geographical outcomes. Even more importantly, Marshall's discussion of his famous 'localization externalities' (or 'external economies') triad[8] became a cornerstone in the theory of economic agglomeration. From then on, however, diverse trajectories of exploration emerged.

A first large class of models hinges upon the basic idea that many different spatial agglomeration patterns (from concentration of economic activities in few locations to hierarchical structures) can be explained as the solution of a static, well-defined, trade-offs between identifiable agglomeration and dispersion forces. This intuition, rooted once again in Von Thunen's work, has become the core of the analyses provided by 'central-place' theory developed by Christaller (1933) and Lösch (1940) - and more generally by 'regional science' models of Isard (1956) and by Henderson's (1974) treatments of urban systems. More recently, it has inspired static models with non-market externalities such as Papageorgiou and Smith (1983) and Fujita (1988, 1989). For instance, central place theory stresses the importance of economies of

[8] That is: (i) backward/forward linkages associated to the trade-off between market-size and market-access; (ii) informational spillovers and (iii) advantages of thick markets for specialized local providers of inputs.

scale in the process of agglomeration of any economic activity and transportation costs in a community of farmers, while Henderson (1974), represents the economy as a system of cities and formalizes as an "inverted U" the relation between individual gains (due to some form of Marshallian localization externalities) and individual losses (due to some form of crowding effect) caused by concentrating activities in a single location. However, in order to explain hierarchical features of central places (an their supposed optimality) central place theory resorts to quite counterintuitive ideas as "nested hexagonal patterns" (!!), while urban theory relies on the existence of exogenous institutions such as city corporations. More elegantly, Papageorgiou and Smith (1983) and Fujita (1988, 1989) envisage agglomeration patterns as the outcome of the trade-off between some form of locally positive informational spillovers arising among agents endowed by heterogeneous information (e.g. social or technological spillovers) and congestion effects arising in spatial systems when concentration is too high (use of limited land, commuting costs, wage rate and land rent, etc.).

A second class of models that has become prominent in the last few years, now known under the perhaps misleading heading of 'New Geographical Economics'[9], acknowledges instead some form of increasing returns to scale (or indivisibilities) at the level of individual agents as both the incentive triggering agglomeration and the force able to sustain concentration (once the latter has emerged). The basic challenge of this stream of research - derived mainly from the theory rather than from any empirical puzzle - was to provide a satisfactory treatment of increasing returns to scale and monopolistic competition in a static equilibrium framework *cum* fully rational agents. By bridging monopolistic competition models à la Dixit and Stiglitz (1977) and Samuelson "iceberg-like" trade costs, such models have been able to account for agglomeration patterns and inter-locational specialization by positing a self-reinforcement process - stemming from some form of market externality - which finds its counterpart in dispersion forces caused by competitive pressures implied by either agglomeration itself or immobility of some factors (e.g. labor).

Although the wide proliferation of models sharing this common framework does not make easy to provide a taxonomy of both assumptions and results, the basic argument[10] hinges upon a circular causation between: (i) the decision of a firm to concentrate in a given area; and (ii) the positive net increase in profits enjoyed by firms deciding to follow it thereafter. Indeed, localized market-size effects in presence of imperfect competition usually offset the decrease in profits due to fiercer competition (unlike what would have happen under perfect competition)[11]. In a two-region, two-industries economy, this can account for the emergence of core-periphery patterns with agglomerations sustainable as stable equilibria and all (horizontally-differentiated) industrial goods produced in one region. However, multiple equi-

[9] See among others Krugman (1991a, 1991b, 1993), Krugman and Venables (1995a, 1995b, 1996), Venables (1996, 1998), Ottaviano and Thisse (1998), Fujita, Krugman and Venables (1999), Puga and Venables (1996). Cf. also Ottaviano and Puga (1998), Fujita and Thisse (1996).

[10] Cf. in particular Krugman (1991a, 1991b).

[11] An alternative but complementary argument (cf. Venables, 1996) stresses cost-linkages instead of demand-linkages as the engine of agglomeration. Agglomeration in a given region with the associated fiercer competition does not only lower revenues, but also decreases costs due to the existence of input-output links between firms. Hence, the effect on net profit can once again be positive.

libria arise and small asymmetries in initial parameters can be amplified to give rise to very different spatial patterns. In particular, crucial to equilibrium selection are the roles played by the degree of immobility of production factors, transportation costs, degree of differentiation of the horizontally differentiated industrial good and the importance of indivisibilities in production.

The most important contribution made by 'New Geographical Economics' models is perhaps having provided closed-form solutions to the problem of describing in a common framework monopolistic competition, transportation costs and increasing returns at the microeconomic level. In fact, this same formal machinery (of variants thereof[12]) has been recently applied to diverse open issues in spatial economics such as industrial clustering in open economies (and its relationships with economic growth)[13], the emergence of the evolution of urban systems and cities formation[14], industrial specialization in an array of imperfectly competetive sectors[15]. However, any hope for analytical tractability and clearly interpretable closed-form results strongly clashes with many attempts to generalize the basic framework (cf. the case of many locations discussed in Fujita and Thisse, 1996; see also the discussion in Martin, 1999). Even though these models have been dealing only with one element of the Marshall's proposed triad[16], thus neglecting issues as informational spillovers and the advantages of thick markets for specialized local providers of inputs, they need to rely on highly disputable oversimplifications in order to retain elegance and analytical tractability, such as the special Dixit-Stiglitz framework itself and Samuelson's scheme of transportation costs (i.e. no description of a separated transportation sector), to name a few[17].

In our view, the commitment to mainstream formalism of an 'equilibrium *cum* fully rational agents' framework (and to analytical solutions) has strongly limited the explicative power of 'New Geographical Economics'[18]. In fact, notwithstanding verbal acknowledgment of the very dynamic nature of any spatial agglomeration processes (cf. Fujita *et al.*, 1999), the treatment of dynamics in their models is admittedly unsatisfactory. So, instead of following their own mainstream prescriptions and endogeneizing dynamics as the outcome of intertemporal maximization problems by economic agents, Fujita *et al.* (1999) discuss issues of stability and selection among multiple equilibria in an essentially static framework. Finally, the list of empirically testable implications that such models are able to provide is intrinsically quite

[12] The basic model sketched above has been extended to allow for endogenous wage determination in a general equilibrium setting (cf. Krugman and Venables, 1995b; Puga and Venables, 1996); and for initial comparative advantages (cf. Krugman, 1993).

[13] Cf. for instance Fujita, Krugman and Venables (1999), Ch. 4, and Englmann and Waltz (1995).

[14] See Fujita, Krugman and Mori (1999), and Fujita, Krugman and Venables (1999), Ch. 3.

[15] See Krugman and Venables (1996) and Venables (1998).

[16] That is the backward/forward linkages associated to the trade-off between market-size and market-access.

[17] Notice also that these models do not allow for any treatment of uncertainty. On the contrary, static models based on spatial competition (i.e. the so-called "shipping" and "shopping" models) introduced some uncertainty in consumers perceptions of payoffs from locational choices. See e.g. Anderson, de Palma and Thisse (1992).

[18] A similar point about 'New Geographical Economics' has been also made by Martin (1999). However, we do not agree with his analysis of Polya-Urns type models (cf. Arthur, 1994), as the latter class of formalizations clearly avoid any commitment to concepts like full rationality and general equlibrium. See also below.

poor and always of an indirect nature (cf. Martin, 1999; p. 70). Even more dramatically, 'New Geographical Economics' formalizations do not lend themselves to generate testable implications about industry distributions across locations, so that there is very little hope that any predictions about e.g. rank-size relationships could be ever taken to the data employing such models.

Despite 'New Geographical Economics' has often been claimed to be the most prominent attempt to provide a unified framework for spatial economics (as well as the sole robust answer to the resurgence of interest in agglomeration issues recently prompted by real-world concerns such as European market integration), there actually exist at least three other broad streams of research that in the last decades have been trying, in partly complementary ways, to open up the black box of spatial issues in economics with quite eclectic theoretical spectacles.

First, many scholars have been providing rich and qualitative analyses, mostly (but not entirely) empirically focused, of urban/regional development and industrial agglomeration phenomena. In particular, by thoroughly analyzing the role of externalities and technological spillovers, as well as the importance of social, cultural and institutional forces in shaping the rise and the decline of industrial districts, these authors have been providing a huge amount of illuminating insights about specific examples together with some attempts to offer interpretative frameworks able to grasp the larger picture[19].

Second, a long stream of literature on multinational investment - from the pioneering works by Vernon (1966), all the way to the recent contributions by Cantwell and colleagues[20] - are rich of insights on the interaction between technologies, corporate strategies and locational features. It is indeed surprising that geography-centered investigations have largely neglected such complementary contributions.

Third, building on the seminal work by Brian W. Arthur and Paul David, a more theoretically grounded literature has been attempting to analyze the nature of economies/diseconomies of agglomeration in a truly dynamic framework in which persistent spatio-temporal patterns are conceived as emerging out of direct interactions among very stylized, boundedly-rational, heterogeneous economic agents. By acknowledging the history- (or path-) dependent nature of the observed uneven spatial distribution of economic activities, the basic argument stresses the importance of dynamic increasing returns implied by some form of agglomeration economies/diseconomies (cf. Arthur, 1994; Ch. 4 and 6) and/or local network externalities (cf. David *et al.*, 1998; Cowan and Cowan, 1998). Even more importantly, by recasting the analysis of agglomeration phenomena in a truly dynamical setting, one is able to appreciate the subtleties of the trade-offs between purely random factors and more systematic, historical forces (or, put it differently, the issue of necessity vs. chance) underlying the emergence of spatially ordered structures.

Without entering into the mathematical details[21], the basic argument envisages an discrete-

[19] We refer here to a huge body of literature covering both 'economic geography' studies (see Lee and Willis, 1997 for a survey; and the references in Martin, 1999), and in particular, the Italian studies on industrial districts, cf. Antonelli (1990, 1994), Brusco (1989), Sforzi (1989), Beccattini (1990), Brusco and Paba (1997), Signorini (2000), Tattara (2001) .

[20] Cf. e.g. Cantwell (1989) and Cantwell and Iammarino (1998).

[21] See however Arthur (1994), Dosi, Ermoliev and Kaniovski (1994) and Dosi and Kaniovski (1994) for more

time economy with a finite set of regions (say R) and an enumerable population of firms deciding where to locate. To keep things as simple as possible, assume that firms $i = 1, 2, ...$ enter sequentially the decision stage[22]. Firm i entering at time t has an idiosyncratic perception of the gain associated to the choice of locating in region $r = 1, ..., R$, equal to the sum of an intrinsic, time-independent, attractiveness term q_i^r (e.g. the *ex-ante* geographical benefit) and some function g of the number of firms $y_i^r(t)$ that have so far decided to locate there (i.e. a measure of agglomeration economies - if $g' > 0$ - or, respectively, diseconomies - if $g' < 0$). Assume that firms choose to locate in the region associated to the best perceived gain. If the intrinsic attractiveness terms are randomly drawn from some given distribution F, then one can easily work out the function mapping current regional shares into the probability that each region will be chosen next.

This extremely simple framework (and extensions thereof) can indeed provide a rather wide array of predictions, in particular concerning the ability of economies/diseconomies of agglomeration to shape the long-run concentration patterns. Together, it is also able to account for early, small, mainly non-predictable, events as they interact with more systematic forces in conveying observable structures.

Despite their highly stylized nature (firms are indeed conceived as very naïve entities; microeconomic foundations are rather poor; etc.), this class of models begins to open-up the black box of spatial phenomena in economics by focusing on inherently dynamical decentralized systems populated by simple interacting agents.

To summarize: multiple strands of theoretical and historical literature do highlight the renewed richness of the investigation of spatial phenomena in economics. However, it is also fair to say that major persistent shortcomings of the theory concern, at the very least: (i) thorough and relatively general accounts of the interaction patterns between forms of knowledge accumulation and types of agglomeration phenomena, and (ii) the ability of yielding robust empirical predictions concerning agglomeration patterns conditional on underlying technological and organizational characteristics of diverse industrial activities. Let us now turn to the latter issue and suggest a formal machinery able to detect the different revealed strength of agglomeration in different sectors.

4 A Stochastic Dynamical Model of Plants Location

As mentioned in the foregoing section, a class of models aimed at empirical predictions on the grounds of explicit dynamics of firm location is the one presented in Arthur (1994, Chs. 4 and 6). There are however some drawbacks in such a methodology.

First, the prediction of this type of model generally concerns the asymptotic state of the system, i.e. its state when an infinite number of firms has chosen its location. The comparison of different asymptotic outcomes does represent a valuable theoretical method to compare the effect and the relative strength of the different determinants of the location

detailed discussions.

[22] The assumption of sequential one-time decisions is not actually crucial. See e.g. David *et al.* (1998) for an example in which firms are allowed to revise their current choice from time to time.

dynamics (agglomeration economies, scale economies, etc.). Nevertheless, it is obvious that its predictive power concerning actual empirical distribution should be taken with some caution since one is often facing empirical processes involving a relatively small number of firms (so that "infinity" might well be a misleading approximation).

Moreover, the mathematical tools based on Polya-like processes are particularly well-suited to the description of sequential entry settings where each decision is primarily influenced by the choices of earlier entrants: due to its infinite memory, this machinery does in fact provide an elegant formulation of "history-dependant" processes. However, it is less suited to all circumstances where individual decisions are much less irreversible and/or the stochastic component of the process does not tend to zero (as in Polya dynamics), due to persistent entry *and mortality*.

Here, in order to account for these drawbacks, we shall explore a distinct (Markovian) framework wherein, first, we will consider a finite number of firms and locations and second, we will describe industry dynamics as belonging to an invariant dynamical process. That is, we shall try to capture the idea that the actual distribution of plants on the territory keeps changing with the passing of time, even if generated by a stationary probability distribution. The probabilistic character of our model, when it comes to firms location choices, can be thought as taking in account the plausible existence of different "unobservable" constraints that shape the locational incentives of different plants (or firms).

Notice that the ongoing displacement of plants (firms) can be thought of as the actual change of location of a given production activity, as well as the death of a plant/firm in a given location and the birth of a similar one in a different place.

In order to simplify the treatment, we consider the number of firms constant along the system evolution. (Indeed, one can think to the number of firms as an "average" over the period of observation[23]).

Suppose to have N firms distributed over M distinct locations. Consider the occupation number vector

$$\mathbf{n} = (n_1, \ldots, n_M) \quad n_i > 0 \quad \sum_{i=1}^{M} n_i = N \tag{1}$$

which provides the number of firms belonging to each location. If, in a "heroic" simplification, one assumes that all firms are identical, the vector $\mathbf{n}$ completely specifies the state of the system.

The dynamical evolution of such a system can be described as a finite Markov chain. Let $P(\mathbf{n}'|\mathbf{n})$ be generic element of the transition matrix, i.e. the probability that if the state of the system is $\mathbf{n}$ at time t, its state at time $t+1$ would be $\mathbf{n}'$. This probability does not depend explicitly on time and its specification completely defines our model.

In order to capture the effect produced on the distribution of plants by the presence of agglomeration economies, the probability that a firm moves to a given location should depend on the number of firms already located there. Moreover, it is straightforward to introduce some degree of heterogeneity among locations: this can be done by allowing for intrinsic

[23] Notice that if one is on the contrary interested in the actual time evolution of the plant/firm distributions, the exact specification of the entry/exit dynamics becomes mandatory.

"geographical benefits", in general heterogeneous across locations (in analog with Arthur, 1994). Finally, for the sake of simplicity, we assume that just one firm changes location at a given time[24].

At each time step, a firm is chosen at random with equal probability $1/N$ and exits the industry. Then a randomly chosen, new, firm enters a location with a probability proportional to the sum of the number of firms already there and a "geographical benefit" term. The transition element thus becomes:

$$P(\mathbf{n} + \mathbf{\Delta_k} - \mathbf{\Delta_i}|\mathbf{n}) = \begin{cases} \frac{n_i}{N} \frac{a_k+n_k}{A+N-1} & k \neq i \\ \frac{n_i}{N} \frac{a_k+n_k-1}{A+N-1} & k = i \end{cases}, \tag{2}$$

where $\mathbf{a} = (a_1, \ldots, a_M)$ is the array of intrinsic "benefits" for the M locations, $A = \sum_{k=1}^{M} a_k$ and $\mathbf{\Delta_i} = (0, \ldots, 1, \ldots, 0)$ is the unitary vector with i-th component equal to 1. Some considerations are in order. First, notice that the intrinsic benefit a_k is proportional to the probability of choosing location k when the latter is empty[25]. Second, we have chosen the simplest linear relationship between the probability of choosing a location and the number of firms already there[26]. In fact, a more realistic account of location-specific returns to agglomeration should allow for the dependence of the $\mathbf{a}$ terms upon the number of plants/firms located there and/or for threshold effects. However, as we shall see, even the foregoing simpler approximation does not fare too badly with the data[27].

If $a_i > 0, \ \forall i$, each location has a positive probability of receiving the entering firm: hence, any possible state of the system is reachable, in a suitable number of steps, with finite probability starting from any other state and the Markov chain defined by (2) is irreducible.

If $p(\mathbf{n}, t)$ is the probability to find the system in state $\mathbf{n}$ at time t, its evolution reads:

$$p(\mathbf{n}, t+1) = \sum_{\mathbf{n'}} P(\mathbf{n}|\mathbf{n'}) p(\mathbf{n'}, t). \tag{3}$$

The invariant distribution $\pi(\mathbf{n}, t)$ is thus obtained by imposing the detailed balance condition:

$$P(\mathbf{n}|\mathbf{n'})\pi(\mathbf{n'}) = P(\mathbf{n'}|\mathbf{n})\pi(\mathbf{n}). \tag{4}$$

The explicit expression for the invariant distribution, known as the M-dimensional Polya distribution, can be easily obtained and reads:

$$\pi(\mathbf{n}, \mathbf{a}) = \frac{\Gamma(N+1)\,\Gamma(A)}{\Gamma(A+N)} \prod_{i=1}^{M} \frac{\Gamma(a_i + n_i)}{\Gamma(a_i)\,\Gamma(n_i+1)} \tag{5}$$

[24] Notice that this assumption has no effect whatsoever on the form of the invariant distribution of the process.

[25] This model is known as Ehrefest-Brillouin model and has been introduced in Garibaldi and Penco (2000) as a generalization of the famous Ehrefest model of statistical physics. A similar simplified version has been introduced in Kirman (1993).

[26] This model overlaps with the Arthur's one with linear returns function, cf. Arthur (1994).

[27] Moreover, negative values for the a's can be in principle considered, in order to describe the presence of agglomeration diseconomies characterizing the distribution of firms over the different locations. Nonetheless, the purely random exit dynamics constitutes, as such, a limit to the actual concentration of plants/firms in a given site, since more populated sites are also more likely to yield dying ones.

The values of the parameters a_k determine the nature of the distribution: for lower values of the a parameters, the effect of agglomeration becomes more relevant. In the limit $a_k \to +\infty$ and $a_i/a_k \to 1$ for any i and k, "agglomeration economies" disappear and the expression in (5) reduces to a multinomial distribution, while for $a_k = 1, \forall k$ it becomes what is known in statistical physics as the Bose-Einstein distribution.

5 Some Empirical Evidence

The complete multivariate distribution in (5) does provide a complete probabilistic description of our model. However, in order to obtain a quantity which can be more easily compared with empirical data, it is better to consider the marginal probability distribution of the occupancy number of a given site. The problem is to compute the probability that a site with "intrinsic value" a would end up, after the placement of N firms, with exactly n among them. By summing over all the residual degrees of freedom, one gets (see Bottazzi (2001)):

$$p(n; a, A, N) = \binom{N}{n} \frac{\Gamma(a+n)}{\Gamma(a)} \frac{\Gamma(A-a+N-n)}{\Gamma(A-a)} \frac{\Gamma(A)}{\Gamma(A+N)} \tag{6}$$

In the following we shall use this expression, whose parameter will be set by a fitting procedure, in order to compare the prediction of our model with the empirical observations. We shall use a database from the Italian Census of Manufacturers for the year 1996 containing business units (BUs) belonging to $M = 784$ "local system of labor mobility" (LSLM, for a definition see Sforzi (2000)) and to $L = 25$ different sectors for a total of 591,110 local units (plants). Here, we present some experiments over three sectors - primary metals, transport equipment and furniture - which one should expect to display different degrees of agglomeration economies and different drivers of the latter (cf. also the taxonomic discussions of Section 2).

Let $n_{i,l}$ be the number of BUs in LSLM i operating in sector l. Moreover we denote with $n_{.,l}$ the total number of BUs operating in sector l and with $n_{i,.}$ the total number of BUs belonging to i-th LSLM. As already mentioned, instead of considering average quantities measuring the "strength of agglomeration" of a given sector (as done, for instance, in Sforzi (1990)) we shall analyze the complete "occupancy distribution" of the BUs in the various LSLM, i.e. we compute the observed frequency $f_{obs.}(n; l)$ with which a LSLM hosting exactly n BUs active in sector l appears in our data:

$$f_{obs.}(n; l) = \frac{1}{M} \sum_{i=1}^{M} \delta_{n_{i,l},n} \tag{7}$$

where δ is the Kronecker (index) function, and we compare this expression with the theoretical prediction of (6), once having of course specified the parameters $\mathbf{a}$ characterizing the theoretical distribution.

As a first benchmark, one could consider all the LSLM as equal (i.e. with the same "intrinsic appeal") and obtain a theoretical expression directly from (6) putting $a_i = \beta$,

$\forall i$ and $A = M\beta$. This model would depend on a single parameter β which measures the "strength" of the agglomeration effect - with a low β meaning high agglomeration economies.

However, tests of this model yield quite bad agreement with data, and the theoretical description constantly underestimates the observed distribution tails. The reason for this becomes apparent if one plots, for a given sector i, the number of BUs $n_{i,l}$ of a LSLM against the total number of BUs in all the other sectors, except the one under consideration (that is $n_{i,\cdot} - n_{i,l}$). Under the previous assumption of *a priori* equiprobability, no dependence should appear between the two variables, since BUs belonging to different sectors should choose their locations independently. On the contrary, a strong positive correlation appears which contradicts the purported identity among the various LSLM's: we plot the result of this analysis in Fig. 4, for the three chosen sectors. The parameters fitted from a log-linear regression are reported in Table 1.

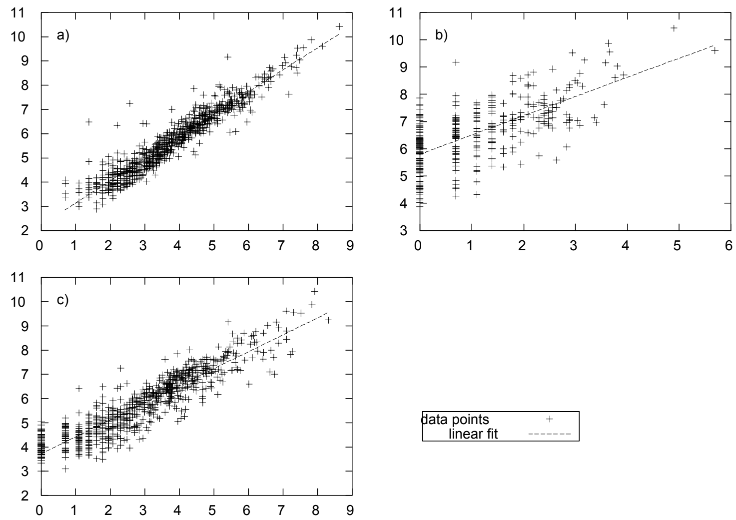

Figure 4: Total number of plants in a LSLM (Local System of Labor Mobility) vs. the number of plants in that location pertaining to a specific sector. **a)** primary metal, **b)** transport equipment, **c)** furniture. All the variable are in log scale. Source: ISTAT, Censimento Intermedio dell'Industria e dei Servizi, 1996.

	Primary Metals	Transport Equipment	Furniture
β	10.00	0.32	0.50
a	0.91±0.01	0.70±0.04	0.70±0.01

Table 1: The "agglomeration" parameter β and
the slope a of the linear regression by sector and by LSLM

As an alternative, let us assign to each location an "intrinsic attractiveness" which is proportional to the number of BUs which are located there and belong to all sectors but the one under analysis:

$$a_{i,l} = \beta_l \, \frac{n_{i,.} - n_{i,l}}{N - n_{.,l}}, \tag{8}$$

where l is the sector under analysis and the β_l coefficient captures, as above, the intensity of agglomeration economies. This procedure meant to capture also "geographical" effects that make a location intrinsically preferable compared to others, in terms of better industrial infrastructures, sheer overall size, etc.. It is likely that these advantages are location-specific and apply to all sectors under consideration. After controlling for "horizontal" locational effects, one can derive a measure of relative advantages between locations.

Following this idea, the predicted "weighted" frequencies become:

$$f_l^{wg}(n) = \frac{1}{M} \sum_{i=1}^{M} p(n; a_{i,l}, A_l, n_{.,l}) \tag{9}$$

where p is the distribution in (6) ans $A_l = \sum_i a_{i,l}$.

As can be seen in Figs. 5 through 7, the accordance of the theoretical prediction with data is quite high. The values of the βs used for the theoretical curves are reported in Table 1. Out of the three sectors chosen, the first, primary metals, does show an almost total lack of agglomeration effects, while the other two, transport equipment and furniture, seems to display rather high agglomeration economies. Notice, however, that the nature of such an agglomeration is actually very different for the latter two sectors: transport equipment displays a scattered locational patterns made-up of relatively few firms (possibly hinting at the "hierarchical agglomerations" mentioned in Section 2), while furniture highlights more "district-like" patterns.

6 Conclusions

We mentioned in the Introduction the highly preliminary nature of these notes. In this spirit, we have tried to, first, flag out some taxonomies of agglomeration structures and agglomeration drivers; second, suggest some links between the observed patterns and the underlying dynamics of knowledge accumulation; third, identify some related achievements and limitations of current theorizing; and, finally, fourth, develop a formal machinery able to statistically characterize the revealed intensities of agglomeration forces in different sectors.

Indeed, one could consider such a contribution as a small step toward bridging "spatial" analyses on the one hand, and investigations of knowledge-driven patterns of industrial change on the other.

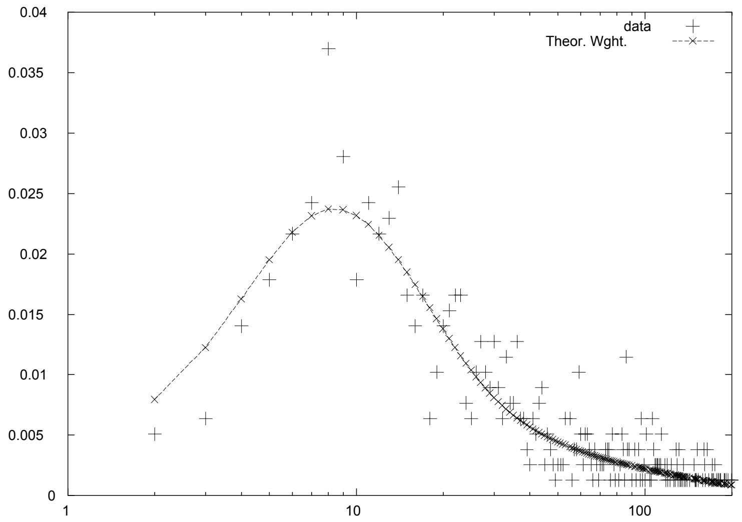

Figure 5: Frequencies and number of firms by LSLM (Local System of Labor Mobility). The primary metal sector. Source: ISTAT, Censimento Intermedio dell'Industria e dei Servizi, 1996.

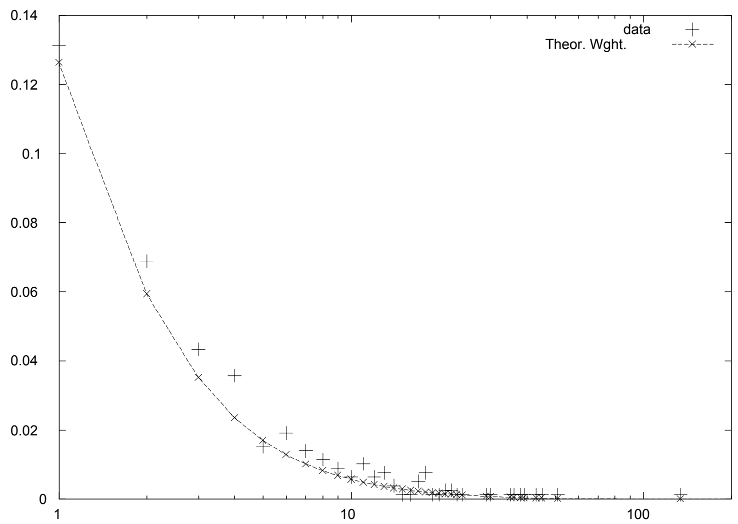

Figure 6: Frequencies and number of firms by LSLM (Local System of Labor Mobility). The transport equipment sector. Source: ISTAT, Censimento Intermedio dell'Industria e dei Servizi, 1996.

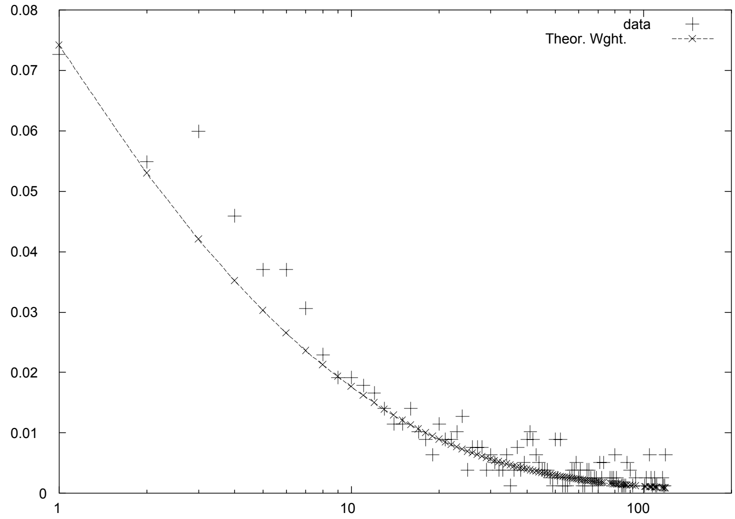

Figure 7: Frequencies and number of firms by LSLM (Local System of Labor Mobility). The furniture sector. Source: ISTAT, Censimento Intermedio dell'Industria e dei Servizi, 1996.

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Appendix A.
Background Evidence on the Distribution of Exports by Sector and by District

Table A1.
Rank of Italian Districts contribution to export by product category
Ateco 91 Classification Year: 1996.
Source: ISTAT, Censimento Intermedio dell'Industria e dei Servizi

Rank	**Product category**	**Contr.**
1	Sports goods	0,935
2	Tanning and dressing of leather	0,842
3	Ceramic tiles and flags	0,820
4	Repair of watches, clocks and jewellery	0,746
5	Musical instruments	0,720
6	Other agricultural and forestry machinery	0,715
7	Knitted and crocheted fabrics n.e.c.	0,711
8	Footwear	0,690
9	Nonwovens and articles made from nonwovens, except apparel	0,669
10	Other furniture	0,658
11	Other textiles n.e.c.	0,655
12	Tanks, reservoirs and containers of metal	0,654
13	Veneer sheets; plywood, laminboard, particle board, fibre board	0,648
14	Knitted and crocheted underwear	0,643
15	Other textiles products (n.e.c.)	0,620
16	Nonwovens and articles made from nonwovens, except apparel	0,618
17	Weapons and ammunition	0,598
18	Cutlery	0,586
19	Man. Of other basic iron, steel and ferro-alloys (ecsc), n.e.c.	0,570
20	Other products of wood	0,566
21	Meat and meat-based products	0,562
22	Textiles manufacturing (clothes excl.)	0,561
23	Steel tubes	0,549
24	Nonwovens and articles made from nonwovens, except apparel	0,544
25	Sawmilling and planing of wood, impregnation of wood	0,535
26	Refractory ceramic products	0,531
27	Other manufacturing products n.e.c.	0,530
28	Other fabricated metal products, n.e.c.	0,530
29	Lighting equipment and electric lamps	0,527
30	Household and sanitary goods and of toilet requisites	0,520
31	Other transport equipment n.e.c.	0,517
32	Machine- tools	0,515
33	Accumulators, primary cells and primary batteries	0,515
34	Dressing and dyeing of fur; articles of fur	0,511
35	Other special purpose machinery n.e.c.	0,505
36	Cement	0,497
37	Optical instruments and photographic equipment	0,480
38	Cutting, shaping and finishing of stone	0,460
39	Electric motors, generators and transformers	0,460
40	Wooden containers	0,458
41	Games and toys	0,457
42	Other plastic products	0,442
43	Pesticides and other agro-chemical products	0,432
45	Other articles of concrete, plaster and cement	0,428
46	Other non-metallic mineral products n.e.c.	0,423
47	Production and distribution of electricity	0,418
48	Electricity distribution and control apparatus	0,418
49	Other general purpose machinery n.e.c.	0,417
50	Insulated wire and cable	0,406

Table A1 Continued

51	Bricks, tiles and construction products, in baked clay	0,398
52	Other electrical equipment n.e.c.	0,391
53	Beverages	0,385
54	Non-electric domestic appliances	0,383
55	Manufacture and processing of other glass including technical glassware	0,382
56	Bicycles	0,373
57	Pharmaceutical preparations	0,353
58	Processing and preserving of fish and fish products	0,353
59	Paints, varnishes and similar coatings, printing ink and mastics	0,352
60	Watches and clocks	0,341
61	Paper and paperboard	0,322
62	Parts and accessories for motor vehicles and their engines	0,320
63	Precious metals production	0,317
64	Other food products n.e.c.	0,317
65	Bodies (coachwork) for motor vehicles; trailers and semi-trailers	0,312
66	Soap and detergents, cleaning and polishing preparations	0,302
67	Builders' carpentry and joinery	0,294
68	Man-made fibres	0,292
69	Printing n.e.c.	0,287
70	Basic iron and steel and of ferro-alloys	0,276
71	Instr. And appliances for measuring,checking,testing and navigating	0,275
72	Milk and cheese products	0,258
73	Luggage, handbags and the like, saddlery and harness	0,257
74	Other rubber products	0,240
75	Processing and preserving of fruit and vegetables n.e.c.	0,238
76	Other organic basic chemicals	0,220
77	Printing of newspapers	0,218
78	Television & radio receivers, sound/video recording etc.	0,202
79	Prepared feeds for farm animals	0,191
80	Other chemical products n.e.c.	0,188
81	Tobacco industry	0,188
82	Motor vehicles	0,170
83	Railway and tramway locomotives and rolling stock	0,168
84	Steam generators (central heating excl.)	0,160
85	Crude oils and fats	0,155
86	Starch and related products	0,136
87	Renting of office machinery and equipment including computers	0,132
88	Basic pharmaceutical products	0,130
89	Aircraft and spacecraft	0,128
90	Nuclear fuels treatment	0,078
91	Building and repairing of ships	0,062
92	Electronic valves and tubes and other electronic components	0,050
93	Television and radio transmitters and apparatus for line telephony	0,047
94	Refined petroleum products	0,008
95	Coke and coal related products	0,001