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On the Marshall – Jacobs Controversy: It takes two to tango

By

Gerben van der Panne and Cees van Beers

Danish Research Unit for Industrial Dynamics

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Gerben van der Panne
Assistant professor of Economics
Delft University of Technology
Jaffalaan 5
2628 BX Delft,
The Netherlands
E-mail: g.vanderpanne@tudelft.nl

Cees van Beers
Associate professor of Economics
Delft University of Technology
Jaffalaan 5
2628 BX Delft,
The Netherlands

Abstract:
The literature is inconclusive as to whether Marshallian specialization or Jacobian diversification externalities favour regional innovativeness. The specialization argument poses that regional specialization towards a particular industry improves innovativeness in that industry. Regional specialization allows for knowledge to spill over among similar firms. By contrast, the diversification thesis asserts that knowledge spills over between firms in different industries, causing diversified production structures to be more innovative. Building on an original database, we address this controversy for the Netherlands. We thereby advance on the literature by providing a two-level approach, at the region's and the firm's level. At the regional level, we compare specialized with diversified regions on numbers of accommodated innovators. At the firm level, we establish causalities between externalities and degree of innovativeness. The results suggest Marshallian externalities: specialized regions accommodate increased numbers of innovating firms and, consistently, incumbent firms' innovativeness increase with regional specialization. Once the product has been launched, innovators in diversified Jacobian regions prove more successful in commercial terms than innovators in specialized Marshallian regions.

Key words: Industrial clusters; innovation; knowledge externalities

JEL Codes: O18; O31; R10

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1. Introduction

Firms' location decisions are the outcome of a search for a match between the firm's requirements and the endowments provided by the respective regions. As to the innovator's need to create and sustain a competitive knowledge base, the literature remains inconclusive as to whether specialized or diversified regions are conducive. The Marshallian specialization hypothesis asserts that regions with production structures specialized towards a particular industry tend to be more innovative in that particular industry. The Jacobian diversification hypothesis, by contrast, argues that diversified production structures favour regional innovativeness.

Generally, two levels of analysis are adopted in attempting to address this controversy. Studies at the regional level can be distinguished from those at the firm level. At the regional level, specialized and diversified regions are compared on numbers of accommodated innovators. These are expected to increase with the merits of either type of externalities. At the firm level, causalities are established between externalities and innovative performance of the individual firm. The advantages of each type of externalities would be resembled by the innovation performance of firms in either specialized or diversified regions.

Our contribution to the literature is threefold. First, unique data allow for adopting both levels of analysis simultaneously. We analyse regional counts and individual firm performance. In adopting this two-level approach, new evidence is provided to build the case for both Marshallian or Jacobian externalities. Second, the paper builds on an original database of innovators compiled by screening 43 specialist trade journals for new-product-announcements. These data are more appropriate for industrial clusters research than traditional databases, for reasons to be discussed below. Moreover, the data allow us to distinguish between technological and commercial success. Third, our analysis deals with the Netherlands, where the homogeneity across the regions regarding general business conditions allows us to measure knowledge externalities more accurately than in case of a large and heterogeneous country like the United States (see among other Feldman & Audretsch 1999).

The arguments for the specialization and diversification hypotheses are briefly discussed in section 2. The data collection procedure is described in section 3. In section 4 the modeling framework is presented. The empirical results are shown and discussed in section 5, followed by conclusions in section 6.

2. Specialization and diversification externalities

Externalities are defined as economies of scale external to the firm. An increase in industry-wide output within a given geographical area decreases average costs for the individual firm. The 'Industrial District-argument', put forward by Marshall (1890), asserts that spatial concentration of production may sustain asset-sharing, the provision of specific goods and services by specialized suppliers and a local labour market pool. A local concentration of production is therefore expected to reduce the production costs incurred by individual firms in the cluster.

In this paper we focus on externalities related to the individual firms' ability to create and sustain a competitive knowledge base. Newly-created knowledge can be appropriated only to a limited extent and may spill over to other firms. By "working on similar things and hence benefiting much from each others' research" (Griliches 1979), knowledge spillovers increase the stock of knowledge available for each individual firm. Knowledge spillovers relate to the dissemination of tacit knowledge. As opposed to codified knowledge, tacit knowledge is ill-documented, uncodified and can only be acquired through the process of social interaction. Hence knowledge spillovers are limited in geographic scope and bounded to the region where the new economic knowledge is originally created (Feldman & Audretsch 1999). The concept of knowledge spillovers is generally acknowledged as an important determinant of regional innovation dynamics (Karlsson & Manduchi 2001).

There are two competing hypotheses on the nature of these externalities. As put forward by Marshall (1890), Arrow (1962), and Romer (1986), and later formalized by Glaeser *et al.* (1992) as the Marshall-Arrow-Romer (MAR) model, the specialization hypothesis argues that knowledge tends to be industry-specific. Consequently, spillovers are expected to arise between firms within the same industry and can only be supported by regional concentrations of similar industries. These intra-industry spillovers are known as localization or 'specialization' externalities. By contrast, the alternative hypothesis asserts that knowledge spills over between complementary rather than similar industries. As argued by Jacobs (1969), the exchange of complementary knowledge across diverse firms and economic agents facilitates search and experimentation in innovation. A diversified regional production structure is therefore expected to increase the stock of knowledge available for the individual firm and gives rise to urbanization or 'diversification' externalities.

Several empirical studies set out to address the controversy. Using patent data for Italy, Paci and Usai (1999) establish that both specialization and diversification externalities positively affect regional innovativeness, the latter being more pronounced for high technology industries and metropolitan environments. Shefer and Frenkel (1998) arrive at similar conclusions for Israel, though only for high technology sectors; low technology sectors are not affected by externalities. By contrast, Feldman and Audretsch (1999) argue that diversification rather than specialization externalities foster regional innovative activity in the United States. Numbers of new-product announcements even tend to be lower in specialized regions. This corroborates with Kelly and Hageman (1999): "the location of Research and Development (R&D) is determined more by the location of other sectors' innovation than by the location of its own production". Using R&D labour costs data for the Netherlands, Van Oort (2002) also establishes diversification externalities for innovation in manufacturing industries, as do Ouwersloot and Rietveld (2000).

A closely related debate is on the impact of local market structure on innovative behaviour. The Marshallian model holds that local market power of firms in the labour market favours innovation. Local monopoly restricts the flow of ideas to others and maximizes the innovating firm's capability to appropriate the innovation rents (Glaeser *et al*. 1992). Jacobs (1969), by contrast, asserts that local competition is an incentive to engage in innovation. Jacobs' (1969) concept of local competition is substantially different from the traditional notion of competition on product markets. It evolves around the struggle for ideas. The local firms' competition for ideas, which are embodied in individual employees, is determined by the industry-specific firm-employment ratio: the more firms per employee, the better individuals are enabled to pursue and implement new ideas. Feldman & Audretsch (1999) observe that, consistent with Jacobs' (1969) hypothesis, local competition positively affects innovative activity. For the Netherlands, Van Oort (2002) establishes that, consistent with the Marshallian model, local competition hampers innovation.

3. Collection of data

For the purpose of this paper we compiled an innovation database. The data have been collected using the Literature-based Innovation Output (LBIO) method. The LBIO method has been used by several authors like Edwards and Gordon (1984), Acs and Audretsch (1988) for the USA, Kleinknecht *et al* (1993) for the Netherlands, Cogan (1993) for Ireland, Coombs *et al* (1996) for the United Kingdom and Santarelli, Piergiovanni (1996) for Italy and Flor and Oltra (2004) for Spain. The method has several advantages. First, as opposed to traditional indicators like R&D labour costs, it is a direct innovation output indicator, i.e. it measures the market introduction of new products. Second, as opposed to patent statistics, the LBIO method also retrieves data on innovations that are not patented. Third, the LBIO-method also accounts for the population of young and small firms. These are insufficiently covered by traditional indicators: LBIO data are among the most comprehensive of those using secondary data (Flor and Oltra 2004). A drawback associated with the LBIO method is that the probability to announce a new product in a journal need not be equal for all firms and products.

Two volumes of forty-three trade journals have been screened for new-product announcements. The screening method excluded advertisements. Only announcements in the editorial sections of the journals have been taken into account. In the editors' expert opinion these products apparently embody a surplus value over previous versions or substitutes. In order to further reduce the risk of counting mere product differentiations, the announcements were required to report at least one characteristic feature of superiority over previous versions or substitutes concerning functionality, versatility or efficiency. During September 2000 – August 2002 we counted 1,585 new-product-announcing firms located in the Netherlands and sent these a questionnaire in order to obtain additional information on the firm and its innovation activities. 1,056 firms responded, of which 658 firms reported to have imported the innovation. These 658 cases have been omitted: As we are interested in in-house developed innovations we use the remaining 398 cases for further analysis. These 398 firms have been re-contacted two years after product launch in order to obtain information on the commercial viability of the product.

Referring to the issue of sample representativeness, we compared our LBIO sample to the Dutch *Community Innovation Survey* (CIS). As to the distribution of innovators across industries, both databases run parallel and are significantly correlated.[1] This result can be considered reassuring. Relative to the CIS data, the LBIO database comprises many small firms. This bias towards small firms is accounted for by a minimum size restriction of 10 employees applied in the CIS database. Controlling for this threshold, both databases take on similar size distributions.

The 398 surveyed firms show much concern for innovation as more than eighty percent report to engage in research activities on a continuous basis, rather than only occasionally. Approximately three out of every four announcements refer to products new to the industry rather than new to the firm only. Half the firms with in-house developed innovations reported to have applied for patents. In terms of R&D expenses and new-product turnover, the firms identified in the LBIO database are no less innovative than those in the CIS (see Table 1).

Table 1. Comparison of Community Innovation Survey (CIS) and LBIO data.

			CIS	LBIO
R&D intensity		Mean	7	8.9
		Median	2.2	5
		Sd	66.7	12.9
R&D output	Improved	Mean	20.8	23.3
		Median	15	20
		Sd	20.7	16.1
	New	Mean	11.3	24.1
		Median	8	20
		Sd	14.6	20.51
patents	Yes		28.3%	51.3%
	No		71.7%	48.7%
R&D activities	Permanently		72.0%	82.2%
	Occasionally		28.0%	17.8%

In order to address the Marshall – Jacobs controversy, we examine the merits of specialization and diversification externalities at the regional and firm level. At the regional level, we examine whether the Marshallian model (specialization externalities and local market power) or Jacobian model (diversification externalities and local competition) can explain regional innovativeness in the Netherlands.[2] More specifically, we test whether regions endowed with specialized or diversified production structures accommodate more innovators. The count of innovators is regressed on three regional production structure characteristics: (1) degree of specialization, (2) degree of diversification and (3) degree of competition. The 398 innovators are disaggregated at the 2-digit postal code level, subdividing the Netherlands into 98 regions. Industries are disentangled at the 2-digit SIC-level, distinguishing 58 industries.

4. Model operationalization

Feldman & Audretsch (1999) and Paci & Usai (1999) are followed in using the production structure specialization index (PS) to measure Marshallian specialization externalities. Based on employment data,[3] the PS-index measures the extent to which region *j* is specialized towards industry *i*:

$$PS_{ij} = \left[E_{ij} / \sum_{i} E_{ij} \right] / \left[\sum_{j} E_{ij} / \sum_{i} \sum_{j} E_{ij} \right] \qquad (1)$$

where i = 1..58 industries

j = 1..98 postal code regions

E = employment

The PS_{ij} variable is a location coefficient, measuring the share of employment accounted for by industry *i* in region *j*, relative to this industry's share in national employment. High PS_{ij}-values imply regional specialization externalities in industry *i*. Specialization and diversification externalities are, however, not mutually exclusive; any diversified region may also accommodate the larger part of a particular industry, leaving the region both diversified and specialized simultaneously. We therefore need an additional measure of diversification externalites, taking into account the employment distribution across all industries in the region; a separate coefficient $GINI_j$ has been calculated for each region *j* (see e.g. Wen (2004)).

$$GINI_j = \frac{1}{2n^2 \bar{s}_j} \sum_{k=1}^{n} \sum_{i=1}^{n} | s_{ij} - s_{kj} | \qquad (2)$$

where s_{ij} is the share of industry *i's* employment in region *j* and s_{kj} is the share of industry *k*'s employment in region *j*; *n* is the number of industries, $\bar{s}_j$ is the mean of the shares. The Gini-coefficient measures for each postal region *j* the area between a 45 degrees line and a Lorenz curve. This curve is derived by ranking s_{ij} in ascending order and plotting its cumulative values to the cumulative values of employment. An index close to one implies that employment in a region is strongly concentrated in one industry. If a region is characterized by an equal distribution of industries' employment, the Gini-coefficient equals zero. For ease of interpretation, we proceed with the complement of the Gini-coefficient, $GINIC_j$, defined as ($1-GINI_j$). $GINIC_j$ varies between 0 and 1 and associates larger values with diversified local production structures, indicating Jacobian externalities.[4]

The degree of local competition is measured by the competition coefficient COMP:

$$COMP_{ij} = \left[\left(FIRMS_{ij} / E_{ij} \right) / \left(\sum_j FIRMS_{ij} / \sum_j E_{ij} \right) \right] \qquad (3)$$

where *i*, *j* and E_{ij} are defined as in (1) and $FIRMS_{ij}$ = total number of firms, whether innovative or not.[5] The $COMP_{ij}$ variable relates the number of firms per worker per industry *i* in region *j* to its national equivalent and refers to Jacobs' (1969) notion of labour market competition. High values are associated with fierce competition between local firms for labour, low values indicate less fierce local labour market competition (Glaeser *et al.* 1992; Feldman & Audretsch 1999). Alternatively, the values for $COMP_{ij}$ can be read in terms of average firm size. Values smaller than 1 relate to large average firm size relative to the industries' national equivalent and suggest less fierce competition on the regional level. Following the Marshall-Arrow-

Romer (MAR) model, small values for $COMP_{ij}$ suggest local market power enabling the innovator to appropriate the innovation rents (Glaeser *et al*. 1992; Feldman & Audretsch 1999).

As emphasized by Jaffe *et al.* (1993), the propensity for innovations to cluster geographically differs by industry simply because the location of production is more concentrated in some industries than in others. To control for total firm population, the variable $FIRMS_{ij}$ introduced in the $COMP_{ij}$ variable is re-introduced into the model as an autonomous control variable. Equation (4) summarizes the regional level analyses:

$$\textit{Number of innovators}_{ij} = \mathrm{f}\ (\textit{Regional specialization}_{ij}, \textit{Regional diversification}_{j}\ \textit{competition}_{ij}, \textit{firm population}_{ij}) \qquad (4)$$

Summing up, the Marshallian model (specialization externalities and local market power) will be suggested by both a positive coefficient for PS_{ij} and a negative coefficient for $COMP_{ij}$. The Jacobian model (diversification externalities and local competition) will be validated by positive estimates for both $GINIC_j$ and $COMP_{ij}$.

The regional analyses are extended with firm level analyses. These examine the impact of Marshallian and Jacobian externalities on the individual firms' innovation activities. We use four different dependent variables, providing a comprehensive description of innovative behaviour of the individual firm. The first variable is defined as the share of total sales generated with (re)newed products and measures innovation output. Variable two is also a measure of innovation output and takes on the value 1 if the product announced can be considered radically new and 0 for incrementally improved innovations. Variables three and four deal with the propensity to participate in innovation networks. Variable three takes on the value 1 if the product announced is developed in partnership, 0 otherwise. Variable four denotes the number of partners involved in developing the product announced.

In examining the effect of externalities (PS_{ij} and $GINIC_j$ variables) on innovative behaviour we control for general firm characteristics. The first control variable is firm size in terms of employment (SIZE). Large firms are expected to produce more innovative output as they have more means at their disposal to innovate. The variable RD measures the R&D-intensity, i.e. the share of R&D expenditures in total sales. Innovative output can be expected to increase with R&D spending. The variable AUTONOMY distinguishes between dependent and autonomous firms. Dependency affects the ability to realize innovative output. A dependent firm might not have the capability or permission to develop innovative products on its own. The share of export in total sales (EXPORT) is expected to affect the share of new products in total sales positively. Exporting firms are exposed to competition in global product markets, which provokes a tendency to innovate. A dummy MANUFACTURING that takes on the value 1 if the firm is manufacturing, 0 otherwise, accounts for the industry structure of the sample. Equation (5) summarizes the firm level analyses:

Innov = f (*Regional specialization, Regional diversification, R&D intensity, Firm size, Autonomy,Export intensity, Manufacturing*) (5)

Two years after market launch, we re-contacted the 398 firms in order to obtain information on the extent to which the announced products have been successful in commercial terms. A Likert-scale has been applied, which measures product performance relative to its initial expectations. The scale distinguishes between ‘below expectations’ (40%), ‘as expected’ (35%) and ‘above expectations’ (25%). Determinants of commercial viability differ from those explaining success in technological terms (see Van der Panne *et al.* 2003). Development and production require technical knowledge while the successful launch of the product relies on financial, market and marketing knowledge. Hence, the importance of Marshallian and Jacobian knowledge externalities may change once the product has been developed and is being introduced on the market. The variables R&D intensity, autonomy and manufacturing are not expected to be relevant in explaining commercial success and are omitted. Firm size and export intensity are maintained. Firm size is expected to affect post-launch performance positively as large firms have the means for marketing and distribution at their disposal. Export intensity also affects commercial performance as exporting firms develop a clear understanding of foreign potential market demand. Equation (6) is used to examine the impact of externalities on commercial product performance, two years after launch:

$$\textit{Commercial performance} = \mathrm{f}\,(\textit{Regional specialization, Regional diversification, Firm size, Export intensity}) \qquad (6)$$

5. Estimation results

Table 2 shows the results of regional level analyses, based on equation (4). The count of innovating firms per industry *i* per region *j* follows a Poisson distribution, suggesting the use of a count data model. For reasons of overdispersion, the negative binomial regression model is applied instead.[6] Model 1 explains the number of innovators per postal code region per industry.

Table 2. Regional level analysis: externalities and innovation

	Model 1 Regional count of innovators
Constant	-4.04**
	(-6.15)
PS_{ij} (specialization)	1.15*
	(1.72)
$GINIC_j$ (diversification)	1.10
	(1.59)
$COMP_{ij}$ (competition)	-0.34**
	(-3.99)
$FIRMS_{ij}$ (total firm population)	1.85**
	(10.93)
Log Likelihood	-1291.9
N (98 regions • 58 industries)	5684

** Significant at 5%-level; *significant at 10%-level; z-values in parentheses. All explanatory variables are standardized; estimates are heteroscedasticity-consistent (Huber-White).

The results on the product specialization coefficient PS_{ij} suggest Marshallian specialization externalities. Given the number of firms per industry per region, numbers of innovators in that particular industry and region tend to increase with specialization. In other words, an increase in regional specialization towards a particular industry positively affects regional innovativeness in that particular industry more than proportionally. The estimate on the $GINIC_j$ variable suggests that Jacobian diversification externalities and more innovations also go together but to a lesser extent than Marshallian specialization externalities.

Following Jacobs (1969) and Porter (1990), competition on labour demand enables employees to implement innovative ideas and favours the pursuit and adoption of innovation. This assumption does not hold for the Netherlands. The estimate on the $COMP_{ij}$ variable suggests that fierce competition among firms for labour affects regional innovativeness negatively. Rather, this estimate is consistent with Marshall's (1890) argument of local market power: less fierce competition enables the innovator to appropriate the innovation rents. Considering that both Marshallian specialization externalities and local market power act as incentives to engage in innovation, at the regional level, the results appear more consistent with the Marshallian than the Jacobian model.

The regional level analysis above suggests that Marshallian externalities are conducive for innovativeness. To build the case for Marshallian externalities, these preliminary conclusions are to be sustained by similar analyses at the level of the individual firm. These are based on equation (5) and shown in Table 3.

Table 3. Firm level analysis: externalities and innovation

	Innovation output		Innovation process	
	Model 2 Share-in-sales (re)newed products†	Model 3 Radical innovation (yes/no) ††	Model 4 Innovation in partnership (yes/no) ††	Model 5 Number of partners†††
Control variables:				
constant	3.31**	3.64**	5.09**	1.77**
	(4.76)	(2.23)	(2.37)	(2.83)
RD	0.34**	1.45**	-0.90	1.13*
	(5.59)	(2.54)	(-0.65)	(1.74)
SIZE	0.10	-0.88	1.69	1.03
	(1.60)	(-0.81)	(1.09)	(0.58)
AUTONOMY	-0.07	1.09	-0.96	1.17**
	(-1.27)	(0.57)	(-0.19)	(2.48)
MANUFACTURING	0.07*	1.04	1.46*	1.11
	(1.65)	(0.28)	(1.89)	(1.56)
EXPORT	0.11**	1.18	-0.88	1.03
	(2.12)	(1.11)	(-0.70)	(0.54)
Externalities:				
PS_{ij} (specialization)	0.09*	1.14	1.35	1.07
	(1.79)	(0.99)	(1.18)	(1.12)
$GINIC_j$ (diversification)	-0.08	-0.68**	-0.72*	-0.89**
	(-1.34)	(-2.60)	(-1.77)	(-1.97)
Number of obs.	232	221	238	238
R^2	0.71	-	-	-
Log Likelihood	-	-145.1	-97.5	-490.8

† Least squares estimates (elasticities)
†† logit estimates
††† Negative binomial regression estimates

** Significant at 5%-level; *significant at 10%-level; t-values (Model 4) and z-values (Models 5 – 7) in parentheses. All explanatory variables are standardized; estimates are heteroscedasticity-consistent (Huber-White).

The estimates on innovative output (Model 2) suggest that Marshallian externalities positively affect R&D output. Given R&D inputs, innovators located in specialized regions tend towards increased shares of sales generated with (re)newed products. This suggests that, consistent with the Marshallian model, regional specialization improves the availability of knowledge spillovers and allows for efficient use of externally derived knowledge. By contrast, knowledge spillovers cannot be capitalized upon in diversified regions: Jacobian externalities and increased R&D output are not positively correlated. This relates to reduced propensities to introduce radical innovations (as opposed to incrementally improved products) for innovators in diversified regions (Model 3). The lower propensity for firms in diversified regions to introduce highly innovative products is consistent with reduced propensities to innovate in partnership for firms in the respective regions (Model 4). One may argue that engaging in innovation on an autonomous basis prevents the firm from capitalizing on external knowledge, inducing the firm to rely on less innovative products. Indeed, firms in diversified regions tend towards less innovation partners, whereas firms in specialized regions engage in extended innovation networks (Model 5).

So far we have examined innovative output (Table 3), which indicates technological success but not necessarily commercial viability. In order to examine the relationship between externalities and commercial success, we explain post-launch performance with regional specialization and diversification, see equation (6). Table 4 presents the results using the ordered logit model (see Maddala 1986).

Table 4. Externalities and commercial success

	Model 6	Model 7
Control variables:		
SIZE	-	1.06
		(0.44)
EXPORT	-	1.23**
		(2.18)
Externalities:		
PS_{ij} (specialization)	-0.85	-0.85
	(-1.53)	(-1.49)
$GINIC_j$ (diversification)	1.21*	1.23*
	(1.91)	(1.94)
Log Likelihood	-475.3	-442.3
Number of obs.	324	304

Two years after product launch, firms located in diversified regions report positively on the product's commercial performance more than do innovators in specialized regions. Jacobian diversification externalities seem favourable for commercial performance. This relates to, among others, Feldman (1994) in arguing that the proximity of specialized business services providing knowledge on regulations, standardization, marketing and product testing reduces the risks of commercial failure.

6. Conclusions

In this paper it is examined whether Marshallian specialization or Jacobian diversification externalities favour regional innovativeness in the Netherlands. Building on an original and highly appropriate database of new-product-announcements in trade journals, we establish that regions endowed with specialized production structures accommodate more innovators than do diversified regions. In addition, we establish that innovators in specialized regions stand out on their counterparts in diversified regions. Innovators in specialized regions engage in extended innovation networks and report increased levels of innovation output. By contrast, innovators in diversified regions are less inclined to innovate in partnership and introduce less radical innovations. This leads to the conjecture that Marshallian specialization externalities favour innovativeness. However, Jacobian diversification externalities prove relevant as well, albeit at other stages in new product development. These externalities are conducive to the new products' commercial viability. Two years after market launch, products introduced by innovators in diversified regions outperform innovations developed in specialized regions. At different stages in new product development, there is a case for both Marshallian and Jacobian externalities.

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[1] Spearman’s $\rho =$ 0.7, p-value= 0.001

[2] In addition to the Marshallian and Jacobian models, Porter's (1990) model is occasionally referred to. The Porter model agrees with the Marshallian model in that it asserts specialization externalities, but agrees with the Jacobian model that local competition rather than monopoly favours knowledge externalities as it accelerates the pursuit and adoption of innovation.

[3] Data provided by Marktselect plc (2002).

[4] The original Gini coefficient decreases with diversification; the complement GINIC is positively related to diversification.

[5] Data provided by Marktselect plc (2002) De DM-CD. Amsterdam, Applidata BV. This CD-rom documents information on postal code and main activity of every single firm registered at the Dutch Chamber of Commerce.

[6] In case of overdispersion, i.e. $\sigma_x > \mu_x$, the Poisson model under-estimates dispersion, resulting in downward biased standard errors (Cameron and Trivedi, 1986). The negative binomial regression model addresses this issue by introducing the parameter α, reflecting unobserved heterogeneity among observations.