J Evol Econ (2004) 14: 593–604
DOI: 10.1007/s00191-004-0232-x

Journal of Evolutionary Economics

Agglomeration externalities: Marshall versus Jacobs*

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Abstract. The literature remains inconclusive as to whether Marshallian specialization or Jacobian diversification externalities favor regional innovativeness. The specialization thesis asserts that regions with production structures specialized towards a particular industry tend to be more innovative in that particular industry, as it allows for knowledge to spill over between similar firms. The diversification thesis argues that knowledge spills over between different industries, causing diversified production structures to be more innovative. A closely related debate evolves around local competitiveness hypotheses. Using an original database of innovation counts, both these issues are addressed for the Dutch context. The results show that the Marshallian specialization thesis holds, though more pronounced for R&D intensive and small firms. Fierce local competition within an industry negatively affects innovativeness in that particular industry.

Keywords: Innovation – Agglomeration externalities – Knowledge spillovers

JEL Classification: O18, O31, R10

1 Introduction

The literature on innovation and agglomeration externalities remains inconclusive as to whether specialized or diversified local production structures favor local innovative activity. In addition, ambiguity exists as to whether local market power or competition is favorable. Using a collection of new product announcements in specialist trade journals in the Netherlands, these issues are addressed in this paper. The Dutch case may be interesting, as some authors argue that agglomeration

* The author wishes to thank Fia Wunderink, Wilfred Dolfsma and Alfred Kleinknecht for helpful comments on an earlier version of this paper.

externalities do not affect or discriminate between regions in innovative activity (Pellenbarg and Kok, 1985; Atzema, 2001), whereas others tend towards opposite conclusions (Dieperink and Nijkamp, 1986; Brouwer et al., 1999; Ouwersloot and Rietveld, 2000; Van Oort, 2002).

The contribution to the literature is twofold. First, the paper builds on an original database of new-product-announcing firms, which is appropriate for spatial research. Second, the geographic scope of both specialization and diversification externalities is assessed for the Dutch case, thereby distinguishing between the local and the regional level.

The arguments for the specialization, diversification and competition hypotheses are briefly discussed in Section 2. The data collection procedure is described in Section 3. The econometric model is presented in Section 4, followed by conclusions in Section 5.

2 Specialization and diversification

Increasing returns to scale, or economies of scale, translate increased levels of output into downward sloping average costs curves. Economies of scale may also be external to the firm: an increase in industry-wide output within a given geographical area decreases average costs for the individual firm. Dating back to Marshall's (1890) 'Industrial District-argument', asset-sharing, such as the provision of specific goods and services by specialized suppliers and the creation of a local labour market pool sustained by a local concentration of production may serve as an example. In addition to these 'pecuniary' externalities transmitted by the market, knowledge externalities may positively affect the regionally residing firms' ability to innovate. As newly-created knowledge can be appropriated only to a limited extent, knowledge created by one firm 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.

These spillovers are, however, not invariant to distance as these concern tacit knowledge. Tacit knowledge is ill-documented, uncodified and can only be acquired through the process of social interaction. Hence, knowledge spillovers are geographically bounded to the region in which the new economic knowledge is created (Feldman and Audretsch, 1999) and introduce the need for geographical proximity to be capitalized upon.

Although the importance of knowledge spillovers to regional innovation dynamics is generally acknowledged in the innovation literature (Karlsson and Manduchi, 2001), there is debate as to whether agglomeration economies arise between firms belonging to either the same or to different industries. 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, knowledge is predominantly industry-specific. Knowledge spillovers may therefore arise between firms within the same industry and can only be supported by regional concentrations of a particular industry. These intra-industry spillovers are known as localization or 'specialization' externalities.

Jacobs (1969), by contrast, argues that knowledge may spill over between complementary rather than similar industries as ideas developed by one industry can be applied in other industries. The exchange of complementary knowledge across diverse firms and economic agents facilitates search and experimentation in innovation. Therefore, a diversified local production structure leads to increasing returns and gives rise to urbanization or 'diversification' externalities.

Most studies on Marshallian specialization and Jacobian diversification externalities focus on firm level productivity growth.[1] Studies explicitly examining the impact of agglomeration externalities on regional innovativeness remain inconclusive as to whether Marshallian specialization or Jacobian diversification externalities are conducive.

Several studies report evidence of both types of externalities. Using patent data for the Italian case, Paci and Usai (1999) observe that both specialization and diversification externalities positively affect regional innovativeness, the latter being more pronounced for high technology industries and metropolitan environments. For the Israeli case, Shefer and Frenkel (1998) also argue that both specialization and diversification externalities positively affect the rate of innovation, though only in high technology sectors (i.e. electronics); low technology sectors (metals and plastics) are not affected by agglomeration externalities.

Others argue that only Jacobian diversification externalities are innovation-conducive. Following Feldman and Audretsch (1999), diversification rather than specialization externalities foster regional innovative activity in the US. Numbers of new product announcements even tend to be lower in "industries located in cities specialized in economic activity in that industry". Based on US patent data, Kelly and Hageman (1999) observe diversification externalities, as "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 labor costs data for the Netherlands, Van Oort (2002) emphasizes diversification externalities for innovation in manufacturing industries, as do Ouwersloot and Rietveld (2000).

A closely related debate concerns the impact of local market structure on innovative behavior. The Marshallian model argues that local market power favors innovation, as 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 acts as an incentive to engage in innovation. Instead of the traditional notion of competition within product markets, Jacobs' (1969) concept of local competition 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. Again the empirical literature remains inconclusive. Feldman and Audretsch (1999) observe that, consistent with Jacobs' (1969) hypothesis, local competition positively affects innovative activity. For the Netherlands, Van

[1] Among others see Moomaw (1988), David and Rosenbloom (1990), Capello (2002), and Henderson (2003).

Oort (2002) reports that, consistent with the Marshallian model, local competition tends to hamper innovation.

3 Data and model

In the remainder of this paper, 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] Three hypotheses are derived:

(H1) Relative to less specialized regions, those regions specialized towards a specific industry tend towards increased levels of innovativeness in that particular industry (Marshallian specialization externalities)
(H2) Relative to less diversified regions, those regions with a diversified production structure tend towards increased levels of innovativeness (Jacobian diversification externalities)
(H3) The fierceness of competition in a particular industry in a particular region affects innovativeness in that particular industry, in that particular region

New product announcements in specialist trade journals are used in measuring innovativeness. The database of new-product-announcing firms was built by screening two successive volumes of 43 journals for new product announcements. This data collection method is referred to as the Literature-based Innovation Output (LBIO) method and was first applied by The Futures Group (Edwards and Gordon, 1984). The latter data have been analyzed by Acs and Audretsch in a series of articles (for a survey see Acs and Audretsch, 1993). In Europe similar studies have been conducted by Kleinknecht et al. (1993) in the Netherlands, Cogan (1993) in Ireland, Fleissner et al. (1993) in Austria, Coombs et al. (1996) in the United Kingdom and Santarelli and Piergiovanni (1996) in Italy.

For spatial analysis, this innovation count indicator may be considered more appropriate relative to traditional indicators such as patent or R&D statistics. As opposed to patent statistics, this indicator also retrieves data on those innovations not protected by patents. Other than R&D statistics, the LBIO indicator measures innovation output directly, i.e. new products introduced on the market. Moreover, this indicator accounts for the rapidly changing population of young and small firms that are insufficiently covered by official R&D statistics. The LBIO indicator allows for detailed regional disaggregation of innovative activity, whereas traditional indicators are confined to firm level data. Particularly in the cases of multi-plant firms, this is a major advantage over traditional indicators in spatial research. The innovation count indicator incurs two drawbacks though. First, one cannot presume that the likelihood to announce a new product in a journal is equal for all firms and all products. Second, numbers of reported announcements run parallel with the number of journals screened.

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

In screening the trade journals for new product announcements, advertisements are excluded; only announcements in the editorial sections of the journals are counted. In the editor's expert opinion, these products apparently embody surplus value over preceding versions or substitutes. In order further to reduce the risk of counting mere product differentiations, the announcements are required to report at least one characteristic feature of superiority over preceding versions or substitutes (concerning functionality, versatility or efficiency). Each announcing firm was sent a questionnaire to document additional information on the firm and its innovation activities. Most importantly, the firms were explicitly asked whether the product is indeed of domestic origin. Approximately 60 percent of all product-announcing firms reported to have the innovation imported rather than developed in-house, within the Netherlands. These cases were omitted. Over the September 2000 – August 2002 period, 398 valid cases of new-product-announcing firms were counted.[3]

As the LBIO database is not based on standard sampling procedures, it is not claimed to be representative for the population of Dutch innovators. It is, however, reassuring that the distribution of new-product-announcing firms across industries shows a fairly strong correlation with the distribution of product innovators identified in the 1996 *Community Innovation Survey*, which is stratified by industry and firm size (Spearman's rank correlation coefficient is .7). In the absence of any minimum firm size restrictions, the LBIO database comprises many small firms.[4] Though small, the 398 firms are dedicated innovators as nearly eighty percent report engaging in innovation on a continuous, rather than occasional, basis.

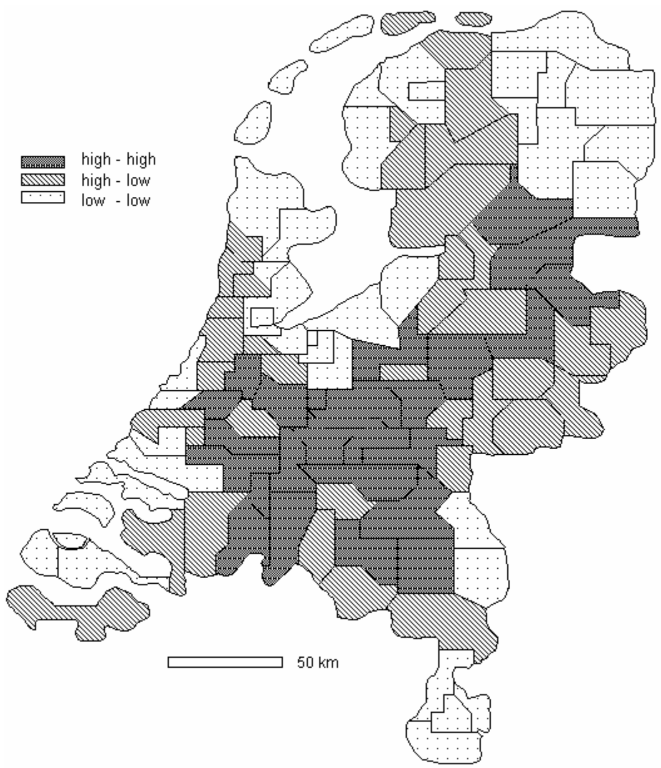
Moran's scatter plot is used to visualize these firms' spatial pattern. The share of new-product-announcing firms in total firm population is classified into three categories according to value similarity between proximate regions: highly innovative regions surrounded by highly innovative regions (referred to as 'high-high'), highly innovative regions surrounded by modestly innovative regions ('high-low'), and proximate modestly innovative regions ('low-low').[5]

Assuming regional agglomeration externalities do not systematically affect innovativeness, one would expect the share of innovators in total firm population to be distributed randomly throughout the Netherlands. This is, however, not the case:

[3] In total, 1585 firms were surveyed. The respons rate is 66,6 % (1056 firms), of which 37,7% (398 firms) reported to have the innovation developed in-house, within the Netherlands. These 398 cases are considered valid.

[4] Firm size of innovators identified in the LBIO database: 22 employees (median); Inter Quartile Range $= 6 - 71$ employees. Distributions across firm size do not systematically differ between the LBIO and *1996 Community Innovation Survey* databases when controlling for differences in survey procedures, i.e. the minimum firm size restriction of 10 employees applied in the latter.

[5] Moran's scatterplot plots spatially lagged values against original values, or $\mathbf{Wx}_i$ against x_i. $\mathbf{W}$ is a binary contiguity matrix, denoting whether region i's geographic center is within a 20 kilometers distance band from region j's geographic centre. $\mathbf{W}$ is row-standardized using $w_{ij}/\sum_{j=1}^{n} w_{ij}$. A threshold of 20 kilometers is applied to have every region associated with at least one neighboring region. Second, spatial concentration among observations across regions is most pronounced over the 0–20 kilometers distance band; see footnote 6.



Source: Delft University of Technology 2002

Fig. 1. Share of new-product-announcing firms in total firm population by 98 postal code regions: value similarity between neighboring regions. Moran's scatter plot

the sampled firms are spatially clustered.[6] In the remainder of this paper, we examine whether Marshallian specialization, Jacobian diversification, or competition arguments explain the spatial pattern shown in Figure 1.

Hypotheses H1–H3 are tested and regional innovativeness 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 disaggre-

[6] Moran's I statistic provides a formal test for spatial autocorrelation or spatial dependency. It reads as

$$I = \frac{N \sum_{i=1}^{N} \sum_{j=1}^{N,j\neq i} w_{ij}(x_i - \mu)(x_j - \mu)}{S_0 \sum_{i=1}^{N} (x_i - \mu)^2}$$

where N equals the number of regions, x is the observation in region i resp. j with μ as the mean of observations and S_o is the sum of the weights. W_{ij} is defined as in footnote 5.
In case of spatial independency, $E(I) = (-1/(N-1))$, or -0.01 evaluated at $N = 98$ postal code regions. For this sample, Moran's I test statistic for the regional share of new-product-announcing firms in the total regional firm population is estimated at 0.26, which is significantly different from the expected value in the absence of spatial dependency, or -0.01 (p-value $= 0.00$).

gated 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.

Feldman and Audretsch (1999) and Paci and Usai (1999) are followed in using the production structure specialization index (PS) to measure Marshallian specialization externalities. Based on employment data,[7] the PS-index measures the extent to which region j is specialized towards sector i:

$$PS_{ij} = \left[E_{ij} / \sum_i E_{ij} \right] / \left[\sum_j E_{ij} / \sum_i \sum_j E_{ij} \right]$$

where $i = 1..58$ industries
$j = 1..98$ postal code regions
$E =$ employment

The PS 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.

Jacobian diversification externalities are measured by the extent to which the local production structure in region j is diversified according to the production structure diversity index PD (Paci and Usai, 1999):

$$PD_j = \left[2/(n_j - 1) \sum_i E_j{}^* \sum_{i=1}^{n-1} \sum_i E_j \right]$$

where n is the number of regionally residing industries, and E is employment in industry i, ordered ascendingly by size. Larger values correspond to more diversified local production structures.

Note that, though counter-intuitive, specialization and diversification are not mutually exclusive. Whereas the PD variable is region-specific only, the PS variable is both region *and* industry-specific; a diversified region may also accommodate the larger part of a particular industry. Hence, regions can be both diversified and specialized towards particular industries simultaneously.

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

$$COMP_{ij} = \left[[\mathrm{FIRMS}_{ij} / E_{ij}] / \left[\sum_i \sum_j \mathrm{FIRMS}_{ij} / \sum_i \sum_j E_{ij} \right] \right]$$

where FIRMS $=$ total number of firms
$E =$ employment

This relates the number of firms per worker per industry i per region j to its national equivalent and refers to Jacobs' (1969) notion of labor market competition: high values are associated with increased levels of industry-specific local labor market competition. Alternatively, it can be read following Marshall's (1890) notion of competition, relating low values to large average firm size and market power.

[7] Data provided by Marktselect plc (2002)

As stressed 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 sectors than in others. To control for total firm population, the variable FIRMS introduced in the COMP variable is re-introduced into the model as an autonomous control variable.

Summing up, the Marshallian model (specialization externalities and local market power) will be evidenced by both a positive coefficient for PS and a negative coefficient for COMP.

The Jacobian model (diversification externalities and local competition) will be validated by positive estimates of both PD and COMP.

The counts of innovating firms per sector i per region j follows a Poisson distribution, suggesting the use of a count data model. However, for reasons of overdispersion, the negative binomial regression model is applied instead.[8] Its probability distribution function reads as

$$P(y_{ij}|x) = \frac{\Gamma(y_{ij} + \alpha^{-1})}{y_{ij}!\Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu}\right)^{\alpha^{-1}} \left(\frac{\mu}{\alpha^{-1} + \mu}\right)^{yij} \tag{1}$$

where y_{ij} = numbers of innovators per industry i per region j
Γ = gamma function
α = unobserved heterogeneity parameter among observations
$\mu_{ij} = \exp(\mathbf{x}'_{ij}\boldsymbol{\beta})$
$\mathbf{x}'_{ij} = [1\mathrm{PS}_{ij}\mathrm{PD}_j\mathrm{COMP}_{ij}\mathrm{FIRMS}_{ij}]$

In assessing the geographic scope of externalities, one usually examines whether externalities affect innovativeness in adjacent regions (Paci and Usai, 1999; Van Oort, 2002). There are two drawbacks associated with this approach. First, the grid of regions applied in these studies is arbitrary, as regional boundaries are administrative rather than derived from innovation or agglomeration data. Second, the region grids are irregular and differ in size, complicating the measurement of the externalities' geographic scope. In this paper, both these issues are addressed by constructing a concentric distance band around each postal code region's geographic center, denominated in kilometers. This distance band is used to create 'ring variables', measuring the extent to which each region's neighboring regions, within this distance band, are specialized or diversified. In creating the ring variables, a distance band of 20–35 kilometers is applied.[9] Significant coefficients suggest spillovers originating in the neighboring regions and measure the extent to which these affect regional innovativeness. As such, the measurement of inter-regional spillovers is no longer encumbered with the arbitrary and irregular grid of (postal code) regions.

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

[9] A lower limit of 20 kilometers is applied for reasons of consistency with the spatial concentration of innovators, which is most pronounced over the 0–20 kilometers distance band: see footnote 5. The ring variables, or spatially lagged explanatory variables, are constructed by pre-multiplying the explanatory variables PS_{ij} and PD_j by the spatial weights matrix $W_{20-35KM}$.

One may argue that sustainability in maintaining the regional knowledge base increases with region size. Consequently, firms located in larger regions may be assumed to be less affected by equally vigorous externalities originating in neighboring regions. As a control for region size, an additional variable REGIONSIZE is introduced.

4 Estimation results

The results on Marshallian specialization externalities (H1), Jacobian diversification externalities (H2), and competition hypotheses (H3) are summarized in Table 1.[10] The sample of new-product-announcing firms is, however, quite heterogeneous with respect to R&D intensity and firm size. One cannot presume that regional performance on PS, PD and COMP affects the dissimilar innovators equally. Three different models are estimated. Model I, II and III apply to the total sample of firms (398 innovators), the 33 percent most R&D intensive innovators (84 firms) and the 33 percent smallest firms (127 firms), respectively.

The results for the total sample (Model I) on the product specialization coefficient PS suggest Marshallian specialization externalities (H1). Given the number of firms per industry per region, numbers of innovators in that particular industry and region tend to increase with specialization.[11] Put differently, an increase in regional specialization towards a particular industry positively affects regional innovativeness in that particular industry more than proportionally.

Strikingly, these Marshallian specialization externalities do not attenuate within 35 kilometers: the extent to which neighboring regions are specialized affects the region equally. For R&D intensive firms, distance-decay becomes more pronounced. Model II shows that the most innovative firms are prone to distance in capitalizing upon knowledge spillovers and benefit more from those originating within the region. These results correspond with Paci and Usai (1999) and Shefer and Frenkel (1998) for the Italian and Israeli cases, respectively, in that for high technology industry innovation, externalities attenuate over distance. As argued by Audretsch and Feldman (1996), tendencies to geographically cluster increase with importance of knowledge spillovers.

In capitalizing upon specialization externalities, small firms are also prone to distance (Model III). Following Feldman (1994), small firms rely on firm-external knowledge more than do large firms, since the resources needed for maintaining the knowledge base are typically beyond the means of small firms.

The estimates on the PD variable do not suggest that Jacobian diversification externalities affect innovativeness (H2). This result is consistent with Pellenbarg and

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[10] Considering the highly significant Moran's I statistic on spatial autocorrelation (see footnote 6), one should introduce a spatially lagged dependent variable into equation (1) to correct for spatial dependence among the new-product-announcing firms across the regions (see Anselin, 1988). However, Moran's I statistic becomes insignificant when estimated separately for the industries represented in the LBIO sample: *within* these industries, innovators are not geographically clustered. Hence there is no need to correct for spatial dependence when analyzing at the industry level.

[11] The results in Table 1 hold when numbers of firms are replaced by numbers of jobs per industry i per region j.

Table 1. Negative binomial regression (Model I) and logit estimates (Models II and III) of new-product-announcing firms per industry per region[a]

	Model I Total sample	Model II R&D intensive innovators[b]	Model III Small innovators[c]
Constant	−4.41**	−4.30**	−5.40**
Intra regional spillovers:			
PS_{ij} (specialization)	0.41**	0.38**	0.43**
PD_j (diversification)	0.01	−0.04	−0.10
$COMP_{ij}$ (competition)	−1.17**	−0.58*	−0.53**
$FIRMS_{ij}$ (total firm population[d])	1.03**	0.60**	0.65**
$REGIONSIZE_j$ (surface area)	0.15	−0.09	0.17
Inter regional spillovers:			
PS_{ij} 20–35 KM distance band	0.43**	0.28*	0.28*
PD_j 20–35 KM distance band	−0.13	−0.05	−0.10
R^2	0.10	0.09	0.10
N (58 industries*98 regions)	5684	5684	5684

** = significant at 5% level; * = significant at 10% level.

[a] Models II and III are estimated using the logit model since these apply to sub-samples of the database, reducing the maximum count of innovators per industry i per region j to 1.

[b] The 33 percent most R&D intensive firms: R&D expenses exceeding 15 percent of total sales, Inter Quartile Range (IQR)= 20–52 percent.

[c] The 33 percent smallest firms: less than 10 employees, IQR= 2–6 employees.

[d] per 1000 firms in industry i in region j.

Kok (1985), not observing any clear relationship between innovativeness and the urban environment. One explanation may be the absence of any marked difference between regions in degrees of diversification. This relates to Atzema's (2001) results on Dutch ICT firms, suggesting that, due to the poly-nucleated structure of the urban system, agglomeration externalities arise almost throughout the Netherlands.

Following Jacobs (1969) and Porter (1990), competition enables employees to implement innovative ideas and favors the pursuit and adoption of innovation (H3). Consistent with Van Oort (2002), this assumption does not hold for the Netherlands. The estimates on the COMP variable show that fierce competition among firms negatively affects regional innovativeness. Rather, Marshall's (1890) argument of local market power applies: less fierce competition enables the innovator to appropriate the innovation rents. As the competition index COMP merely measures local average firm size, this result is consistent with what has come to be called the 'Schumpeter Mark II' assertion: large firms are expected to have advantages over smaller firms in the innovation process as they have at their disposal substantial means to engage in R&D and exploit economies of scale and scope in the innovation process (Schumpeter, 1943).

Considering that both Marshallian specialization externalities and local market power act as incentives to engage in innovation, the results suggest that, for the Dutch case, the Marshallian rather than the Jacobian model holds.

5 Concluding remarks

Using a database of new product announcements in Dutch specialist trade journals, we have examined whether specialized or diversified local production structures favor local innovativeness in the Dutch context. The results show that, given the local production structure, a regional specialization towards a particular industry tends to increase regional innovativeness in that industry. This suggests that intra- rather than inter-industry knowledge spillovers positively affect regional innovativeness. For R&D intensive firms and small firms, these knowledge spillovers are prone to distance-decay and limited in geographic scope. Increased levels of local production structure diversification do not favor local innovativeness. In addition, fierce local competition within a specific industry negatively affects innovativeness. Instead, local market power enabling the innovator to appropriate the innovation rents proves an incentive to engage in innovation.

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