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Collecting new pieces to the regional knowledge spillovers puzzle: high-tech versus low-tech industries

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Abstract:

This paper revisits the puzzling question regarding the role of spatial agglomeration of production activities and knowledge on firm's total factor productivity (TFP). In particular, it addresses the overlooked issue of a plausible non-linear effect and different across industries. Using a panel of Portuguese manufacturing firms, we found that specialization economies have a positive impact on firms' productivity, especially for those operating in medium-high and high-tech sectors. Diversity externalities, for its part, have an inverted U-shaped relationship with firms' TFP in low, medium-low and medium-high tech sectors. The relationship between regional R&D employment and productivity differs across sectors: in all manufacturing firms and firms from medium-low and high-tech sectors, there is an inverted U-shaped relationship; in low-tech sector, there is a U-shaped relationship and a positive elasticity for any employment level higher than the 20th percentile. Overall, agglomeration economies differ substantially across industries and they are non-linear.

Keywords: regional knowledge spillovers; agglomeration economies; low-tech vs. high-tech industries; total factor productivity.

1 Introduction

The literature has greatly emphasized the role of both knowledge spillovers and agglomeration economies as drivers of firms' performance (Audretsch and Feldman 2004; Döring and Schnellenbach 2006). However, while it has been widely acknowledged that knowledge spillovers have positive effects on firm productivity, the role of spatial agglomeration is still a puzzling question (Griliches 1992; Breschi and Lissoni 2001; Tappeiner et al. 2008; de Groot et al. 2015).

A number of studies in both new economic geography and new economic growth theory have provided clear evidence that knowledge transmission is limited by distance and therefore bounded in space (Audretsch and Feldman 2004; Rosenthal and Strange 2004). The proximity to knowledge sources encourages the circulation of ideas and the transmission of knowledge thanks to face-to-face contacts and social networks, which allow units operating close to those sources of knowledge to innovate at a faster rate than rival firms located elsewhere (Storper and Venables 2004; Lambooy 2010). The knowledge-transfer environment in which a firm is embedded plays a key role too (Amesse and Cohendet 2001). Overall, geographical location of firms matters.

Technologies are path-dependent as they evolve as an historical process along technological trajectories (Nelson and Winter 1982). Industry-specific technological regimes strongly determine potential learning effects. This implies that firms' learning opportunities, while rather invariant across firms for the same industry, are different among industries depending on technology specifics (Klevorick et al. 1995; Malerba and Orsenigo 1997; Grimpe and Sofka 2009).

The main objective of this paper is to provide new evidence on whether multiple sources of local knowledge spillovers have different impacts across industries. To try to open the "black box" of knowledge spillovers, we assume two central hypotheses: *i*) the learning effects of agglomeration economies depend on the firm’s technological regime, which is mainly industry-specific; *ii*) these effects should be non-linear.

Three major channels of local externalities are identified in our empirical inquiry:[1]

i. *Specialization* (or *localization*) economies, arising from the spatial concentration of firms belonging to the same industry. In essence, localization externalities rely on the spread of specialized knowledge through firms of the same industry, the increased variety (at lower prices) of shared inputs and the specialized labour market pooling (Marshall 1890, Arrow 1962; Romer 1986).

ii. *Diversity* externalities, spurred by the variety and diversity of local economic activities. They capture knowledge spillovers from the cross-fertilization of ideas external to the industry within which the firm operates (Jacobs 1969).

iii. *Knowledge base* externalities, arising from the agglomeration of universities, research laboratories, trade associations and other knowledge generating organizations (Frenken et al. 2007).

These three forms of local externalities are expected to be present simultaneously in a different mix for firms belonging to different industries (Beaudry and Schiffauerova 2009). It is also reasonable to anticipate the presence of certain nonlinearities associated with the impact of this forms of economies on productivity.

The present paper addresses to this issue by assuming a non-linear relationship between regional knowledge spillovers and productivity at the firm level using a panel

[1] Some authors identify a fourth channel: the competition (or Porter) externalities. However, in highly integrated markets such as in European countries, the effect of local competition does not appear to be statistically significant, which is not so surprising since its marginal impact shrinks at high levels of competition (Martin et al. 2011; Carreira and Lopes, 2015; Cainelli et al. 2015).

of Portuguese manufacturing firms and splitting the sample into low, medium-low, medium-high and high technology industries. It contributes to the ongoing debate on whether regional environment is beneficial to firms collecting three new pieces to the puzzle. Firstly, very few papers study the nexus between different forms of regional knowledge and firms' performance across industries, a critical issue to understand the impact of regional disparities on economic growth and, as a result, to promote and design new, more assertive, regional policies. Secondly, even if it is reasonable to expect the presence of threshold effects or marginally decreasing/increasing externalities, little attention has been paid until now to the potential non-linear features of the relationship. Finally, despite a number of studies examining the effect of either agglomeration economies or knowledge spurred by public organizations such as universities and research laboratories, the research to assess the role of these two knowledge sources together is still limited.

The remainder of the article is organized as follows. Section 2 presents an overview of the literature on the role of spatial knowledge agglomeration on firms' productivity. Section 3 discusses the methodology and describes the dataset, while the main empirical results and their discussion are presented in Section 4. Section 5 concludes.

2 Related literature

Traditional studies generally adopt regional (or city) aggregation level. In a seminal work, using a panel of US cities between 1956 and 1987, Glaeser et al. (1992) found that localization externalities have a negative impact on urban employment growth, while diversity and competition economies positively affect it. The approach of Glaeser et al. (1992) has been replicated to other countries with results that are to some extent puzzling may be due to the aggregated level of analysis (see, among others, Bradley and Gans 1998, for Australia; Cainelli and Leoncini 1999; and Forni and Paba 2002, for Italy; Combes 2000, for France). In fact, as argued by van Oort et al. (2012), the theories that underlie agglomeration economies are microeconomic in nature, then showing that regional economic performance is higher in regions where spatial agglomeration is higher does not entail that a similar relationship holds at the level of the individual firms. As a result, empirical studies using rich micro-level data on firms (or establishments) have had an important development in the last decades (see Audretsch and Feldman 2004, Döring and Schnellenbach 2006, or Combes and Gobillon 2015, for a survey; and Melo et al. 2009, or de Groot et al. 2015, for a meta-analysis).

Since data on productivity are generally not available at the firm level, most of the studies use employment or wages growth as a proxy for productivity.[2] Cingano and Schivardi (2004), using 1991 Italian census data, show that the specialization impact on local employment growth is negative and variety has a significant positive effect, in line with Glaeser et al.'s results. However, using total factor productivity (TFP) as the dependent variable, they find that the specialization effect is reversed and becomes positive, and neither sectorial variety nor the degree of local competition has any effect. Cingano and Schivardi (2004) question the conclusions of previous works arguing that employment growth regressions suffer from "identification problems" when interpreted

[2] The use of employment or wages growth at firm level as dependent variable is based on the (unlikely) assumption that productivity growth will result in proportional employment gains through shifts in labour demand.

as evidence of dynamic externalities, given that the chain of causality from agglomeration economies to employment growth could be reversed.

As agglomeration externalities lead to a change in output not fully accounted for by a change in inputs, TFP would be a better measure of performance (Puga 2010; Combes and Gobillon 2015). Presumably due to data constraints, only a small number of studies draw inferences from TFP at the firm level. Anderson and Lööf (2011), for example, find that Swedish manufacturing firms in the period 1997–2004 located in larger regions are more productive after controlling for firm's participation in international trade, ownership structure and industry affiliation. Moreover, the marginal effect of agglomeration on firms' productivity growth can be given a causal interpretation, suggesting a positive learning effect. In the case of Italian manufacturing firms over the period 1995–2006, Di Giacinto et al. (2014) also observe productivity advantages for firms located in both urban areas and industrial districts, with a higher premium for urban areas.

Distinguishing among different forms of agglomeration economies, López and Südekum (2009) find evidence from Chilean manufacturing plants in the period 1990–1999 for intra-industry spillovers, but none for general cross-industry spillovers. Similar results were found by Martin et al. (2011) and Hashiguchi and Tanaka (2015) for French manufacturing plants, in the 1996–2004 period, and Chinese manufacturing firms in 2004, respectively. Cainelli et al. (2015) add a new piece to the regional knowledge spillovers puzzle investigating the nonlinearities in the relationship between spatial agglomeration and productivity. Using a panel of Italian manufacturing firms over the period 1999–2007, they find a positive and statistically significant effect of localization and diversity economies, but only above a certain threshold. Moreover, diversity seems statistically significant only once non-linear effects are allowed for.

Remarkably, the previous studies do not address the role of regional knowledge base. In fact, while knowledge produced within incumbent firms that spills over to other firms was largely analysed, the role of universities and other local research institutions was rather neglected. Favoured by the flourishing endogenous growth theory, empirical evidence seems to support the idea that universities, research laboratories and other local knowledge organizations matter for innovative activity of firms (see, for example, Acs 2002; Johansson and Lööf 2008; Bronzini and Piselli 2009; Acs et al. 2013).

Very few studies have also analysed the effect of local knowledge spillovers across industries, even though we should expect substantial differences in the magnitude of agglomeration economies among industries. Henderson (2003), using the US census data for 1972–1992 period, finds that localization economies have strong positive effect on productivity in high-tech industries, but not in mechanical industries. He also finds little evidence of diversity and region size economies. Ehrl (2013), using German establishment and employment-level data from 2000 to 2007, finds that the effect of agglomeration economies differs substantially across industries. The high-tech sector benefits from knowledge spillovers (i.e. number of job changes) and diversity. A rather surprising finding is however that low-tech industries knowledge spillovers matter most. One explanation is that even though low-tech firms' research and development (R&D) investments are relatively low, external knowledge is very important as they compete for the leadership in technology and design. Kancs and Siliverstovs (2016) also find evidence of a non-linear relationship statistically significant and positive, between R&D expenditures and productivity growth, but only after a certain accumulated critical mass of knowledge. They also find that there are important inter-sectoral differences relatively to R&D investment effects on firms' productivity.

3 Empirical methodology

3.1 The data

The empirical study is based on an unbalanced panel of Portuguese manufacturing firms covering the period 1996–2004. The raw data is drawn from the combination of two statistical data sources, both administrated by the Portuguese Statistical Office (INE): *Inquérito às Empresas Harmonizado* (IEH), which is an annual business survey with detailed input and output information required for the computation of firm-level productivity; and *Ficheiro de Unidades Estatísticas* (FUE), a file that contains information on firm's location, number of employees and the main economic activity of all Portuguese firms, critical to compute spatial agglomeration variables.[3] The longitudinal dimension of the panel, required for our analysis, was constructed using firm (unique) identification code.

The unit of production considered is therefore the firm. Each firm is assigned to a given NUTS 3-region (Nomenclature of Territorial Units for Statistics at level 3 of the European regional classification, Portuguese definition of 2002) through a spatial identification code (see Figure A1). Thus, the first drawback of our dataset is that multi-plant firms may affect our results if their different plants are located in different regions.

[3] The industrial classification used is CAE Rev.2.1, the Portuguese version of the European nomenclature NACE Rev. 1.1.

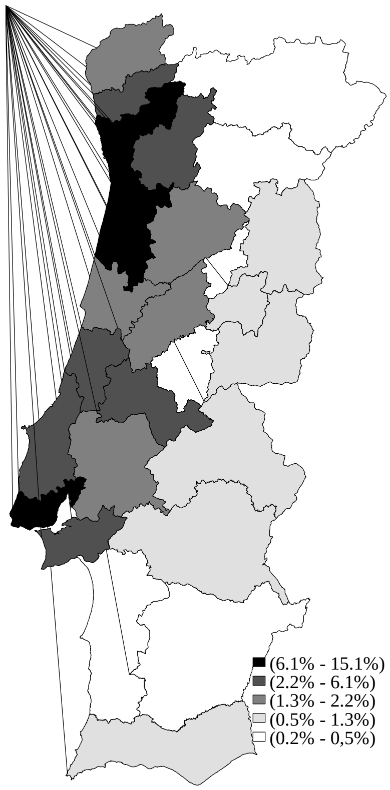
However, we note that the different plants of corporations are often registered as distinct legal entities, so the multi-plant phenomena impact on results may be negligible.[4]

The IEH survey comprises all firms operating in Portugal with more than 100 employees, plus a representative random sample of firms with 20 to 99 employees.[5] We excluded from the dataset firms located in the island regions (i.e. Madeira and Azores) and highly concentrated industries (i.e. *tobacco products* and *coke and refined petroleum products*). Firms with missing observations or unreasonable values (negative values or outliers) were also ignored. We define as an outlier a firm for which the log difference between an input and the output is in the top and bottom one percentile of the respective industry distribution. After these procedures, our estimation sample comprises an unbalanced panel of 8,074 firms or 32,003 year-firm observations. Table A1 (in Appendix) presents the lists of industries covered by the study and the corresponding number of firms. Figure 1 shows the number of firms per region. There appears to be substantial agglomeration of manufacturing firms along the coastal regions of central and northern Portugal, mainly in the central region of Grande Lisboa and northern regions of Grande Porto and Ave.

[4] Plant disaggregated data required for the computation of plant-level TFP is not available for the Portuguese firms. Cainelli et al. (2015) and Hashiguchi and Tanaka (2015), among others, also exploit firm-level data in their estimations. Henderson (2003) and Martin et al. (2011) have used plant-level data.

[5] The sample of firms with 20–100 employees is representative of the Portuguese sector disaggregation (at 3-digit level), both in terms of employment size and sales. We note that firms with less than 20 employees represent about 71% of Portuguese manufacturing firms, but only 16% of total employment (average over the period; source: OECD database).

Figure 1 Number of firms by NUTS 3 regions (percentage of total)



3.2 The model

The general model that we use for our empirical analysis is based on a firm-level Cobb-Douglas production function:[6]

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} M_{it}^{\theta}, \tag{1}$$

where subscripts i and t denote firm and year, respectively. Y_{it} is the real gross output and K_{it}, L_{it} and M_{it} are capital, labour and material inputs, respectively; A_{it} is the total factor productivity; and α, β and θ are the output elasticities of each factor (note that we do not impose any restriction on the sum of the three output elasticities). The *gross output* is given by the sum of total revenues from sales, services rendered and production

[6] We assume that each firm operates in a given industry j and is located in a given region r. We omit subscripts j and r to simplify the notation except when it causes ambiguity.

subsidies. It is deflated by the producer price index at the 3-digit level. The *labour* input is a 12-month employment average. *Materials* include the cost of materials and services purchased and were deflated by the GDP deflator. *Capital stock* is measured as the book value of total net assets excluding financial investments and cash stock (that is, it includes not only tangible and intangible assets but also other elements of the asset side of the balance sheet, such as accounts receivable and inventory, all important to the operation of the firm). Output and input monetary variables are measured in constant 1996 euro prices.

We then assume that firm's TFP depends on its local milieus:

$$A_{it} = \left(LOC_{it}^{jr}\right)^{\gamma} \left(DIV_{it}^{jr}\right)^{\varphi} \left(KNOW_{it}^{r}\right)^{\phi}, \tag{2}$$

where LOC_{it}^{jr}, DIV_{it}^{jr} and $KNOW_{it}^{r}$ are measures of localization (or specialization), diversity and knowledge base (specifically, regional innovation system) externalities, respectively, for firm *i* in year *t*, which operate in industry *j* and region *r*.

3.3 Construction of agglomeration variables

The localization economies are measured, for each firm, as the share of other employees working in the same industry (at the two-digit level) within the region (Combes 2000; Saito and Gopinath 2009; Combes and Gobillon 2015):[7]

$$LOC_{it}^{jr} = \frac{L_t^{jr} - L_{it}}{L_t^{r} - L_{it}}, \tag{3}$$

where L_t^{jr} and L_t^{r} are the total of employees of all firms operating in industry *j* and all manufacturing industries, respectively, located in region *r*, in year *t*. We use the FUE to compute the number of workers by industry, region and year.

[7] Since we subtract *i*th firm's employment, LOC are firm specific

The diversity economies are proxied by the inverse of the Herfindahl-Hirschman index of industry concentration based on the employment share of the different industries (at the two-digit level), except the respective industry *j*, in a region (Henderson et al. 1995; Combes 2000; Combes and Gobillon 2015):

$$DIV_t^{jr} = \left[\sum_{j' \neq j} \left(\frac{L_t^{j'r}}{L_t^r - L_t^{jr}} \right)^2 \right]^{-1}, \tag{4}$$

where $L_t^{j'r}$ is the number of employees in industry $j' \in J^r$ and $j' \neq j$ (J^r denotes the set of industries in region *r*). The measure of industrial diversity (4) ranges between 1 (minimum value), when all other manufacturing employment in the region is concentrated in a single industry, and $J^r - 1$ (maximum value) if it is uniformly distributed across all (other) industries. The value of this indicator is not directly linked with the previous one of industrial localization (3). In fact, for example, if part of regional employment is highly concentrated in a particular industry and if the remaining employment is uniformly distributed over all other industries, the value of both indexes (specialization and diversity) for this industry are high (Combes 2000).

Finally, the regional knowledge base is proxied by two variables: the number of R&D workers and knowledge intensive business services workers (RD_t^r and $KIBS_t^r$, respectively). The role of universities and other regional research institutions as a source of spillovers has been highlighted by various studies (e.g. Fritsch and Slavtchev 2007; Cassia et al. 2009; Acs et al. 2013). The university research is often measured by, inter al, the amount of money spent on R&D, the number of employees engaged in R&D activities, the number of students in higher degree establishments, the number of articles published in scientific and academic journals or the number of patents. However, most of these variables are highly correlated due to complementarity—having a large number of students, for example, means a larger teaching staff and then a greater amount of R&D resources (Fritsch and Slavtchev 2007).[8] The role of KIBS as actors of knowledge transference and dissemination has been stresses by various studies (Muller and Zenker 2001).[9]

3.4 Estimation strategy

Agglomeration variables may be endogenous. To deal with this issue, Combes and Gobillon (2015) suggest the implementation of a two-step approach where the production function is estimated in a first step without introducing local variables. Firm-level TFP is then computed and regressed in a second-step on agglomeration economies dealing with the endogeneity of regional characteristics (Martin et al. 2011, Di Giacinto et al. 2014, and Cainelli et al. 2015, for example, also implemented this estimation strategy).

Accordingly, we first compute consistent estimates of TFP at firm level using two-step system Generalized Method of Moments (GMM) estimator (Arellano and Bover 1995; Blundell and Bond 1998). Ordinary least squares (OLS) estimates of the log-linear transformation of model (1) may suffer from endogeneity problems due to simultaneity and selection bias.[10] The equation cannot be estimated using the within estimator (FE) either, since it requires strict exogeneity of regressors, a non-realistic

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[8] As proxy for the regional knowledge base we have also used the number of students in higher degree establishments and the number of higher degree establishments. The results do not significantly change—results available from authors upon request.

[9] According to *European Monitoring Centre on Change*, KIBS comprises the following CAE-rev2.1 divisions: (CAE 72) computer and related activities, (CAE 73) research and experimental development and (CAE 74) other business activities.

[10] The simultaneity bias arises because input demands are also determined by firm's knowledge of its productivity level; and the selection bias is generated by endogenous exit, as smaller firms, with lower intensity of capital, are more likely to exit.

assumption. In contrast, the system GMM estimator provides consistent estimates in the presence of endogeneity issues (Blundell and Bond 2000; Bond 2002).

After estimating the output elasticity coefficients at the industry level, the firm-level (log) TFP can be computed as the residual:

$$\hat{a}_{it} = y_{it} - \hat{\alpha}\, k_{it} - \hat{\beta}\, l_{it} - \hat{\theta}\, m_{it}\,, \tag{5}$$

where lower-case letters denote the log of corresponding upper-case variables in model (1).

In the second stage of our procedure, we regress the TFP on proxies aimed at capturing the effect of local milieus, as proposed in model (2). In particular, to account for the existence of non-linear effects, we introduce in the log-linear specification quadratic terms as follows:

$$\begin{aligned} a_{it} = \lambda + \gamma_1\, loc_{it}^{jr} + \gamma_2 \left(loc_{it}^{jr}\right)^2 + \varphi_1\, div_t^{jr} + \varphi_2 \left(div_t^{jr}\right)^2 + \phi_1\, rd_t^{\,r} + \phi_2 \left(rd_t^{\,r}\right)^2 \\ + \psi_1\, kibs_t^r + \psi_2 \left(kibs_t^r\right)^2 + \omega_t + v_j + \upsilon_i + \mu_{it} \end{aligned}\,, \tag{6}$$

where ω_t, v_j and υ_j are year, industry and firm-fixed effects, respectively; and μ_{it} is a standard error term. We cannot disentangle firm and regional fixed effects. A common strategy used to deal with this issue is to include regional-fixed effects in the estimated specification. However, Combes and Gobillon (2015) highlight several reasons why this strategy may not work. Our empirical model includes two aggregate variables that vary little over year, RD_t^r and $KIBS_t^r$, as a result, their effect is difficult to identify separately form the unobserved, time invariant, characteristics affecting firms' productivity across regions. Moreover, if we consider that firms do not change region over year, firm-level local milieus unobserved characteristics can be appropriately dealt with using firms' fixed effects. Industry fixed-effects control not only for the technological differences across industries, but as well as for the well-known problem of comparing productivity levels of different industries.

Estimating empirical model (6), endogeneity can occur due to both unobserved heterogeneity and simultaneity bias. Some region characteristics (e.g. public infrastructures, local climate, natural resources, etc.) can affect the propensity to agglomerate, while at the same time agglomeration influences these region characteristics. Additionally, high-productivity firms show a strong preference for location in large markets and as a consequence are more likely to be attracted to them. However that preference and the consequent relocation is not a result of agglomeration economies (selection effect). To deal with this endogeneity problem, as proposed by Combes and Gobillon (2015), we estimate the model using again the system GMM estimator.

4 Results

4.1 Production function results

In the first step of our empirical strategy, we use the two-step system GMM approach to estimate the (log-linear) Cobb-Douglas production function at the industry (two-digit) level and compute the firm-level TFP.[11] Given that output elasticities may vary significantly across industries due to differences in production technology, we run distinct regressions for each industry. To choose the level of industry disaggregation, we strike a balance between ensuring the homogeneity of the technology within each industry and preserving a significant number of observations by industry.

[11] Regressions were performed using the Stata *xtabond2* command (Roodman, 2009a).

Table 1 presents the output elasticity parameters for each factor, not imposing constant returns to scale. All regressions include year dummies, exit dummy and firm's age variable (Olley and Pakes 1996). Test statistics for auto-correlation of the error term indicate for all regressions significant negative first-order serial correlation at standard significance levels, but no significant second-order serial correlation, as expected. The validity of lagged instruments dated t–2 (and earlier) is also clearly not rejected by Hansen tests of overidentifying restrictions in all estimates (Sargan test is less clear for some regressions).

Given that the test of common factor restrictions (COMFAC) is easily accepted in all regressions, we focus on these results henceforth (Bond 2002). Estimates of output elasticities range from 0.023 to 0.262 for capital, from 0.109 to 0.248 for labour and from 0.511 to 0.774 for material. They are significant at standard levels, except in the case of capital coefficient for *rubber and plastic products* industry that it does not seem to be statistically significant. Constant returns to scale seem to be the prevalent regime in our estimates. They are rejected in favour of decreasing returns for only three industries: *textiles and wearing apparel*, *rubber and plastic products* and *manufacturing n.e.c.*.

Table 1 Production function elasticities by industry

Industry	α_K	β_L	θ_M	*COMFAC*
Food products and beverages	0.088**	0.185***	0.722***	0.829
	(0.041)	(0.060)	(0.034)	
Textiles and wearing apparel	0.088**	0.222***	0.570***	0.981
	(0.045)	(0.051)	(0.039)	
Leather and leather products	0.184***	0.197***	0.613***	0.591
	(0.059)	(0.060)	(0.041)	
Wood and wood products (except furniture)	0.083*	0.185***	0.713***	0.527
	(0.045)	(0.049)	(0.034)	
Pulp, paper, paper products and publishing	0.104***	0.224***	0.667***	0.120
	(0.037)	(0.056)	(0.046)	
Chemical and chemical products	0.068***	0.179***	0.774***	0.158
	(0.034)	(0.042)	(0.036)	
Rubber and plastic products	0.023	0.109*	0.708***	0.306
	(0.042)	(0.060)	(0.045)	
Other non-metallic mineral products	0.107*	0.151***	0.760***	0.998
	(0.060)	(0.056)	(0.038)	
Basic metals and fabricated metal products	0.146***	0.248***	0.617***	0.081
	(0.048)	(0.046)	(0.043)	
Machinery and equipment	0.262***	0.229***	0.511***	0.248
	(0.062)	(0.077)	(0.052)	
Electrical and optical equipment	0.097**	0.127**	0.743***	0.189
	(0.045)	(0.056)	(0.039)	
Motor vehicles and other transport equipment	0.117***	0.220***	0.646***	0.740
	(0.039)	(0.074)	(0.038)	
Furniture, manufacturing n.e.c. and recycling	0.091**	0.191***	0.669***	0.082
	(0.043)	(0.048)	(0.047)	

Notes: Blundell and Bond (1998) two-step system GMM estimates of model (1). In order to save space, only the three output elasticities are reported (full results available from authors upon request). COMFAC is a minimum distance test of the non-linear common factor restrictions imposed in the restricted model. P-values are reported. Results for the restricted model are reported since the COMFAC test is easily passed in all regressions at standard significance levels. Year dummies, exit dummy and age variable included. α_K, β_L and θ_M denote capital, labour and material elasticities, respectively. Robust standard errors are given in parentheses. ***, **, and * denote statistical significance at the .01, .05, and .10 levels, respectively.

4.2 General results

Tables 2 and 3 show the descriptive statistics and the correlation matrix, respectively, of variables used in our empirical model (6). As can be seen, the standard deviation is about one-third of the respective mean for all variables except the localization economies one, which is two-third. Even if the between standard-deviation account for a large part this variability, within variation is not negligible, accounting for about 13 to 31% of the variability (Table A2 in Appendix). The minimum value for the localization economies variable is –11.513, that is, some firms are the sole representative of their industry in their region (since $LOC_{it}^{jr} = e^{-11.513} \cong 0$). The heterogeneity in both R&D and KIBS employment across regions is very high: the R&D employment ranges from 0 (no R&D employment) to 11,990 ($= e^{9.392} - 1$); the minimum KIBS employment is 24 ($= e^{3.178}$) and the maximum is 143,322 ($= e^{11.873}$). Finally, it should be further noted that the correlation between proxies of knowledge base externalities (i.e. RD_t^r and $KIBS_t^r$) is significantly high.

Table 2 Descriptive statistics (pooled yearly values)

Variable	Obs.	Mean	Std. Dev.	Skewness	Kurtosis	Min.	Max.
a_{it}	32,003	3,001	0,900	0,684	2,270	1,139	5,472
loc_{it}^{jr}	32,003	-2,602	1,547	-2,538	14,904	-11,513	-0,217
div_t^{jr}	32,003	1,839	0,494	-0,514	2,294	0,204	2,589
rd_t^r	32,003	6,448	1,751	-0,318	3,359	0	9,392
$kibs_t^r$	32,003	7,447	2,302	0,413	2,204	3,178	11,873

Note: See Table A2 in Appendix for between and within variations.

Table 3 Correlation across variables (pooled yearly values)

	a_{it}	loc_{it}^{jr}	div_t^{jr}	rd_t^r
loc_{it}^{jr}	0.243*	1		
div_t^{jr}	-0.284*	-0.124*	1	
rd_t^r	-0.080*	-0.052*	0.624*	1
$kibs_t^r$	-0.137*	-0.074*	0.668*	0.851*

Note: * denotes statistical significance at the .05 level.

Table 4 reports estimates of model (6) obtained by applying the two-step system GMM approach. As explained by Arellano and Bover (1995) and Roodman (2009a), the system GMM easily generate numerous instruments that can be mathematically redundant (i.e. containing no new identifying information). We apply principal components analysis in order to produce a smaller instrument set that is maximally representative of the original (Roodman 2009b).[12] All of the GMM-estimates for the lagged dependent variable lie within the bounds set by the OLS and FE (upward-bias and downward-bias, respectively; Blundell and Bond 2000; Roodman 2009a).[13] Moreover, both the Arellano-Bond test statistics for autocorrelation and the Sargan/Hansen test statistics of overidentifying restrictions suggest that the models presented in Table 4 yield statistically valid estimates.

[12] The procedure was implemented using the *pca* option of the Stata *xtabond2* command.

[13] The OLS and FE estimates are available from the authors upon request.

Table 4 Regression results by technology level

Variable	Overall (1)	Low (2)	Medium-low (3)	Medium-high (4)	High (5)
loc_{it}^{jr}	0.547***	0.029	-0.025	0.099*	0.074*
	(0.209)	(0.061)	(0.066)	(0.061)	(0.045)
$\left(loc_{it}^{jr}\right)^2$	0.037**	0.002	-0.003	0.009**	0.004
	(0.015)	(0.004)	(0.006)	(0.005)	(0.003)
div_{t}^{jr}	-0.408	1.078*	0.661**	0.631*	-0.583
	(0.487)	(0.573)	(0.308)	(0.340)	(0.492)
$\left(div_{t}^{jr}\right)^2$	0.134	-0.299*	-0.210**	-0.157*	0.188
	(0.140)	(0.173)	(0.095)	(0.088)	(0.141)
rd_{t}^{r}	0.348*	-0.110*	0.210*	0.103	1.104***
	(0.185)	(0.061)	(0.120)	(0.104)	(0.192)
$\left(rd_{t}^{r}\right)^2$	-0.026*	0.011*	-0.016*	-0.009	-0.089***
	(0.015)	(0.007)	(0.010)	(0.008)	(0.016)
$kibs_{t}^{r}$	-0.024	0.003	-0.052	0.027	-0.425***
	(0.053)	(0.076)	(0.070)	(0.063)	(0.111)
$\left(kibs_{t}^{r}\right)^2$	0.002	-0.001	0.005	0.000	0.031***
	(0.004)	(0.006)	(0.005)	(0.004)	(0.007)
$a_{i(t-1)}$	0.699***	0.858***	0.353*	0.785***	0.653***
	(0.189)	(0.256)	(0.198)	(0.122)	(0.151)
$a_{i(t-2)}$	0.104	-0.078	-0.180	0.109	0.123
	(0.131)	(0.174)	(0.192)	(0.131)	(0.129)
AR(1) [*p-value*]	-4.59 [*0.000*]	-2.81 [*0.005*]	-2.20 [*0.028*]	-2.92 [*0.004*]	-4.02 [*0.000*]
AR(2) [*p-value*]	0.10 [*0.924*]	1.64 [*0.102*]	1.18 [*0.239*]	0.89 [*0.376*]	-0.71 [*0.478*]
Sargan test [*p-value*]	16.95 [*0.076*]	4.75 [*0.191*]	25.29 [*0.117*]	15.51 [*0.115*]	8.18 [*0.611*]
Hansen test [*p-value*]	3.30 [*0.973*]	5.07 [*0.167*]	13.06 [*0.788*]	9.76 [*0.462*]	6.53 [*0.769*]
N. instruments	41	27	40	32	31
Observations	14,900	8,342	3,152	2,619	574

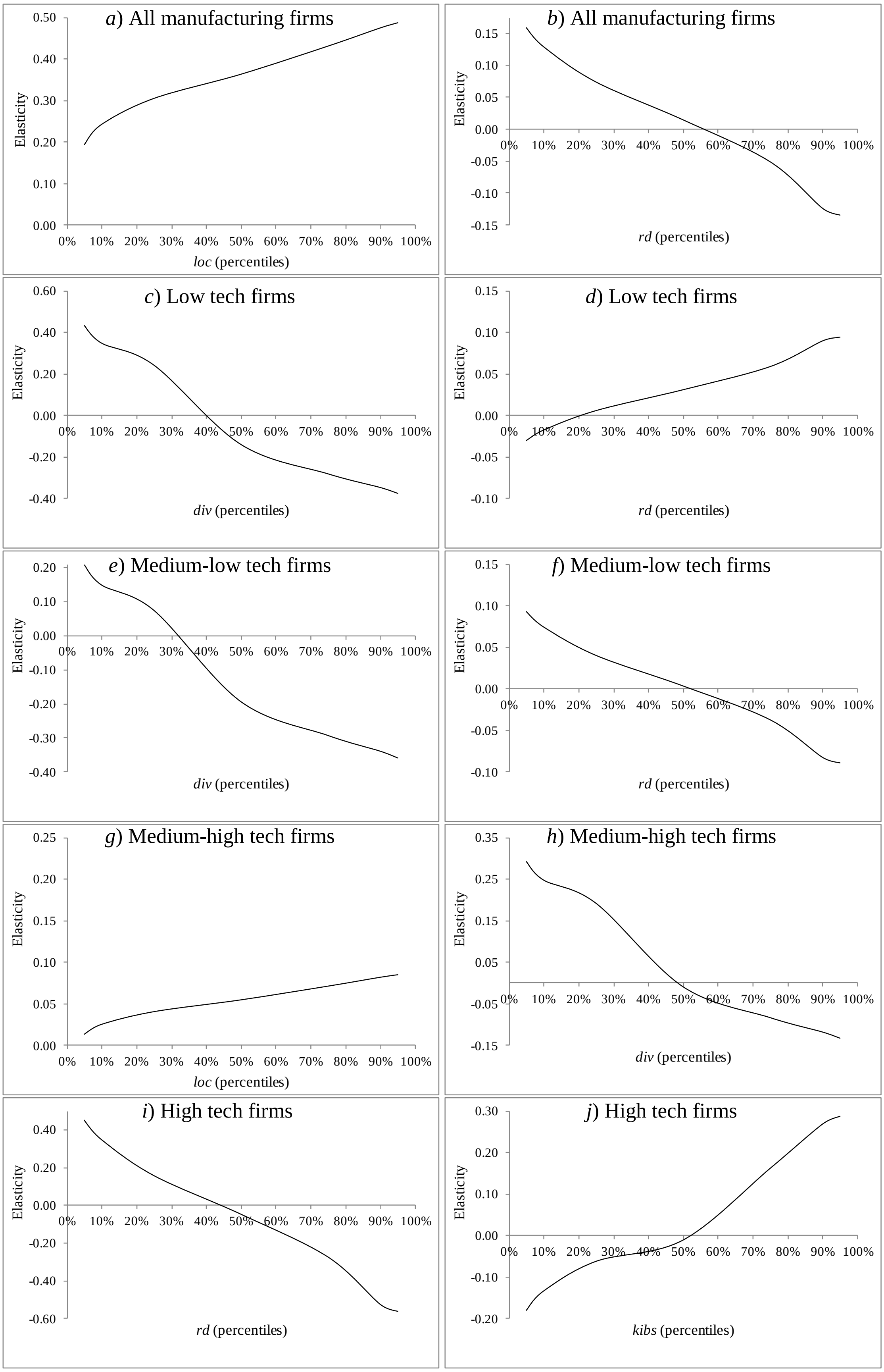
Notes: Blundell and Bond (1998) two-step system GMM estimates of model (6). Constant, industry dummies and year dummies included in all models. (1) All manufacturing firms, (2) low tech firms, (3) medium-low tech firms, (4) medium-high tech firms and (5) high tech firms. Robust standard errors are given in parentheses. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

Column (1) of Table (4) reports the results for all manufacturing firms. As it can be seen, there is a significant and positive relationship between localization and firm productivity (both linear and squared terms are positively signed and statistically significant at the 0.01 and 0.05 levels, respectively). In particular, a 1% increase in the share of employment in neighbouring firms of the same industry implies, on average, a 0.354% ($= \hat{\gamma}_1 + 2\hat{\gamma}_2\, loc$) increase in firm TFP, all else constant—since all variables are expressed in logarithms, the estimated coefficients can be interpreted as elasticity parameters. The estimated convex relationship between the two variables suggests that the higher is localization the increasingly larger is the effect (Figure 2*a*).

The linear R&D coefficient is positively signed, while the coefficient of the corresponding squared term is negative (both statistically significant at the 0.1 level). The null hypothesis of existence of an inverted U-shaped relationship over the range of the data is not rejected at the 0.1 significance level by the Lind-Mehlum U-test (Lind and Mehlum, 2010).[14] Hence, all else constant, more R&D employment in a region seems to be beneficial for improving firm productivity, but only up to a certain critical level (approximately 55th percentile, as can be seen in Figure 2*b*). For its part, the *diversity* and *KIBS* variables do not seem to have any statistically significant impact on TFP at conventional levels.

[14] The U-test was performed using the Stata *utest* command (Lind and Mehlum, 2010).

Figure 2 Elasticity of (significant) dependent variables by percentile



4.3 Industry-specific results

In order to investigate whether the impact of agglomeration economies may differ across sectors, on basis of the OECD classification, we split the sample into four sectors: low, medium-low, medium-high and high technology industries (see Table A3 in Appendix). From columns (2) to (5) of Table 4, there is broad evidence in favour of our hypothesis that the effect of local externalities differ substantially across industries. In particular, the medium-high and high-tech sectors seem to benefit from localization economies, while sectorial specialization does not impact (at conventional significance levels) on the productivity of low and medium-low-tech firms. The elasticity is quite similar across the two sectors: it ranges from 0.026 (10^{th} percentile) to 0.082 (90^{th} percentile) in the medium-high-tech sector and it is equal to 0.074 in the high-tech sector.

Regarding diversity externalities, the coefficients on the linear term are significantly positive, while on the squared term are significantly negative, except in the high-tech sector where we found no statistically significant coefficients. (Note that the latter result is much in line with that reported by Henderson (2003), who found that high-tech firms benefit from localization economies, but not from diversity economies.) Moreover, we cannot reject the null-hypothesis of an inverted U-shaped relationship over the range of the data for the three estimates (at the 0.10, 0.05 and 0.10 significance levels in the low, medium-low and medium-high tech sectors, respectively; Lind-Mehlum U-test). The diversity economies are thus only observed up to a certain critical level, after which there are agglomeration diseconomies may be due to congestion effects—the elasticity becomes negative at about 40^{th} (low), 35^{th} (medium-low) and 50^{th}

(medium-high) percentiles, as can be seen in panels (*c*), (*e*) and (*h*) of Figure 2, respectively.

The results for regional R&D employment are interesting. On the one hand, in the low-tech sector, the significantly negative/positive coefficient on the linear/squared term depicts a U-shaped relationship (the Lind-Mehlum U-test is passed at 0.10). Moreover, the elasticity is increasingly positive above the 20th percentile (Figure 2*d*): a 1% increase in R&D employment at the median (90^{th} percentile) point, all else constant, increases the TFP by about 0.031% (0.090%). One plausible interpretation for this result is that, even though low-tech firms invest relatively less in R&D and are less innovative than high-tech firms, they do nevertheless create new products and techniques for achieving competitive advantage. A vital part of this process in low-tech sector is the external technological knowledge (Grimpe and Sofka 2009; Robertson et al. 2009).

On the other hand, surprisingly enough, the data seem to support an inverted U-shaped relationship between regional R&D activity and firm productivity in the medium-low and high-tech sectors (the Lind-Mehlum U-test is significant at the 0.10 and 0.01 levels, respectively). In particular, the elasticity becomes negative near of median in both sectors (panels (*f*) and (*i*) of Figure 2). There are two potential explanations for the existence of these diseconomies of scale (Yang et al. 2013). Firstly, as R&D agglomeration increases, congestion or density costs may eventually offset the benefits to firms. Secondly, highly R&D agglomeration can result in a so-called free rider problem, that is, under highly knowledge spillovers firms may find that imitation is cheaper and less-risky than internal R&D.

Finally, *KIBS* only seems to impact on firm productivity in the case of high-tech sector, where we found a statistically significant U-shaped relationship over the range of the data (at the 0.01 level). As can be seen from Figure 2*j*, high-tech firms do benefit from the presence of KIBS activities, but only when the agglomeration of KIBS employment is higher than the median.

5 Conclusion

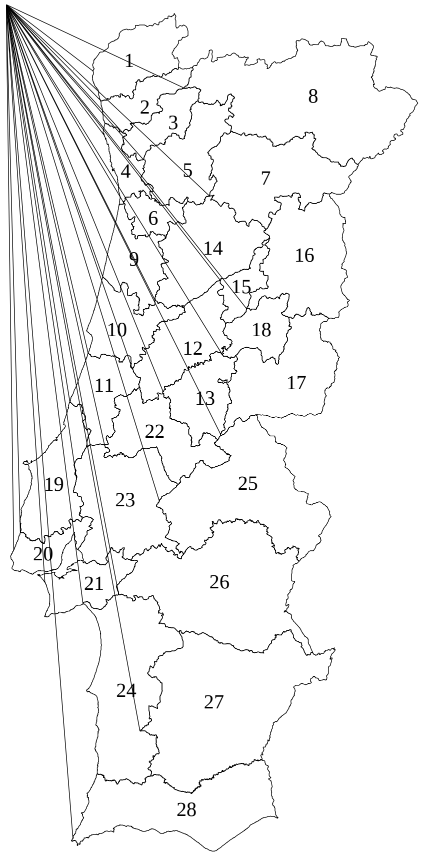
The role of spatial agglomeration of production activities and knowledge on firms' productivity remains a puzzling question in the literature. Based on a panel of Portuguese manufacturing firms over the period 1996–2004, this study shed further light on whether agglomeration economies have different, non-linear, effects across industries.

Our econometric estimates confirm the hypothesis that local knowledge spillovers play an important role in explaining firm productivity. Moreover, they are present in different combinations for firms belonging to different industries. Indeed, while in the case of estimates for all manufacturing sectors pooled together localization economies have a significantly positive effect on firms' productivity, in the case of distinct regressions by sector only medium-high and high-tech firms seem to benefit from this source of economies. More puzzling are the results on the relationship between regional R&D level and firms' productivity. On the one hand, we found an inverted U-shaped relationship for all manufacturing firms and firms from medium-low and high-tech sectors—the elasticities become negative for values higher than the median. On the other, we found a U-shaped relationship and an increasingly positive elasticity for R&D levels higher than the 20th percentile in low-tech sector. Apparently, regional R&D efforts matter most for low-tech firms. Diversity externalities, for its part, have an inverted U-shaped relationship with firms' TFP in all sectors (except in the case of high-tech sector whose coefficients are not statistically significant), that is, there are agglomeration diseconomies due to congestion effects after a certain critical level. Finally, high-tech firms benefit from KIBS activities when their employment in the region is higher than the median.

Overall, this study contributes to a better understanding of the regional knowledge spillovers at the sectoral level, a critical issue to promote and design new, more assertive, regional policies to enhance economic growth. In particular, our findings suggest that fostering firms' productivity could require different instruments across industries.

Appendix

Figure A1 NUTS 3 regions of mainland Portugal



Region:
1-Minho-Lima
2-Cávado
3-Ave
4-Grande Porto
5-Tâmega
6-Entre Douro e Vouga
7-Douro
8-Alto Trás-os-Montes
9-Baixo Vouga
10-Baixo Mondego
11-Pinhal Litoral
12-Pinhal Interior Norte
13-Pinhal Interior Sul
14-Dão-Lafões
15-Serra da Estrela
16-Beira Interior Norte
17-Beira Interior Sul
18-Cova da Beira
19-Oeste
20-Grande Lisboa
21-Península de Setúbal
22-Médio Tejo
23-Lezíria do Tejo
24-Alentejo Litoral
25-Alto Alentejo
26-Alentejo Central
27-Baixo Alentejo
28-Algarve

Table A1 Number of firms by industry

CAE	Industry	Mean	SD	Min	Max
15	Food products and beverages	459	18.5	429	482
17/18	Textiles and wearing apparel	817	109.8	659	971
19	Leather and leather products	215	51.8	162	339
20	Wood and wood products (except furniture)	192	11.8	168	207
21/22	Pulp, paper, paper products and publishing	207	10.7	191	226
24	Chemical and chemical products	155	3.9	148	161
25	Rubber and plastic products	87	12.3	69	105
26	Other non-metallic mineral products	316	19.7	278	333
27/28	Basic metals and fabricated metal products	359	18.9	327	387
29	Machinery and equipment	279	19.8	244	310
30/31/32/33	Electronic and electrical equipment	159	4.5	154	167
34/35	Motor vehicles, trailers and other transport equipment	133	8.8	120	147
36	Furniture, other manufacturing n.e.c. and recycling	178	16.7	146	203

Notes: The decomposition uses the two-digit level of the Portuguese Classification of Economic Activities (CAE Rev. 2.1). At least at this disaggregation level there is a direct correspondence between this classification and the classifications of both the European Community (NACE-Rev. 1.1) and the United Nations (ISIC Rev. 3.1). Mean values over the period 1996–2004 and standard deviations (SD) of the number of firms.

Table A2 Descriptive statistics (between and within variations)

Variable		Mean	Std. Dev.	Min	Max	Observations
a_{it}	overall	3.001	0.900	1.139	5.472	N = 32,003
	between		0.895	1.139	5.323	n = 8074
	within		0.120	0.942	5.083	T-bar = 3.964
loc_{it}^{jr}	overall	-2.602	1.547	-11.513	-0.217	N = 32,003
	between		1.439	-11.513	-0.230	n = 8074
	within		0.476	-10.819	4.248	T-bar = 3.964
div_{t}^{jr}	overall	1.839	0.494	0.204	2.589	N = 32,003
	between		0.492	0.214	2.589	n = 8074
	within		0.086	0.507	2.988	T-bar = 3.964
rd_{t}^{r}	overall	6.448	1.751	0	9.392	N = 32,003
	between		1.738	0	9.392	n = 8074
	within		0.281	1.463	10.970	T-bar = 3.964
$kibs_{t}^{r}$	overall	7.447	2.302	3.178	11.873	N = 32,003
	between		2.213	3.178	11.873	n = 8074
	within		0.518	-0.004	14.415	T-bar = 3.964

Table A3 Classification of manufacturing industries into categories based on R&D intensities

High-technology industries	**Medium-high-technology industries**
Aircraft and spacecraft	Electrical machinery and apparatus, n.e.c.
Pharmaceuticals	Motor vehicles, trailers and semi-trailers
Office, accounting and computing machinery	Chemicals excluding pharmaceuticals
Radio, TV and communications equipment	Railroad equipment and transport equipment, n.e.c.
Medical, precision and optical instruments	Machinery and equipment, n.e.c.
Medium-low-technology industries	**Low-technology industries**
Building and repairing of ships and boats	Manufacturing, n.e.c.; Recycling
Rubber and plastics products	Wood, pulp, paper, paper products, printing and publishing
Other non-metallic mineral products	Food products, beverages and tobacco
Basic metals and fabricated metal products	Textiles, textile products, leather and footwear

References

Acs, Z. (2002). Innovation and the growth of cities. Cheltenham, Edward Elgar.

Acs, Z., Audretsch, J.D.B. and Lehmann, E.E. (2013). The knowledge spillover theory of entrepreneurship. Small Business Economics 41(4), 757–774.

Amesse, F. and Cohendet, P. (2001). Technology transfer revisited from the perspective of the knowledge-based economy. Research Policy 30, 1459–1478.

Anderson, M. and Lööf, H. (2011). Agglomeration and productivity: Evidence from firm-level data. Annals of Regional Science 46(3), 601–620.

Arellano, M. and Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. Journal of Econometrics 68, 29–51.

Arrow, K.J. (1962). The economic implications of learning by doing. Review of Economic Studies 29, 155–173.

Audretsch, D.B. and Feldman, M.P. (2004). Knowledge spillovers and the geography of innovation. In Henderson, V. and Thisse, J.F. (Eds), Handbook of Urban and Regional Economics, Vol. 4, Elsevier, Amsterdam, pp. 2713–2739.

Beaudry, C. and Schiffauerova, A. (2009). Who's right, Marshall or Jacobs? The localization versus urbanization debate. Research Policy 38(2), 318–337.

Blundell, R. and Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. Journal of Econometrics 87, 115–143.

Blundell, Richard and Bond, Stephen (2000). GMM Estimation with persistent panel data: an application to production functions. Econometric Reviews 19(3), 321–340.

Bond, S. (2002). Dynamic panel data models: A guide to micro data methods and practice. Portuguese Economic Journal 1, 141–162.

Bradley, R. and Gans, J. (1998). Growth in Australian Cities. Economic Record 74, 266–278.

Breschi, S. and Lissoni, F. (2001). Knowledge Spillovers and Local Innovation Systems: A Critical Survey. Industrial and Corporate Change 10(4), 975–1005.

Bronzini, R. and Piselli, P. (2009). Determinants of long-run regional productivity with geographical spillovers: The role of R&D, human capital and public infrastructure. Regional Science and Urban Economics 39, 187–199.

Cainelli, G., Fracasso, A. and Marzetti, G. V. (2015). Spatial agglomeration and productivity in Italy: A panel smooth transition regression approach. Papers in Regional Science 94(S1), S39–S68.

Cainelli, Giulio and Riccardo Leoncini (1999). Externalities and Long-Term Local Industrial Development: Some Empirical Evidence from Italy. Revue d'economie industrielle 90, 25–40.

Carreira, C. and Lopes, L.P. (2015). Are Small Firms More Dependent on the Local Environment than Larger Firms? Evidence from Portuguese Manufacturing Firms. In Leitao J.C. and Baptista, R. (eds.), Entrepreneurship, Human Capital, and Regional Development. Springer, pp 263–280.

Cassia, L., Colombelli, A. and Paleari, S. (2009). Firms' growth: Does the innovations system matter?. Structural Change and Economic Dynamics 20(3), 211–220.

Cingano, F. and Schivardi, F. (2004). Identifying the sources of local productivity growth. Journal of the European Economic Association 2(4), 720–742.

Combes, P.P. (2000). Economic Structure and Local Growth: France, 1984–1993. Journal of Urban Economics 47, 329–355.

Combes, Pierre-Philippe; Gobillon, Laurent (2015). The Empirics of Agglomeration Economies. In Duranton, G., Henderson, J.V. and Strange, W.C. (eds.), Handbook of Urban and Regional Economics, Vol. 5, Elsevier, Amsterdam, pp. 247-348.

Di Giacinto, V., M. Gomellini, G. Micucci, and M. Pagnini (2014). Mapping local productivity advantages in Italy: Industrial districts, cities or both? Journal of Economic Geography 14, 365–394.

Döring, T. and Schnellenbach, J. (2006). What do we know about geographical knowledge spillovers and economic growth? A survey of the literature. Regional Studies 40(3), 375–395.

Ehrl, Philipp (2013). Agglomeration economies with consistent productivity estimates. Regional Science and Urban Economics 43(5), 751–763.

Forni, M. and Paba, S. (2002). Spillover and the growth of local industries. Journal of Industrial Economics 50(2),151–171

Frenken, K., van Oort, F and Verburg T. (2007). Related variety, unrelated variety and regional economic growth. Regional Studies 41(5), 685–697.

Fritsch, M. and Slavtchev, V. (2007). Universities and innovation in space. Industry Innovation 14, 201–218.

Glaeser, E., Kallal, H., Sheikman, J. and Shleifer, A. (1992). Growth in cities. Journal of Political Economy 100(6), 1126–1152.

Griliches, Z. (1992). The search for R&D spillovers. Scandinavian Journal of Economics 94, S29–S47

Grimpe, Christoph and Sofka, Wolfgang (2009). Search patterns and absorptive capacity: Low- and high-technology sectors in European countries. Research Policy 8(3), 495–506.

de Groot, H. L.F., Poot, J. and Smit, M. J. (2015). Which agglomeration externalities matter most and why? Journal of Economic Surveys. (doi:10.1111/joes.12112)

Hashiguchi, Yoshihiro and Tanaka, Kiyoyasu (2015). Agglomeration and firm-level productivity: A Bayesian spatial approach. Papers in Regional Science 94(S1), S95–S114.

Henderson, J.V. (2003). Marshall's scale economies. Journal of Urban Economics 53, 1–28.

Henderson, J.V., Kuncoro, A. and Turner, M. (1995). Industrial development of cities. Journal of Political Economy 103, 1067–1090.

Jacobs, J. (1969). The economy of cities, Vintage, New York.

Jacobs, J. (1969). The economy of cities. New York, Vintage.

Johansson, B. and Lööf, H. (2008). Innovation activities explained by firm attributes and location. Economics of Innovation and New Technology 17(6), 533–552.

Kancs, d'Artis and Siliverstovs, B. (2016). R&D and Non-linear Productivity Growth. Research Policy 45(3), 634-646.

Klevorick, A., Levin, R., Nelson, R. and Winter, S. (1995) On the Sources and Interindustry Differences in Technological Opportunities. Research Policy 24, 185–205.

Lambooy, Jan G. (2010). Knowledge Transfers, Spillovers and Actors: The Role of Context and Social Capital. European Planning Studies 18(6), 873–891.

Lind, J.T. and Mehlum, H. (2010). With or without U? The appropriate test for a U shaped relationship. Oxford Bulletin of Economics and Statistics 72(1): 109-118.

López, R.A. and Südekum, J. (2009). Vertical Industry Relations, Spillovers, and Productivity: Evidence from Chilean Plants. Journal of Regional Science 49(4), 721–747.

Malerba F. and Orsenigo L. (1997). Technological regimes and sectoral patterns of innovative activities. Industrial and Corporate Change 6(1), 83–117.

Marshall, A. (1890). Principles of Economics, (9.ª ed. 1961). Macmillan Press, London.

Melo, P.C., Graham, D.J. and Noland. R.B. (2009). A meta-analysis of estimates of urban agglomeration economies. Regional Science and Urban Economics 39, 332–342.

Martin, P., Mayer, T. and Mayneris, F. (2011). Spatial concentration and plant-level productivity in France. Journal of Urban Economics 69, 182–195.

Muller, E. and Zenker, A. (2001). Business services as actors of knowledge transformation: The role of KIBS in regional and national innovation systems. Research Policy 30, 1501–1516.

Nelson, R.R. and Winter, S.G. (1982). An Evolutionary Theory of Economic Change, Belknap Press of Harvard University Press, Cambridge, MA.

Olley, G.S. and Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. Econometrica 64(6), 1263–1297.

van Oort FG, Burger MJ, Knoben J, Raspe O (2012) Multilevel approaches and the firm-agglomeration ambiguity in economic growth studies. Journal of Economic Surveys 26(3), 468–491

Puga, D. (2010). The magnitude and causes of agglomeration economies. Journal of Regional Science 50 (1), 203–219.

Robertson, P., Smith, K. and von Tunzelmann, N. (2009). Research Policy. Introduction: Innovation in low- and medium-technology industries 38(3), 441–446.

Romer, P.M. (1986). Increasing returns and long-run growth. Journal of Political Economy 94, 1002–1037.

Roodman, D. (2009a). How to do xtabond2: An introduction to difference and system GMM in Stata. Stata Journal 9(1), 86-136.

Roodman, David (2009b). A Note on the Theme of Too Many Instruments. Oxford Bulletin of Economics and Statistics 71(1), 135–158.

Rosenthal, S.S. and Strange, W.C. (2004). Evidence on the nature and sources of agglomeration economies. In Henderson, V. and Thisse, J.F. (Eds), Handbook of Urban and Regional Economics, Vol. 4, Elsevier, Amsterdam, pp. 2119–2172.

Saito, Hisamitsu and Gopinath, Munisamy (2009). Plants' self-selection, agglomeration economies and regional productivity in Chile. Journal of Economic Geography 9, 539–558.

Storper, M. and Venables, A.J. (2004). Buzz: Face-to-face contact and the urban economy. Journal of Economic Geography 4, 351–370.

Tappeiner, G., Hauser, C. and Walde, J. (2008). Regional knowledge spillovers: Fact or artifact? Research Policy 37, 861–874.

Yang, C.-H, Lin, H.-L. and Li, H.-Y. (2013). Influences of production and R&D agglomeration on productivity: Evidence from Chinese electronics firms. China Economic Review 27, 162–178.

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