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Knowledge externalities and sectoral interdependences: Evidence from an open economy perspective.

Agnieszka Gehringer
University of Goettingen
Department of Economics
agehrin@gwdg.de

Abstract

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Jelcodes:O30,F10

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Innovative suppliers and creative users benefit from the reciprocal innovative activities. Ideally, such benefits result in an increased innovative dynamics of the knowledge receivers, who accrue pecuniary knowledge externalities. The latter stem from the cost advantage that the knowledge users face when acquiring knowledge from external sources and that is efficiently used in the internal process of innovation. Nothing prevents that, in an increasingly integrated world, such knowledge externalities would be generated both in intra- and inter-country knowledge-based transactions. Nevertheless, the evidence reported in the paper suggests that localized pecuniary knowledge externalities are dominating. In the empirical analysis based on a panel of 25 2-digit manufacturing and service sectors in 15 EU countries, I implement techniques permitting to account for the possible reverse causality between the underlying relations.

Keywords: knowledge externalities, sector-level data, international knowledge spillovers, productivity, manufacturing, services

JEL O31, O30, F01

1. Introduction

The past discussion in the economic literature elaborated a broad consensus over a high degree of complexity accompanying the innovation-based growth process (Andriani, 2011; Dosi and Nelson, 1994; Fischer and Fröhlich, 2001; Nelson and Winter, 1982; Saviotti, 1996; Schumpeter, 1934 and 1943). This complexity is indisputably alimented with the very characteristics of knowledge, its non-divisibility, non-exhaustibility, cumulability and partial appropriability. As a consequence, knowledge generation activities are accompanied by knowledge externalities, which - most of the times – make the private marginal benefit lying below the private one (Gehringer, 2011a).

Based on the sound theoretical elaborations dating back to Alfred Marshall, some later relevant contributions have been dedicated to evaluate the role played by knowledge externalities in an inter-sectoral framework of analysis (Griliches, 1979; Grossman and Helpman, 1991). Nevertheless, the focus of all these contributions was prevalently on technological externalities, deriving from direct interactions disconnected from market transactions. More recently, the role of the market transactions in the transmission of knowledge-based interactions has been conceptually underlined and empirically tested (Antonelli and Gehringer, 2012 and 2013; Gehringer 2011a, 2011b and 2012) as well as Antonelli and Gehringer (2012 and 2013). In particular, positive evidence of the presence and significant influence played by pecuniary knowledge externalities both in a demand-pulling (Antonelli and Gehringer, 2012a and b) and in a technology-pushing (Gehinger, 2011a, 2011b and 2012) has been delivered.

Moreover, some effort has been done to investigate the geographic dimension of knowledge externalities, stemming particularly from R&D activities (Branstetter, 2001) or from foreign direct investment (Aitken and Harrison, 1999; Branstetter, 2006; Eaton and Kortum, 1996; Haddad and Harrison, 1993; Haskel et al., 2007; Javorcik, 2004; Keller and Yeaple, 2009). Other channels of knowledge spillovers discussed in theoretical and empirical literature refer to imports of manufacturing goods (Coe and Helpman, 1995; Keller, 1998) and to "learning by exporting" (Aw et al., 2001; Bernard and Jensen, 1999; Clerides et al., 1998; MacGarvie, 2006). This strand literature examining sources and effects of knowledge spillover in an international context is the one to which my contribution refers most. There are though important extensions made in my approach. On the contrary to the past contributions, I focus on knowledge spillovers stemming from productivity growth. With respect to the R&D-based spillovers, this has an advantage of considering new knowledge actually generated and not only conditionally achievable. Consequently, the uncertainty connected with the final outcome of the R&D activities is eliminated. With respect to spillovers generated through other channels, the advantage of referring to productivity-driven externalities stays in considering a broader source of external knowledge, including knowledge generated by international investors, but also knowledge incorporated in imports and knowledge that might be learned by exporting. Moreover, by working with sector-level data referring to 15 EU countries, I am able to exploit the more localized, European, nature of international knowledge spillovers. Finally, I focus on the significant divergences in economic performance between manufacturing and service sectors and put into evidence the different intensity of pecuniary knowledge externalities exercised by manufactures and services.

The paper is structured as follows. The next section designs a theoretical background, to which the present study belongs. Section 3 discusses some relevant stylized facts regarding the productivity performance between the European sectors. Section 4 describes the empirical methodology and data used. In section 5, I present the results, discuss the main findings and offer some sensitivity analysis. The last section concludes.

2. Knowledge externalities within and between national innovative systems

2.1 Origins and nature of knowledge externalities

Knowledge externalities are a two-fold phenomenon. Quite obviously, they benefit the knowledge users who do not bear the full cost they would have to, if intellectual property rights were assigned correctly and the market priced knowledge at its face value. What the knowledge users make with the novelty depends on the degree of their competence (Antonelli and Gehringer, 2014). If they are moderately competent, they enjoy it without further consequences on their internal innovative performance. Ideally – when the users are highly competent – they take full benefit from the cost advantage coming with the underpriced externally generated knowledge and get involved themselves in creative internal knowledge generation process. The second image of knowledge externalities, however, implies the blame for the innovator, who is unable to appropriate fully the real value of the good he generates. Aware of his “missing wealth”, the innovative agent will prefer not to engage in some of the dynamically beneficial discoveries. Here lays the scope for the innovation policy response. By offering limited-in-time quasi-monopolistic intellectual property rights over the innovative result, the government faces the underproduction problem that is, however, paid in terms of underutilization of the protected innovation.

Although such legal means of protection constitute already standard at least in the industrialized economies, not all relevant knowledge will be formally protected. This is most importantly due to the excessive costs connected with patent protection. But even if protected, nothing prevents that knowledge or its parts incorporated, for instance, in intermediate inputs wouldn’t be re-used in the economic system. Assuming, thus, that some relevant stock of technological and especially non-technological knowledge remains unprotected, knowledge externalities should come into play, benefiting the knowledge users with important cost advantages.

The literature on externalities builds upon three complementary traditions. The first one is the so called MAR tradition, after the names of its main postulators, Alfred Marshall, Kenneth Arrow and Paul Romer. This line of theoretical development emphasized the role of vertical specialization in providing positive productivity impulses. The second tradition refers to the elaborations by Jacobs (1969), whereas the third one to the analysis by Porter (1990). Those last two traditions underline, instead, the importance of horizontal differentiation, as an engine of local innovative capacities. A common feature of all three traditions is the recognition of the localized nature of technological knowledge.

It was also the Marshallian merit to originate the central distinction between technological and pecuniary externalities.[1] To clarify the distinction, technological externalities apply when innovative producers directly interact with the users who benefit from externally generated knowledge in the way to become themselves innovators. In this sense, technological knowledge once generated is in the air and is transferred in user-producer interactions, disconnected from market transactions. On the contrary, pecuniary externalities occur when an innovative item is sold through the market transactions to the users who benefit from a cost advantage of paying a price that is lower than the face value of innovation. Pecuniary externalities are said to be indirect, as they are mediated through the price mechanism. In such a market-based setting, if the user of innovation doesn't take advantage from a) a brand new piece of externally generated knowledge and from b) his cost incentive to involve himself in an internal process of innovation, no further knowledge externality occurs (Brandstetter, 2001). If, instead, the user recognizes the advantage coming from pecuniary knowledge externalities, he uses the external knowledge in a recombinant process of internal knowledge generation and is able to arrive at an innovative outcome (Antonelli, 2008; Gehringer, 2011). Such external effects occur thus when externally generated knowledge is transferred to the users through the market transactions on advantageous cost conditions and contributes to their innovative activity. This cost advantage derives from the price of newly generated knowledge that does not reflect the full burden of knowledge generation activity. The price is lower than in a socially optimal equilibrium, because the innovator is unable to exercise fully his intellectual property rights on his novelty. For the user, this translates in an advantage that, if efficiently used, will ultimately result in his dynamic efficiency increase. At the end, thus, not only the upstream knowledge producer but also the downstream knowledge user will become an innovator.

2.2 Domestic versus international knowledge externalities

Already in the 70s and the 80s of the past century knowledge externalities assumed a certain importance in the economic discussion. Nevertheless, with the subsequent theoretical advances in endogenous growth modeling as well as with the progress made in international economics, knowledge externalities have been recognized to play a crucial role in assuring a long-lasting growth path.

[1] The substantial effort in improving our understanding of the distinction has been subsequently made by Zivi Griliches (1979).

Pure technological externalities have been incorporated in the models of endogenous growth, with the pioneering contributions by Romer (1990) as well as Aghion and Howitt (1992, 1998), in their model of growth through creative destruction.

Analogously, technological externalities have been also intensively investigated in an open economy context, initiated with the theoretical work by Grossman and Helpman (1991). In their later paper from 1995, when assessing international knowledge spillovers, they underline the importance of the national component in assuring the long-run economic growth. The economic significance of this national component has been empirically confirmed by Branstetter (2001) in a panel estimation based on firm-level data from Japan and the United States. In a much more localized context, Irwin and Klenow (1994) asses the economic strength of international and domestic knowledge spillovers based on learning-by-doing in the dynamic random access memory chip industry. The study suffers, however, from the R&D data unavailability on the firm-level, making the exact measurement of the spillover effects less reliable.

The majority of the empirical evidence on international knowledge spillovers is based on country-level data regarding R&D expenditures or R&D-based capital accumulation (Coe and Helpman, 1995; Coe et al., 1995; Bernstein and Mohnen, 1998). More recent works use firm-level data, but in doing so they report mostly a single country evidence (see, for instance, Aitken and Harrison (1999) for an investigation on Morocco and Venezuela and Javorcik (2004) for an analysis of Lithuania).

There are not few examples in the history of industrial development confirming that international knowledge diffusion and consequently knowledge spillovers are relevant determinants of country-level growth. Such examples include the spread of the water wheel, wind mill and printing press through Europe or the spread of computer technology in more recent decades (Mokyr 1990). Whereas it seems indisputable that there is some diffusion of knowledge across borders and between firms, the empirical evidence was not always clear about it.

Another important finding in the past literature concerning international knowledge spillovers regards the importance of search costs in determining the intensity and speed of knowledge diffusion internationally. These findings suggest that knowledge diffusion is much localized, implying that search costs do matter (Audretsch and Feldman, 1996; Jaffe Trajtenberg and Henderson, 1993; Branstetter, 2001; Keller 2002).

3. Economic facts on productivity development in the European industries

The productivity performance in the EU over the last few decades was presenting a rather mixed picture. Figure 1 shows that, overall, up to 2000 (with the exception of 1998) and since 2004 the average growth rates of TFP for all NACE activities were positive. Nevertheless, this average performance diverged much between manufacturing and service activities. For many years, it was manufacturing that has driven the average productivity development, whereas services were performing at very low or even negative TFP growth rates. Only after 2005 services gained importance in terms of TFP growth.

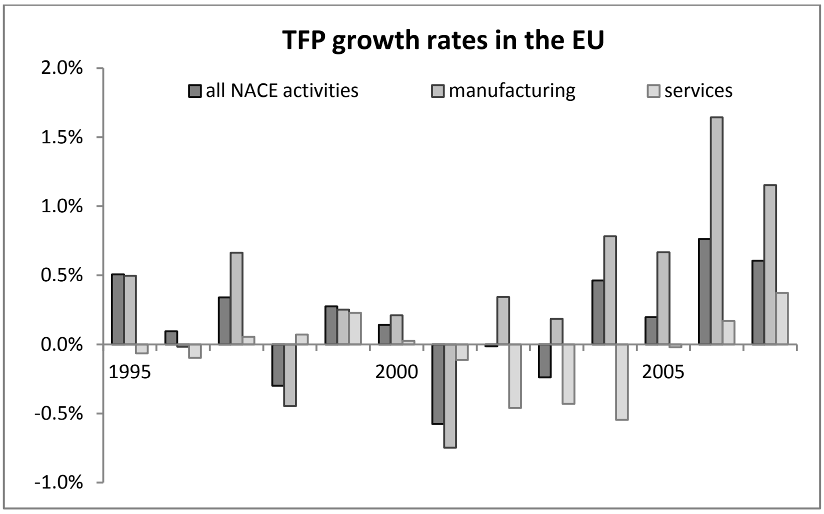

Figure 1. Annual TFP growth rates averaged for 15 EU countries.

Source: Own calculations based on OECD STAN database.

Such differences, but at a more disaggregated, individual-sector level, motivated the previous investigations by Gehringer (2011a, 2011b and 2012). In the three subsequent studies, she assesses empirically the importance of pecuniary knowledge externalities from the overall European perspective, as well as from the country specific and sector-specific perspective. A potential drawback, however, of such analyses could be a high number of explanatory variables included in the estimating equations. To overcome this problem, in the present work, I will concentrate on more aggregated effects. This will permit to extend the set of factors determining TFP growth with respect to the previous investigations, by considering not only domestic knowledge externalities, but also foreign-made knowledge spillovers.

Additionally, as the descriptive analysis of Figure 1 suggests, at least the distinction between manufacturing and service sectors might provide valuable insights to the understanding of the very nature of intersectoral, knowledge-based linkages. Consequently, in the empirical analysis of the following sections, I will estimate the effects of the domestic and international (European) knowledge spillovers both for the overall NACE activities and keeping manufacturing and services separately.

4. Empirical methodology

4.1 Estimation strategy

In the main empirical exercise, I assess the role played by knowledge externalities in a system of market-based knowledge transactions-cum-interactions. To this end, I measure the technology-pushing impact that downstream producers receive on their total factor productivity (TFP) growth when interacting through intermediate market transactions with innovative suppliers. Such an impact will come each time the upstream producers generate a novelty – as measured in terms of the upstream growth rate of TFP – and make this new piece of technological and non-technological knowledge available on the market.

Regarding the TFP variable, I follow the methodology of Jorgenson and Griliches (1967) and Jorgenson et al. (1987), assuming the standard growth accounting framework with a constant returns Cobb-Douglas production function. Consequently, the logarithmic growth rate of TFP is defined as

$$\Delta \ln \mathrm{TFP}_{ikt} = \Delta \ln Y_{ikt} - \bar{\alpha}_{ikt}^{K} \Delta \ln K_{ikt} - \bar{\alpha}_{ikt}^{L} \Delta \ln L_{ikt} - \bar{\alpha}_{ikt}^{X} \Delta \ln X_{ikt} \quad (1)$$

where Y is total output of sector i in country k at time t, K is sectoral capital stock, L is labour force measured in terms of total employment and X expresses intermediate inputs. Moreover, $\bar{\alpha}_{ikt}^{f}$ where f = (K, L, X) denotes the two-period average share of factor f over the nominal output defined as follows:

$$\bar{\alpha}_{ikt}^{f} = \left(\alpha_{ik(t-1)}^{f} + \alpha_{ikt}^{f}\right) / 2 \quad (2)$$

whereas

$$\alpha_{ikt}^{L} = L_{ikt} / Y_{ikt} \; ; \quad \alpha_{ikt}^{X} = X_{ikt} / Y_{ikt} \text{ and } \quad \alpha_{ikt}^{K} = 1 - \alpha_{ikt}^{L} - \alpha_{ikt}^{X} \quad (3)$$

are the respective sector, country and time specific factor elasticities of labour, intermediate inputs and fixed capital.

The basic specification of the model to estimate assumes the following form:

$$\Delta(\mathrm{TFP}_{jkt}) = \alpha + \beta_1 IE_{jkt} + \beta_2 EE_{jkt} + \beta_3 ER\&D_{jkt} + \beta_4 FDI_{kt} + \beta_5 R\&D_{jkt} + \gamma_k + \delta_j + \mu_t + \varepsilon_{jkt} \quad (4)$$

where $\Delta(\mathrm{TFP}_{jkt})$ is the growth rate of TFP in a downstream sector j, in country k, at time t. Among explanatory variables, IE_{jkt} expresses the effect of the domestic technology pushing, generated by the upstream innovative suppliers. This effect is averaged out across all the domestic NACE sectors and can be expressed in terms of the following analytical expression:

$$IE_{jkt} = \frac{1}{N} \sum_{i=1}^{N} s_{ijkt} = \frac{1}{N} \sum_{i=1}^{N} \left[a_{ijkt} \cdot \Delta(\mathrm{TFP}_{ikt}) \right] \quad (5)$$

where a_{ijkt} refers to a technical coefficient calculated as a ratio between the intermediate inputs supplied by sector i to sector j, over the total value of output produced by sector j. Moreover, $\Delta(\mathrm{TFP}_{ikt})$ expresses the growth rate of TFP in an upstream sector i, in country k, at time t. This factor, thus, aims to measure the market-based (measured by a_{ijkt}) technological influence (measured by $\Delta(\mathrm{TFP}_{ikt})$) that each downstream sector j receives from the domestic industries i=1, … N.

The other two explanatory variables, EE_{jkt} and $ER\&D_{jkt}$, measure two distinct kinds of external (international) knowledge spillovers. The first one refers to a TFP-growth-based effect averaged over all the N sectors and over all L countries included in the sample. Such an average effect is weighted with the degree of the sector-specific trade openness of sector j, measured as the ratio between the sum of sector's j imports and exports and this sector's total output. In analytical terms:

$$EE_{jkt} = \left[\frac{1}{N}\frac{1}{L}\sum_{i=1}^{N}\sum_{l=1}^{L}\Delta(\text{TFP}_{ilt})\right]\cdot\frac{Exp_{jkt}+Imp_{jkt}}{Output_{jkt}} \ . \tag{6}$$

The second variable referring to external knowledge spillovers refers more precisely to the possible R&D spillovers, broadly investigated in the past empirical literature (Coe and Helpman, 1995; Coe et al., 1995; Bernstein and Mohnen, 1998). Analogously as in the case of external TFP-based knowledge spillovers, $ER\&D_{jkt}$ is defined as a weighted average over N and over L of sector-level R&D expenditures, with the weights given by the domestic sector's openness to trade. Analytically this can be expressed as:

$$ER\&D_{jkt} = \left[\frac{1}{N}\frac{1}{L}\sum_{i=1}^{N}\sum_{l=1}^{L}R\&D_{ilt}\right]\cdot\frac{Exp_{jkt}+Imp_{jkt}}{Output_{jkt}} \, . \tag{7}$$

I also control for the influence of the inward foreign direct investment (FDI) that are measured at the country level and of the internal R&D efforts performed by each downstream sector j. Finally, γ_k, δ_j and μ_t refer to country, sector and time specific effects, whereas ε_{jkt} measures the idiosyncratic error term.

I estimate the model according to two alternative econometric methods, fixed effects and system GMM. The former permits to account for time-invariant unobservable effects that might exercise significant impact on sectoral TFP growth. Nevertheless, in this static framework, endogeneity might be a serious issue. Indeed, in principle, TFP growth of downstream sectors might directly influence productivity performance of their upstream suppliers. Moreover, also the time-invariant unobservables might have impact on the other explanatory variables in the model. To deal with such possible reverse causality, it might be useful to apply system GMM methodology developed by Arellano and Bover (1995) and Blundell and Bond (1998). It consists in estimating a system of two equations. The first one is an equation in first differences, where the differenced explanatory variables are instrumented with their lagged levels. The second one is an equation in levels, where the explanatory variables are instrumented with their own first differences.

4.2 Data

The database for my empirical analysis constitutes a panel of sector-level observations regarding 15 European countries over the period 1995-2007. More precisely, I included twelve old EU member states (Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, the UK), in addition to a few Eastern European members from the 2004 wave of enlargement (Czech Republic, Hungary and Slovak Republic). Data limitation and excessive fragmentation excluded the remaining Central and Eastern European countries.

The major source of data is given by OECD STAN database and the recently released World Input Output Database (WIOD). From the former I retrieve the variables necessary to calculate the growth rate of TFP, as well as sectoral R&D expenditures.[2] Based on WIOD, I calculated for each country and each year matrices of technical coefficients that express the relative intensity of intermediate market transactions between each receiving and all the supplying sectors (in the sense of columns).[3] Using WIOD, I calculate the weights necessary to construct the two variables measuring foreign knowledge spillovers (equations 6 and 7). Finally, the country-level data on inward FDI are taken from the database by Lane and Milesi-Feretti (2007).

5. Results

5.1 Baseline results

Table 1 reports the results from the estimations of equation (4) both for fixed effects and system GMM specification. In columns 1 and 2, I show the results obtained for the explanatory variables measuring knowledge externalities averaged over all the NACE activities. According to these results, there is strongly significant evidence confirming the role of the domestic knowledge externalities in pushing technological performance of the downstream sectors. On the contrary, almost no evidence could be found for both kinds of international knowledge spillovers. The exception here constitute TFP-based external knowledge spillovers, but only if estimated with the fixed effects method.

In columns 3 and 4, I replace the overall across-NACE effect with the separate effects for manufacturing and service activities. Such disaggregated effects broadly confirm the previous aggregate findings, namely, that exclusively the domestic knowledge spillovers and not also the international ones play a role in pushing internal technological change. Additionally, however, the results report a relatively stronger effect for manufacturing than for services. All those results remain stable irrespective of the methodology used.

Table 1. Evidence on domestic and international knowledge spillovers

dep. var.: Δ(TFP) in a downstream sector j				
	FE	sysGMM	FE	sysGMM
lagged Δ(TFP)		-0.044		-0.049
		(0.046)		(0.047)
IE all NACE	0.787***	0.807***		
	(0.058)	(0.073)		
EE all NACE	0.899	1.281		
	(0.565)	(1.006)		

[2] Data on R&D expenditures are still incomplete, especially regarding services.
[3] In the sense of rows, one can read, for each upstream sector, the relative intensity of intermediate market transactions towards all the other downstream sectors.

ER&D all NACE	0.005*	0.005		
	(0.003)	(0.013)		
IE manufacture			0.462***	0.494***
			(0.049)	(0.050)
IE services			0.267***	0.279***
			(0.041)	(0.046)
EE manufacture			0.185	0.313
			(0.275)	(0.485)
EE services			1.183**	1.605
			(0.573)	(1.015)
ER&D manufacture			0.005*	0.010
			(0.002)	(0.007)
ER&D services			-0.023	-0.043
			(0.020)	(0.044)
inward FDI	0.011**	0.010	-0.010	-0.010
	(0.006)	(0.015)	(0.006)	(0.014)
own R&D	-0.001**	-0.003***	-0.001***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
N. obs.	2859	2655	2859	2655
R-squared	0.357		0.327	
Sargan (p-value)		0.134		0.205
AB m-2 (p-value)		0.873		0.839

Note: ***, **, * imply significance levels at 1%, 5% and 10%, respectively. Robust standard errors are included in parentheses. IE stays for internal (domestic) knowledge externalities; EE refers to external (foreign) knowledge externalities; ER&D represents external (foreign) R&D expenditures. In all sys GMM specifications the number of instruments is not exceeding the number of groups. Moreover, in estimations not reported here, I treat IE, EE and ER&D variables as endogenous, but the results remain basically unchanged. Time dummies are included.

Finally, a comment is due to the results observed for the own R&D expenditures. This evidence reporting a negative sign of the estimated coefficient might be puzzling at the first sight, but one interpretation can be still given. In particular, R&D expenditures might provoke a kind of immediate depressive effect on the own TFP growth, given that they consist in fixed costs for the industry. Once such potentially innovative inputs are efficiently used, their negative cost burden should disappear in the future periods. To this argument, in Appendix A.1, I provide some supportive empirical evidence.

5.2 Are knowledge externalities pure or pecuniary?

In the past theoretical and empirical literature authors concentrated principally on technological (pure) knowledge spillovers (Griliches, 1979). Such externalities would thus consist in direct interactions between innovative producers and innovative users, whereas the latter would be benefitted in their internal production activity by the externally generated new knowledge. As a result, higher production volume by the downstream knowledge user could be achieved.

There are reasons to believe that the knowledge creators will make effort to appropriate – although imperfectly - the benefit they generate with innovation. Indeed, the evidence reported in the previous section confirms that knowledge externalities are pecuniary in nature. In principle, however, nothing excludes that such pure knowledge externalities occur and be present in all these cases, in which knowledge is in the air and can be directly used by the users. It is thus worth verifying, whether pure knowledge spillovers play any significant role in the European context.

To prove this hypothesis, I re-estimate analogous specifications from Table 1 with explanatory variables that now are given by pure TFP and pure R&D effects. More precisely, they are calculated by omitting the expenditure coefficients from equation 5 and the trade openness from equations 6 and 7. Note that I report the results from random effects, instead of fixed effects estimation. This is because the Hausman test failed to reject the null of more efficient random effects estimated coefficients.[4] The results from the estimations are reported in Table 2 and show that, indeed, also pure knowledge externalities positively influence productivity growth at the sector-level. However, it is worth noting here that by considering such pure effects, it is not able any more to distinguish between technology-push and demand-pull effect. More precisely, in the previous setting the direction of the technological interaction between the domestic producers was clearly defined by the technical coefficients from the input-output framework. Instead, here technological interaction might refer both to innovative upstream producers influencing downstream users (technology-push) and to creative downstream users producing technological impact on innovative upstream producers (demand-pull).

Finally, it is worth observing that the overall explanatory power of the model considering only the pure knowledge externalities diminishes with respect to the previous specifications. Indeed, the R-squared statistics decreased.

Table 2. Evidence on pure knowledge spillovers

dep. var.: Δ(TFP) in a downstream sector j				
	RE	sysGMM	RE	sysGMM
lagged Δ(TFP)		0.005		0.002
		(0.055)		(0.056)
pure IE all NACE	0.811***	1.084**		
	(0.278)	(0.401)		
pure EE all NACE	-3.923	-0.986		
	(3.265)	(3.859)		
pure ER&D all NACE	0.001	-0.005		
	(0.001)	(0.004)		
pure IE manufacture			0.620***	0.598***
			(0.123)	(0.135)
pure IE services			0.488**	0.517
			(0.206)	(0.314)
pure EE manufacture			-0.456	-0.621
			(0.727)	(0.756)
pure EE services			3.194	3.552
			(2.202)	(3.835)
pure ER&D manufacture			0.001	0.001

[4] This notwithstanding, the results from the fixed effects estimation were not differing much from those reported here.

			(0.001)	(0.005)
pure ER&D services			-0.003	-0.019
			(0.016)	(0.050)
inward FDI	0.006	0.006	-0.001	-0.014
	(0.006)	(0.001)	(0.007)	(0.014)
own R&D	-0.001***	-0.003**	-0.002***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
N. obs.	2859	2655	2845	2655
R-squared	0.149		0.141	
Sargan (p-value)		0.201		0.276
AB m-2 (p-value)		0.651		0.644

Note: ***, **, * imply significance levels at 1%, 5% and 10%, respectively. Robust standard errors are included in parentheses. In all sys GMM specifications the number of instruments is not exceeding the number of groups. Time dummies are included.

5.3 Are international knowledge externalities localized?

From the basic results it emerges that international, or in my framework rather European, knowledge spillovers do not exercise any significant influence on the domestic sector-level activities. One possible drivers of such a result might be that foreign knowledge spillovers are operating only up to a certain distance. More precisely, in an empirical study over the European regions, Bottazzi and Peri (2003) argue that R&D-based knowledge spillovers are very localized and do not go beyond the maximum distance of 300 km. They admit, nevertheless, that the expected impact from such effects is rather small.

The localization conjecture pushes to ask whether the European average knowledge externalities examined in the previous setting are not appearing with a significant influence due to the fact that they are localized. In particular, it is plausible to expect that due to technological progress in Belgium, countries most profiting from it will be those in the nearest neighbourhood to Belgium.

To prove this hypothesis, I construct, for each country, the "localized" foreign spillovers, by averaging out sector-level TFP and R&D expenditures observed over each country's neighbours.[5] Similarly as in the case of the variables EE and ER&D, defined in equations (6) and (7), I weight the local external effects with sector-level trade openness indicator. Consequently, I replace the previously applied variables EE and ER&D, with their localized substitutes, local EE and local ER&D.[6]

Table 3. Localized foreign knowledge spillovers.

dep. var.: Δ(TFP) in a downstream sector j		
	FE	sysGMM
lagged Δ(TFP)		-0.058
		(0.051)

[5] In Appendix A.2, I list for each country its neighbours considered in the calculation of localized external effects.

[6] I focus here only the effects of local EE and local ER&D for all NACE activities. One possibility could be to distinguish here again between effects for manufacturing and service activities, analogously as in Section 5.1.

IE all NACE	0.773***	0.792***
	(0.057)	(0.074)
local EE all NACE	-0.049	0.305
	(0.129)	(0.350)
local ER&D all NACE	0.001	-0.001
	(0.004)	(0.005)
inward FDI	0.011**	0.005
	(0.005)	(0.011)
own R&D	-0.001***	-0.002**
	(0.001)	(0.001)
N. obs.	2746	2561
R-squared	0.360	
Sargan (p-value)		0.201
AB m-2 (p-value)		0.478

Note: ***, **, * imply significance levels at 1%, 5% and 10%, respectively. Robust standard errors are included in parentheses. In all sys GMM specifications the number of instruments is not exceeding the number of groups. Time dummies are included.

Table 3 summarizes the results of the estimations. Whereas the results regarding the domestic knowledge externalities persist, there is no evidence of localized knowledge spillovers, either for TFP channel or for R&D expenditures channel. This still does not exclude that knowledge externalities are localized at even more disaggregated level. To prove this hypothesis, however, it would be necessary to implement regional and sector-specific data. This issue, nevertheless, goes beyond the scope of the present analysis and is left for the future investigations.

6. Conclusions

The paper investigates the importance of knowledge externalities as drivers of inter-sectoral linkages and a source of productivity growth at the sector level. The results of the estimations using dynamic panel technique confirm that sectoral productivity growth is strongly and positively enhanced when pecuniary knowledge externalities are paramount. Additionally, however, such externalities are generated domestically, with no evidence speaking in favour of international knowledge externalities. This confirms the earlier results, particularly by Branstetter (2001). I also find that the effects of such domestic knowledge externalities are stronger for manufacturing than for service sectors.

The policy implications of such findings are important. The results point out the economic importance of knowledge externalities as a source of productivity increase. Thus, too restrictive rules of intellectual property rights protection might significantly jeopardize the inter-sectoral system of interactions based on newly generated knowledge. Additionally, since the effects carry clearly a national nature, there is the scope for the support to the measures aimed at creating a national system of knowledge management. This most importantly should consist of knowledge platforms through which firms belonging to different industries would directly and indirectly cooperate and exchange their business experience.

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Appendix A.1

Table A.1 The influence of the own R&D expenditures over time

dep. var.: Δ(TFP) in a downstream sector j				
	(1)	(2)	(3)	(4)
IE all NACE	0.792***	0.796***	0.795***	0.771***
	(0.022)	(0.023)	(0.026)	(0.027)
EE all NACE	1.025**	0.992**	1.050**	0.947*
	(0.424)	(0.440)	(0.459)	(0.497)
ER&D all NACE	0.004	0.003	0.001	0.001
	(0.004)	(0.004)	(0.005)	(0.005)
inward FDI	0.011*	0.010	0.007	0.002
	(0.006)	(0.006)	(0.007)	(0.007)
own R&D	-0.004***	-0.005***	-0.006***	-0.006***
	(0.001)	(0.001)	(0.001)	(0.001)
own l.R&D	0.004***	0.005***	0.006***	0.006***
	(0.001)	(0.001)	(0.002)	(0.002)
own l2.R&D		-0.001	-0.003*	-0.003*
		(0.001)	(0.002)	(0.002)
own l3.R&D			0.002	0.001
			(0.001)	(0.001)
own l4.R&D				0.002
				(0.002)
own l5.R&D				
N. obs.	2656	2430	2204	1965
R-squared	0.373	0.376	0.360	0.375

Table A.1 presents the results of the estimations, where I account for a possible lagged effect of R&D expenditures. The results confirm that the current expenditures in R&D exercise a depressive effect on the sectoral productivity growth, but that the past expenditures are enhancing it. This supports the hypothesis that R&D activities need time to produce a positive effect on productivity.

Appendix A.2

country	neighbours
Austria	Czech Republic, Germany, Hungary, Italy, Slovak Republic;
Belgium	Denmark, Germany, Netherlands, France;
Czech Republic	Austria, Germany, Slovak Republic;
Denmark	Belgium, Finland, Germany, Netherlands;
Finland	Denmark, Sweden;
France	Germany, Italy, Spain;
Germany	Austria, Czech Republic, Belgium, Denmark, France, Netherlands;
Hungary	Austria; Slovak Republic;
Italy	Austria, France;
Netherlands	Belgium, Denmark, Germany;
Portugal	Spain;
Slovak Republic	Austria, Czech Republic, Hungary;
Spain	France, Portugal;
Sweden	Denmark, Finland;
United Kingdom	Denmark, Belgium, Finland, France, Germany, Netherlands, Sweden.