Identifying The Knowledge Spillover Hotspot and its Role in Neighbouring Country Innovation

Raymond Darfo-Oduro and Jan Stejskal
Institute of Economic Sciences, Faculty of Economics and Administration, University of Pardubice, Pardubice, Czech Republic

raymond.darfo-oduro@upce.cz
jan.stejskal@upce.cz

Abstract: The question on how to finance innovation activities of countries has taken a center stage in economic policy discussions in countries and among regional bodies. Such discussions require a policy direction to present alternative ways of financing innovation activities at lower cost in the face of dwindling resource available to countries and regional bodies for innovation activities. One important way of dealing with this challenge is to invest the limited resources in countries and sectors with the potential of higher knowledge spillover to benefit other countries and sectors. In this study therefore, we investigate to determine the knowledge spillover hotspot countries in Europe and how they affect neighbouring country's innovation performance. For the purposes of policy to improve innovation performance in Europe, the knowledge spillover hotspot countries will guide European regional bodies to concentrate innovation investments in countries with the potential of high knowledge spillovers for the benefit of other countries. The study specifically investigated R&D spillover and explicit knowledge spillover hotspots in the manufacturing sectors of Europe and their effects. Data for the study is unstructured and sourced from the World bank with the longest spans being 2005 to 2020 and shortest being 2013 to 2017. In all, nine countries were sampled based on data availability for the study. These countries include Poland, Germany, Slovakia, Slovenia, Lithuania, Belgium, France, Spain and Czech Republic. The study employed panel data analysis. Based on the Hausman test, fixed effect model was chosen as against random effect model. The results of the study show that after controlling for institutional and economic factors and ensuring robustness against heteroskedasticity and autocorrelation R&D spillover hotspots in Europe include Germany and Slovakia whereas explicit knowledge spillover hotspots are Poland, Slovenia, Lithuania and France. The results of the study have shown that the relationship between knowledge spillover from the hotspot countries and surrounding country's innovation varies. For some of the hotspots, the relationship is linear whilst in others the relationship is nonlinear. The study also confirm that explicit knowledge is more susceptible to Knowledge spillover.

Keywords: Spillover, Innovation, Knowledge, Hotspot, R&D

1. Introduction

The choices firms and countries make in improving innovation activities and performance will usually come at great cost. This is probably because resources for innovation activities are continually becoming difficult to come by. Generally, countries and firms have relied on several sources to finance innovation activities which have come at great cost (Valencia-Arias et al., 2024; Yılmaz, Bıyıklı, & Demir, 2023). In the innovation literature, knowledge spillover has become an important source through which firms and countries can improve their innovation activities and performance. Knowledge spillover, unlike knowledge transfer, which is a cross party collaboration and compensation, this involves external benefit derived from another agents' investment in knowledge creation (Ko & Liu, 2015). Knowledge spillover has therefore become an important source of input for most firms and countries in their knowledge creation activities. Policy responses to the need to improve innovation and productivity of firms have centered on a hand full of policy tools such as tax credits, subsidies, and R&D expenditures. These tools, even though, have been largely effective, come with their attendant limitation of cost. A large majority of countries and firms have made gains from knowledge spillover. Such spillovers have occurred even where no formal collaborative arrangements have been made between firms and between countries to transfer knowledge (Agarwal, Audretsch, & Sarkar, 2010). These R&D gains come in free without any compensation to the originator of the knowledge and may therefore serve as a cheaper source of input for innovation. It is a long-held view that Knowledge spillover is an important source of innovation performance, however, the literature also recognises the importance of capacity of firms and countries to absorb and utilize these free flowing knowledge to enhance innovation performance (Xie, Zou, & Qi, 2018). Empirical studies, even though, have acknowledged the important role of Knowledge spillover, the benefits of firms and countries relying on such externalities as an important source of R&D input for innovation have not been fully explored. It is rather the case that empirical studies have linked knowledge spillover to firms' productivity mainly (Audretsch & Belitski, 2020) and not innovation.

The European region remains one of the regions with high innovation performance disparities among countries (Dobrotă, Marcu, Siminică, & Nețoiu, 2019). Other studies have explored how innovation lagging countries could

rely on neighbouring countries with high innovation performance as a way of reducing these disparities (Noni, Orsi, & Belussi, 2018). To find alternative, cheaper, and reliable strategies of financing innovation activities of lagging countries, knowledge spillover from knowledge rich countries cannot be overlooked. An important way to address these innovation challenges is to rely on knowledge spillover from knowledge rich countries to less endowed countries. However, identifying the knowledge spillover hotspots as a source of innovation input remains obscured from prior literature. In this study therefore, we aim to identify the knowledge spillover hotspots in Europe to support knowledge innovation activities in the European region.

2. Theoretical Review

This section of the study presents a review of the literature on R&D and explicit knowledge spillover and how these externalities affect innovation performance.

2.1 Knowledge Spillover

Ordinarily firms and countries expend their own resources in the creation of innovation. However, in the creation of innovation some firms and countries are unable to fully appropriate the gains of their innovation activities. The part of the innovation that is not appropriated by the originator feeds into some other agents' knowledge production function as an input in the form of knowledge spillover. Prior literature has explained that inter-firms/country knowledge flow defines knowledge spillover (Bernal, Carree, & Lokshin, 2022). The literature on knowledge spillover splits knowledge spillover into tacit and explicit, depending on the type of knowledge involved (Bernal, Carree, & Lokshin, 2022). The literature on innovation distinguishes between tacit and explicit knowledge and the literature is reviewed along these lines. The literature on knowledge spillover distinguishes between knowledge spillover and a closely related concept, knowledge transfer. Knowledge transfer is the flow of knowledge from an originator of innovation to the intended economic agents (Scarra & Piccaluga, 2022) whereas knowledge spillover is an externality and therefore an unintended flow of knowledge resources from an originator of knowledge to another economic agent without a commensurate compensation (Henderson, 2007). The latter is the focus of this study and is given further attention in this study.

2.2 R&D and Explicit Knowledge Spillover

Knowledge spillover has been well documented in the innovation literature. In the formulation of growth models, knowledge spillover is considered an important determinant (Henderson, 2007; Romer, 1990). Knowledge spillover has been known to be influenced by several factors that either enhance the flow or reduce the flow of knowledge. The distribition of knowledge spillover poles is not even as it is based on the presence of certain essential factors. In the literature, authors have found for example that knowledge spillover has a distance decay (Lucas & Rossi-Hansberg, 2002; Ciccone & Hall, 1996) suggesting that spatial distance between the knowledge source and neighbouring areas determine whether or not the source of the knowledge will be a source of knowledge spillover. In a study by Jasimuddin, Li and Perdikis, (2015), the authors showed that colocation is important to knowledge spillover. It is also known that firms that are colocated bring something more than just proximity. In a study conducted by Cohen and Levinthal (1990), colocation was used rather as proxy for technology relatedness. The authors revealed that knowledge spillover is partly explained by the extent which the firms involved are related. Knowledge spillover is therefore a function of the relationship between the source of innovation and the potential beneficiary of knowledge spillover. Other studies have also focused on the role played by absorptive capacity in knowledge spillover. In a study by Zhao, Jiang, and Wang, (2019), the authors showed that the relationship between knowledge spillover and green economy is positively moderated by absorbtive capacity of the receiver. The authors explained that spillover knowledge is directed at enterprises which can use their absorptive capacity to digest and use the advance technologies. In some instances potential beneficiaries of neighbouring knowledge have not shown interest in adopting available technologies.

The type of knowledge has been observed as an important variable in determining knowledge spillover. In the knowledge spillover literature, two main types of knowledge is discussed, tacit knowledge and explicit knowledge. Tacit knowledge has been considered as task oriented know how embedded in the operational routine of firms and their network (Nahapiet & Ghoshal). Authors such as Lam (2000) and Acs, et al (2009) showed that these characteristics of tacit knowledge makes it more difficult for knowledge spillover relative to explicit knowledge. This is in contrast with explicit knowledge which is codified and detached from the originator of the knowledge and therefore makes spillover relatively easier through oral explanations and written works

(Fu, 2012). Studies on knowledge spillover emphasises the ease with which knowledge can be appropirated is a hindrance to knowledge spillover. Considering the nature of these types of knowledge, tacit knowledge which is attached to the originator of knowledge and the detached explicit knowledge transitted by word of mouth and written works, it is argued that explicit knowledge is more suceptible to knowledge spillover relative to tacit knowledge (Xiang, Cai, Lam, & Pei, 2013). The literature on knowledge spillover has an indepth account on the measurement and flow of explicit knowledge. Even though explicit knowledge is recognised as knowledge that is easy to diffuse relative to tacit knowledge, its measurement has proven to be daunting. Principally, explicit knowledge has been measured by patent citation (Gomes-Casseres, Hagedoorn, & Jaffe, 2006; MacGarvie, 2005; Hu & Jaffe, 2003; Jaffe, Trajtenberg, & Henderson, 1993). Because explicit knowledge is transmited using orderly and formal language (Polanyi, 1966), it lends itself well to spillovers (Fallah & Ibrahim, 2004). Based on the position of the prior literature, the following hypothesis is postulated for testing:

H: There is a significant explict knowledge spillover among European countries

In a study conducted to assess managerial knowledge spillover through the diffusion of managerial practices, Fu (2012) showed that managerial knowledge is both explicit and tacit in nature. Fu (2012) showed that such knowledge geographically bound and the effect of the spillover is greater at the clusters and managerial system level. In this study, apart from explicit knowledge, we also review literature on R&D spillover. R&D of firms are investments into both tacit and explicit knowledge creation activities. We therefore expect R&D spillover to retain the traits of both tacit and explicit knowledge spillover. A study by Spithoven and Merlevede (2023) assessed the productivity impact of R&D and FDI spillovers. The findings showed that R&D spillover is a significant contributer of productivity. In other studies, findings have shown that cross border R&D spillover have contributed to innovation performance in neighbouring countries. For example in a study conducted by Coe and Helpman (1995), the authors showed that foreign R&D has been important in improving the domestic productivity. In a related study, the Coe, Helpman and Hoffmaister (2009) confirmed the findings of Coe and Helpman (1995) even after controlling for institutional factors and human capital. R&D spillover has also been observed to be a function of volume of trade flows. In a study by (Keller, 2004) it was revealed that international R&D spillover is a function of international trade volume. The colocation of countries and trade among countries is therefore a condition nevessary for international R&D spillover. Based on the prior literature thefore, we postulate the following hypothesis for testing:

H: There is a significant R&D spillover among European countries

3. Methodology

In this study was sought to determine the knowledge spillover hotspot countries in Europe. The sampled countries for the study are based on data availability. Nine European countries including Poland, Slovakia, Slovenia, Lithunia, France, Spain, Germany, Belgium and France form the study sample based on data availability. Data for the study is sourced from the World Bank spanning 2005 to 2020. The data sourced includes data on variables such as value addition in the manufacturing sectors as a measure of innovation output. The study also sourced data on R&D in the manufacturing sectors of the respective countries. The study also sourced data on economic and institutional factors. The economic variables include variables such as trade openness, GDP per capita and labour force participation rate. Data on institutional factors include rule of law, political stability, broadband internet subscription, globalization index and property right index. Dependent variable is value addition in the manufacturing sector of the sampled countries. This variable is a measure of innovation. This agrees with prior literature which have generally used value addition or variant of value addition such as productivity and other innovation outcomes (Audretsch & Belitski, 2020). Value addition is also considered as an independent variable and as a measure of explicit variable. This should not be confusing as the dependent variable (value addition) of one country is regressed on explicit knowledge (value addition) of other countries. *see equation 1.* R&D of countries is measured R&D intensity of countries which is a proportion of R&D to the country's GDP.

To ensure that our estimate of spillover is unbiased control variables are introduced. These control variables are the economic and institutional factors.

The estimation technique for the study is multiple regression analysis. This is consistent with studies on knowledge spillover (Audretsch & Belitski, 2020; Nonic, Orsi, & Belussi, 2018; Coe, Helpman, & Hoffmaister, 2009). The study models the equation to determine the countries that are spillover hotspots.

$$lvman_{it} = \beta_1 lMR\&D_{jt} + \beta_2 lMR\&D_{it} + \beta_3 Con_{it} + \alpha_0 + U_{it} \quad (1)$$

Equation 1 presents a model for R&D knowledge spillover between countries. The dependent variable is the logarithmic transformation of value addition in the manufacturing sector of countries. Country is represented by the subscrit *i* whilst *t* is the time dimension of the variables. β are the regression coefficients, $lMR\&D$ is the logarithmic transformation of R&D expenditure of the manufacturing sector of spillover country where the subscript is *jt* and beneficiary country if the subscript is *it*. Con represents vector of control variables which are economic and institutional factors. α_0 is the individual effect which at this point may or may not be correlated with the explanatory variables depending on the outcome Hausman test. *U* is the random error term.

$$lvman_{it} = \beta_1 lvman_{jt} + \beta_2 lMR\&D_{it} + \beta_3 Con_{it} + \alpha_0 + U_{it} \quad (2)$$

In equation 2 the study seek to model explicit knowledge spillover between countries in Europe. The explanation of the model remains the same as equation 1 with the exception that the first right hand side variable is the explicit knowledge of spillover countries. The variables of interest in estimating knowledge spillover in equation 1 and 2 are $lMR\&D_{jt}$ and $lvman_{jt}$respectively. These are the spatial lag variables that measure the effect of one country's innovation activities on other countries innovation output. Knowledge spillover must necessarily have a positive effect on innovation of the beneficiary country or sector (Noni, Orsi, & Belussi, 2018). The criteria for determination of knowledge spillover in equation 1 and 2 is that β_1 must be positive and significant. If the Hausman test suggests a correlation between the explanatory variables and the individual effect (X, α) = 0 then a fixed effect model where the individual effect becomes a parameter to be estimated used. On the other hand where the Hausman test shows no correlation between explanatory variables and the individual effect (X, α) $\neq 0$ a random effect model is used where the random error term then becomes Ϣ = $\alpha_0 + U_{it}$.

3.1 Robustness Checks

In the study, we have implemented several strategies to improve the robustness of the study results. The use of panel data and analysis techniques improves the robustness of the result. With panel data we combine both cross sectional and time series. This is more informative as it allows the study to follow behaviour of the variables over time. The panel data analysis technique also allowed us to account for the individual effect of the data structure which is critical to ensure efficiency of the model. In this study also we use robust standard error to ensure that the model is robust against heteroskedasticity and autocorrelation.

Table 1: Variables and Description

Variables	Description
lpmrd	Log of R&D from manufacturing sector of Poland
lgmrd	Log of R&D from manufacturing sector of Germany
lsmrd	Log of R&D from manufacturing sector of Slovakia
lslmrd	Log of R&D from manufacturing sector of Slovenia
llmrd	Log of R&D from manufacturing sector of Lithuania
lbmrd	Log of R&D from manufacturing sector of Belgium
lfmrd	Log of R&D from manufacturing sector of France
lspmrd	Log of R&D from manufacturing sector of Spain
lcmrd	Log of R&D from manufacturing sector of Czech Republic
lrdman	Log of R&D of spillover beneficiary country
ltop	Log of trade openness
lrl	Log of rule of law
lps	Log of political stability
lbbs	Log of broadband internet subscription
lglx	Log of globalization index
lgdpc	Log of GDP per capita
llfpr	Log of labour rate participation rate
lprind	Log of property right index
lvman	Log of value addition in the manufacturing sector in spillover beneficiary country
lgvman	Log of value addition in the manufacturing sector in Germany
lslvman	Log of value addition in the manufacturing sector in Slovakia
lslevman	Log of value addition in the manufacturing sector in Slovenia
llvman	Log of value addition in the manufacturing sector in Lithuania
lbvman	Log of value addition in the manufacturing sector in Belgium
lfvman	Log of value addition in the manufacturing sector in France
lspman	Log of value addition in the manufacturing sector in Spain
lcvman	Log of value addition in the manufacturing sector in Czech Republic

4. Results and Discussions

In this study, we investigate knowledge spillover among selected countries in Europe. The results present analysis on knowledge spillover from countries with focus on tacit, explicit and R&D. In this section of the study, we present results on R&D spillover among selected European countries.

Table 2: R&D spillover in Manufacturing Sector

Depvar: lvman	**Model 1: Fixed effect (within effect)**		**Model 2: Random Effect (GLS regression)**	
Variables	Coefficients	Std.err	Coefficients	Std. err
lpmrd	0.0334443**	0.0169857	-0.0100191	0.0148073
lgmrd	0.0259228**	0.0104247	0.010595	0.0098405
lsmrd	0.2830048***	0.0771217	0.1754464***	0.0450647
lsmrd^2	-0.0218772***	0.0065201	-0.0108072***	0.0042104
lslmrd	-0.0187662***	0.0071672	-0.0271573***	0.0069395
llmrd	-0.0926193**	0.048655	-0.0585549	0.0439248
lbmrd	-0.0449289**	0.0202088	-0.0545785**	0.0235351
lfmrd	-0.0033951	0.0094567	-0.0188528*	0.0100296
lspmrd	-0.0426425	0.0330766	-0.0585246*	0.0348552
lcmrd	-0.095864	0.1082084	0.0587651	0.0802267
lrdman	0.2192806*	0.1504288	0.2142387***	0.0279487
lrdman2	-0.0197886**	0.0110369	-0.0046694***	0.0016339
ltop	0.5180425***	0.1153108	0.4356211***	0.0684282
lrl	-0.0386761	0.3218812	-0.6337466***	0.1391126
lps	-0.0065939	0.011624	0.0375302***	0.0134325
lbbs	-0.0426492	0.0378756	0.0409689***	0.0185897
lglx	0.2000631*	0.826558	-1.818953***	0.6223957
lgdpc	0.1324167**	0.1594226	0.0418238***	0.0110173
llfpr	0.5655756	0.7537834	2.345537***	0.4059803
lprind	-0.1657463	0.1182489	-0.4636994***	0.1207446
cons	-5.285852*	4.190211	0.6139151	3.667772
Fixed effect	yes	yes	no	no
Random effect	no	no	yes	yes
R-squared:			**R-squared:**	
Within:	0.7613		Within:	0.5062
Between:	0.4911		Between:	0.9971
Overall:	0.5774		Overall:	0.9752
F-statistics	Prob		Wald Chi square	Prob
6.38	0.000000		1890.35	0.000000

****P<0.01, **P<0.05, *P< 0.1. All variables in the logarithm transformation*

In Table 2 we present results on R&D spillover among manufacturing sectors of nine selected European countries. The results present two variants of analysis, fixed effect and random effect. Both models confirm our hypothesis that there is R&D spillover in the manufacturing sector of countries. In the fixed effect model Germany and Poland have R&D spillover but R&D spillover from Slovakia exhibits a quadratic effect with an inverted U-shaped relationship. In Slovakia increasing R&D intensity increases R&D spillover but beyond a minimum level of R&D intensity the effect of R&D knowledge spillover is negative. There is no R&D spillover from Slovenia, Lithuania, Belgium, France Spain and Czech Republic. On the contrary the random effect analysis proves that the only country that is a source of R&D spillover is Germany. All other countries are not R&D spillover hotspots.

Table 3 Hausman Test

Hausman test	Chi square	Prob Chi square
H_0: REE	84.73	0.000000***

Hausman test in Table 3 is employed in selecting between the fixed effect and the random effect model under the null hypothesis that random effect is the efficient model. The Chi square test results shows a significant chi square statistic. The null is therefore rejected for the alternative hypothesis that the fixed effect model is the ideal estimation technique. The fixed effect model from Table 3 has a total variability of 57.7% which decomposes into a within effect variability of 76.13% and between effect variability of 49.1%.

Table 4: R&D Spillover in Manufacturing Sector

Depvar: lvman	Model 1: Fixed effect (within effect)	
Variables	Coefficients	Robust Std.err
lpmrd	0.0334443	0.0187714
lgmrd	0.0259228*	0.0081312
lsmrd	0.2830048***	0.0503231
lsmrd^2	-0.0218772***	0.0054774
lslmrd	-0.0187662**	0.0064493
llmrd	-0.0926193*	0.0547024
lbmrd	-0.0449289***	0.0104878
lfmrd	-0.0033951	0.0074511
lspmrd	-0.0426425*	0.0255217
lcmrd	-0.095864	0.0725371
lrdman	0.2192806	0.1763865
lrdman2	-0.0197886	0.0139775
ltop	0.5180425***	0.1286616
lrl	-0.0386761	0.2579393
lps	-0.0065939	0.0076186
lbbs	-0.0426492	0.0525321
lglx	0.2000631	0.2872693
lgdpc	0.1324167	0.1051878
llfpr	0.5655756	0.7965869
lprind	-0.1657463	0.1185255
cons	-5.285852	3.35003
Fixed effect	yes	yes
R-squared		
Within:	0.7613	
Between:	0.4911	
Overall:	0.5774	
Prob(F-stat)	0.00000	

****P<0.01, **P<0.05, *P< 0.1. All variables in the logarithm transformation*

Table 4 presents robust fixed effect analysis with robust standard errors. These standard errors are robust against heteroskedasticity and autocorrelation. The results confirm the hypothesis that R&D spillovers occur between manufacturing firms in the sampled European countries. Specifically, R&D spillover Germany and Slovakia but none other from the study sample is a knowledge spillover hotspot.

In Table 5 we present the results on explicit knowledge spillover among nine sampled European countries. Model 1 in Table 5 presents the fixed effect model (within effect). The results of the study confirm the hypothesis that explicit knowledge spillover occurs among countries. Our findings show that explicit knowledge spillover from

Poland and Slovenia and France are a quadratic U-shaped relationship. The positive and significant explicit knowledge spillover from Spain is an indication that Spain is a knowledge spillover hotspot. Countries such as Germany Slovakia, Belgium and Czech Republic show no evidence of being explicit knowledge hotspot. As a variant of the fixed effect model, the random effect GLS model in Table 5 shows a similar result that confirms the hypothesis that intercountry explicit knowledge spillover in the manufacturing sector of the sample countries.

Table 5: Explicit knowledge spillover

Depvar: lvman	**Model 1: Fixed effect (within effect)**		**Model 2: Random Effect (GLS regression)**	
Variables	Coefficients	Std.err	Coefficients	Std. err
lpvman	50.86762***	9.568013	49.82592***	11.06921
lpvman2	-8.983034***	1.69918	-8.804508***	1.965431
lgvman	-1.106573***	0.2535892	-1.00138***	0.1920762
lslvman	-0.0580992	0.0637219	-0.0167657	0.0703469
lslevman	24.00535***	9.221881	20.1129**	10.08939
lslevman2	-4.111062***	1.581243	-3.421326**	1.726595
llvman	17.47348***	0.0976156	17.32109***	0.0937914
lbvman	-37.09157***	7.715917	-27.95311***	8.155758
lbvman2	7.166371***	1.480547	5.393298***	1.569189
lfvman	71.62699***	14.33979	68.88908***	13.36702
lfvman2	-14.96662***	3.010636	-14.4334***	2.811215
lspman	0.4321655**	0.1840867	0.2369016	0.1813967
lcvman	-0.2226295**	0.1118284	-0.0687529	0.1077598
lrdman	-0.0067927	0.0092327	0.0052414	0.0039179
ltop	0.000317	0.0883127	0.0335652**	0.0166246
lrl	-0.0345224	0.0255064	-0.0428913**	0.0197098
lps	-0.0032511	0.005434	-0.0057351	0.0061859
lbbs	-0.0096819	0.0217878	0.0013549	0.0043363
lglx	0.2818573	0.4831154	-0.2233576	0.1809568
lgdpc	0.3339777***	0.0658472	0.0014159	0.0024093
llfpr	-1.095911***	0.3817812	-0.2515461**	0.1071945
Lprind	-0.0764222	0.0620404	0.0647073	0.0567142
Cons	-174.8567***	21.78542	-173.8514***	22.2945
Fixed effect	yes	yes	no	no
Random effect	no	no	yes	yes
R-squared:			**R-squared:**	
Within:	0.9999		Within:	0.9998
Between:	0.3507		Between:	0.9999
Overall:	0.7781		Overall:	0.9998
F-statistics	Prob		Wald Chi square	Prob
14107.49	0.000000		208572.90	0.000000

****P<0.01, **P<0.05, *P< 0.1. All variables in the logarithm transformation*

The results show that Poland, Slovenia, and France show an inverted U-shaped relationship indicating that these are spillover hotspots but after a maximum level explicit knowledge is reached, explicit knowledge falls leading to a fall in value addition. Lithuania and Spain also showed evidence of being spillover hotspot. Germany, Slovakia, Belgium, and Czech Republic showed no signs of being a knowledge spillover hotspot.

Table 6: Hausman Test

Hausman Test	**Chi Square**	**Prob Chi Square**
H_0: REE	34.89	0.0397**

****P<0.01, **P<0.05, *P< 0.1. All variables in the logarithm transformation*

The choice between the fixed effect model and the random effect model is determined by the Hausman test. The test is conducted under the hypothesis that the random effect estimate is more efficient. The Chi Square test shows that the test is significant. This rejects the random effect estimates in favour of the fixed effect model as shown in Table 6.

From Table 7 below value added in the manufacturing sectors of Poland, France and Slovenia are significant and are polynomial in degree 2. This indicates that these are knowledge spillover hotspots. However, the quadratic relationship observed indicates that the size of the explicit knowledge matters. An excessively high explicit knowledge spillover reduces knowledge spillover to neighbouring countries. At lower levels of explicit knowledge, the effect of knowledge spillover from Poland, Slovenia and France are high. The study results also show a positive and significant coefficient for explicit knowledge coefficient for Lithuania. This is an indication that Lithuania is a knowledge spillover hotspot.

The results from Table 7 also shows however, that coefficients of explicit knowledge spillover for countries such as Slovakia, Czech Republic, Spain Germany and Belgium are either not significant, negative or U shaped. These indicate the absence of evidence to suggest these countries are knowledge spillover hotspots.

Table 7: Explicit Knowledge Spillover

Depvar: lvman	**Model 1: Fixed effect (within effect)**	
Variables	Coefficients	Robust Std.err
lpvman	50.86762***	6.067932
lpvman2	-8.983034***	1.080955
lgvman	-1.106573***	0.2097516
lslvman	-0.0580992	0.0650751
lslevman	24.00535*	10.6692
lslevman2	-4.111062*	1.837527
llvman	17.47348***	0.0852749
lbvman	-37.09157***	9.289062
lbvman2	7.166371***	1.799445
lfvman	71.62699***	19.29418
lfvman2	-14.96662***	4.02786
lspman	0.4321655	0.2744186
lcvman	-0.2226295	0.1583966
lrdman	-0.0067927	0.0049045
ltop	0.000317	0.0957677
lrl	-0.0345224	0.0250901
lps	-0.0032511	0.0022954
lbbs	-0.0096819	0.0245747
lglx	0.2818573	0.4935258
lgdpc	0.3339777***	0.0584505
llfpr	-1.095911**	0.4584305
Lprind	-0.0764222	0.0585246
Cons	-174.8567***	15.72513
R-squared:		
Within:	0.9999	
Between:	0.3507	
Overall:	0.7781	
Prob(F-stat)	0.000000	

****P<0.01, **P<0.05, *P< 0.1 variables in the logarithm transformation.*

5. Discussions

The findings of the study confirm the position of the literature that R&D spillover has been a major contributor to productivity. Whereas in the study by Spithoven and Merlevede (2023) the authors showed that knowledge spillover contributes to improving productivity of firms, the findings of the current study shows likewise that

there is international R&D spillover to some domestic economies. It is worth mentioning that even though there is evidence that most of the countries are R&D spillover pole in agreement with the position of the literature, there are some exception to this expectation. Countries that are not Knowledge spillover pole could be explained by the reason that the conditions for such knowledge spillover are not present. Henderson (2007) and Romer (1990) highlighted the important precursors for knowledge spillover such as proxity, relatedness of technology among others. Countries that could not be identified as R&D spillover poles most likely lack the determining factors. Considering the closeness of these countries one would expect that, the argument that proximity is a determinant of knowledge spillover (Jasimuddin, Li and Perdikis, 2015) will apply. However, the important point to note here is that colocation as explained by Cohen and Levinthal (1990) is not just an issue of proximity but also relatedness of technology. The study also shows that generally international R&D spillover is more improtant than any other factor in explaining value addition in the manufacturing sectors of the selected European countries. This could suggest the possibility that knowledge among these countries are related or the proximity among the countries has made these countries more reliant on themselves for innovation inputs. It may be expected that the closer countries are the higher international R&D spillover will be. However, the findings of the study showing only two R&D spillover hotspot, Germany and Slovakia may be enough to disprove that. What may be accounting for this can include limited trade relationship among the countries. As Keller (2004) has shown the volume of trade among the countries is important for knowledge spillover. Absorptive capacity of countries could also be a determinant of R&D spillover hotspot. It is noteworthy to state that the results of the study shows that Slovakia R&D intensity exhibit a quadratic (inverted U shaped) relationship with value addition in neighbouring countries. This could point to the role of absorptive capacity of neighbouring countries to the spillover. At lower levels of R&D intensity in Slovakia, neighbouring countries are ready to take on knowledge from Slovakia after a maximum level any extra R&D spillover is not absorbed by the neighbouring countries.

The study's confirmation that there is significant explicit knowledge spillover among European countries is in line with what the literature suggests (Spithoven & Merlevede, 2023). Explicit knowledge, according to Fallah and Ibrahim (2004) are easily transmitted because of its codifies nature. It is important to state however, that findings of the study also confirms that in the absence of the essential factors knowledledge spillover does not occur. It is also striking in the study findings is that countries that are R&D spillover spillover poles such as Poland and Slovakia showed no evidence of being an explicit knowledge spillover poles. This is an indication that the various types of knowledge may behave differently. Countries in contiguity as has been revealed have shown no sign explicit knowledge spillover. This casts doubts on the colocation assumption (Jasimuddin, Li & Perdikis, 2015) for knowledge spillover. What is also important with study findings worth mentioning is that in most of the explicit knowledge spillover hot spots an extremely volume of explicit knowledge reduces knowledge spillover. We interpret that to mean the lack to absorptive capacity on the part of beneficiary countries. This may explain why some large economies with a very vibrant R&D and explicit knowledge sector may not be knowledge spillover hot spot. This is in agreement with Zhao, Jiang, and Wang (2019) who showed a positive moderating effect of absorptive capacity in the relationship between knowledge spillover and green economy. The findings of this study will therefore mean that countries could be doing well with the R&D and explicit knowledge but the extent to which there will be knowledge spillover depends on factors including the absorptive capacity of the receiver. Major economies with large R&D and explicit knowledge which have not proven to be knowledge spillover hot spot could be explained by the fact that perhaps their neighbouring countries do not have the required absorptive capacity to take up the floating knowledge.

6. Conclusions

In this study we have investigated the knowledge spillover hotspots in Europe. Specifically, the study focused on R&D and explicit knowledge spillover hotspots in Europe. The main results reported by large portion of the prior literature are confirmed by the findings of the current study. The study findings are robust, taking into consideration heterogeneity of the different countries, heteroskedasticity and autocorrelation, we conclude that knowledge spillover hotspots in Europe differ based on the type of knowledge considered. After controlling for economic and institutional factors, the fixed effect model showed that R&D spillover hotspot countries in Europe include Poland, Slovenia, Lithuania, France, and Spain. Germany, Slovakia, Czech Republic, and Belgium fell short of being classified as knowledge spillover hotspot. To further ensure robustness to deal with the possibility of autocorrelation and heteroskedasticity, the results showed that Germany and Slovakia are the only countries that show evidence of R&D spillover hotspot. In the case of explicit spillover, the study concludes that Poland, Slovenia, Lithuania, France and Spain show evidence of being knowledge spillover hotspots. This allows

us to make the conclusion in agreement with the position of the prior literature that explicit knowledge by their nature are more susceptible to spillovers.

It is also concluded that knowledge spillover hotspot countries in Europe have contributed to innovation performance of their neighbour.The study also concludes that knowledge spillover is generally not linear for most knowledge spillover hotspots. Knowledge spillover from Slovakia, Slovenia, and France have an inverted U-shaped relationship whereas it is linear for countries such as Germany and Lithuania. In the case of Germany and Lithuania the size of R&D and Explicit knowledge has proportionally the same effect on knowledge spillover. However, the study, based on its findings conclude that in the case of knowledge spillover hotspot countries such as Slovakia, Slovenia and France knowledge spillovers are influenced by the volume of knowledge. We further conclude that above a certain minimum level of knowledge, knowledge spillover begins to reduce which can be interpreted as absorptive capacity constraints in the receiving countries. The implication of the study to European countries is that knowledge sharing among these countries has the potential of reducing the cost of R&D and innovation activities.

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Reference

Agarwal, R., Audretsch, D., & Sarkar, M. (2010). Knowledge spillovers and strategic entrepreneurship. *Strategic Entrepreneurship Journal, 4*(4), 271–283.

Audretsch, D., & Belitski, M. (2020). The role of R&D and knowledge spillovers in innovation and productivity. *European Economic Review, 123*(103391), 1-24.

Bernal, P., Carree, M., & Lokshin, B. (2022). Knowledge spillovers, R&D partnerships and innovation performance. *Technovation, 115*(102456).

Dobrotă, C. E., Marcu, N., Siminică, M., & Neţoiu, L. M. (2019). Disparities, gaps and evolution trends of innovation, as a vector. 22(4), 174. *Romanian Journal of Economic Forecasting, 22*(4), 174-184.

Fallah, M. H., & Ibrahim, S. (2004). Knowledge spillover and innovation in technological clusters. *IAMOT 2004 Conference*, (pp. 1-16). Washington, DC.

Fu, X. (2012). Foreign Direct Investment and ManagerialKnowledge Spillovers through the Diffusionof Management Practices. *Journal of Management Studies, 49*(5), 971-999.

Gomes-Casseres, B., Hagedoorn, J., & Jaffe, A. (2006). Do alliances promote knowledge flows. *Journal of Financial Economics, 80*(1), 5-33.

Henderson, J. (2007). Understanding knowledge spillovers. *Regional Science and Urban Economics, 37*, 497 508.

Hu, A., & Jaffe, A. (2003). Patent citation and international knowledge flows: the case of Korea and Taiwan. *International Journal of Industrial Organization, 21*, 849–880.

Jaffe, A., Trajtenberg, M., & Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics, 108*, 578–598.

Keller, W. (2004). International technology diffusion. *Journal of Economic Literature, 42*(3), 752–782.

Ko, W., & Liu, G. (2015). Understanding the Process of Knowledge Spillover: Learning to become Social Enterprise. *Strategic Entrepreneurship Journal, 9*, 263–285.

MacGarvie, M. (2005). The determinants of international knowledge diffusion as measured by patent citations. *Economic Letters, 87*(1), 121–126.

Nahapiet, J., & Ghoshal, S. (n.d.). Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review , 23*(2), 242–266.

Noni, I., Orsi, L., & Belussi, F. (2018). The role of collaborative networks in supporting the innovation performances of lagging-behind European regions. *Research Policy, 47*, 1-13.

Polanyi, M. (1966). *The tacit dimension.* Garden City, NY: Doubleday & Co.

Scarra, D., & Piccaluga, A. (2022). The impact of technology transfer and knowledge spillover from Big Science: a literature review. *Technovation, 116*.

Valencia-Arias, A., Patiño-Toro, O. N., Coronado, M. H., Bernal, O. V., & Marquina, E. Z. (2024). Knowledge Management in Small and Medium Enterprises: Literature Review and Research Agenda. *Scientific Papers of the University of Pardubice, Series D: Faculty of Economics and Administration, 32*(1), 1-16.

Xiang, X., Cai, H., Lam, S., & Pei, Y. (2013). International knowledge spillover through co-inventors: An empirical study using Chinese assignees' patent data. *Technological Forecasting & Social Change, 80*(1), 161-174.

Xie, X., Zou, H., & Qi, G. (2018). Knowledge absorptive capacity and innovation performance in high-tech companies: A multi-mediating analysis. *Journal of Business Research, 88*, 289–297.

Yılmaz, E., Bıyıklı, S., & Demir, C. (2023). Impacts of Technology on Economic Growth: With Difference Between Tourism Countries and Industry Countries Aspect Based on Extended Solow Growth Model. *Scientific Papers of the University of Pardubice Series D: Faculty of Economics and Administration, 31*(1), 1-14.