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EXPLORING THE DRIVERS OF PATENTING ACTIVITY IN POLISH REGIONS

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Purpose: The main aim of this article is to explore the drivers of patenting activity of Polish regions. We hypothesise that R&D expenditures, as well as internationalization measures or regional economy indicators have statistically significant impact on patenting at the regional level.
Design/methodology/approach: In the following article, an ordinary least squares (OLS) regression is utilized. Specifically, patents granted by Polish Patenting Office are regressed on various standard, as well as non-orthodox measures of innovative activity To account for unobserved, time-invariant region characteristics, a fixed effects (FE) model was chosen, supported by highly significant outcome of the Hausman test.
Findings: The results indicated that the determinants of innovative activity utilized in country-level studies are effective in explaining patenting activity on the regional level. Statistically significant relationship between dependent variable and various independent variables was demonstrated. First of all, region's economy's size, measured by GDP per capita and number of firms show positive impact on the number of patents granted, similarly to utilized internationalization measures (firms with foreign capital, foreign students). On the contrary, the number of university graduates is negatively related to the number of patents granted, which remains slightly less intuitive. At the same time, the impact of R&D and expenditures on patenting appears to be more complex and non-linear.
Research limitations/implications: The following article contains several limitations. The patenting activities should be preferably conducted on the firm or industry level data. Second, a comparison between determinants of patenting activity in developed and non-developed economies would benefit the field, however, given the choice of independent variables, was subject to data availability. Finally, given ambiguous results of the impact of R&D expenditures on patenting in both, absolute and relative terms, different types of R&D expenditures should be compared, once available.
Originality/value: To authors knowledge is the first study that employs panel data framework in the field of patenting at the regional level in Poland – modestly innovative and non-high-income country.
Keywords: innovations, patents, regions, panel data.
Category of the paper: Research paper.

1. Introduction

Inventive and innovative activities of entities leading towards enhancing stocks of knowledge are the discussed in the literature devoted to economic growth and technology change, usually at the country/economy level. However, over the last few decades, increasingly important role has been paid to regions. The starting point of analysis often refers to the theory of industrial districts by Marshall (1920), who identified the factors of industry concentration in a specific place, focusing on access to a specialized workforce, development of the production of intermediate goods, and the processes of spilling knowledge between enterprises within a region. The first two factors are easily measurable, while the latter is relatively difficult to capture due to intangible nature of flows of knowledge (Krugman, 1991). The majority of empirical studies undertake this challenge following the seminal papers by Griliches (1979) who put emphasis on the concept of knowledge production function (KPF). The KPF considers patenting activity as an effect of generating knowledge, resulting from investments by companies and institutions in the U.S. The authors stated that commercial patents are a function of investment in R&D-related activities by given sectors, universities, and federal agencies, while the knowledge diffuses between them, constrained by time and space.

The vast majority of the studies on spatial aspects of patenting activity is fully devoted to developed economies over short periods (Paci, 1999). It is not surprising that the propensity to patent is higher in knowledge-based economies with long-term innovation policies, which enhance the spillovers. At the same time, little attention has been paid to the spillovers in non-developed countries, where both – innovative patterns and their determinants may significantly differ from economies at the world technological frontier (Acemoglu et al., 2006). This knowledge gap is addressed in the present paper which analyses the factors determining patenting activity measured by patents granted in Poland – a modest innovating country, by Polish Patenting Office. The study covers patenting activities at the regional level, and according to authors knowledge is the first to employ panel data framework in the case of Poland.

The structure of the paper is as follows. The first chapter presents a literature review on regional determinants of R&D and patenting activity from theoretical and empirical perspective. Second chapter describes data, methodology and leads to hypotheses development. Third section shows the results and the fourth chapter is devoted to discussion on the results and conclusions.

2. Literature Review

In line with the new growth theory (Romer, 1986; Lucas, 1988) the spillovers between firms contribute to generating increasing returns and economic growth. These effects are the consequence of various phenomena such as networking, mobility of employees, exchange of knowledge, or industrial intelligence and espionage (Mauserth, Verspagen, 2002). At the same time, it is generally agreed that knowledge transfer or technology diffusion is limited by the distance between economic agents, or, more generally, geographical barriers (Marshall, 1920; Krugman, 1991). This, in turn, leads to the spatial concentration of economic activity, especially firms from the same industries, and, to some extent, explains the regional core-periphery setting, widely investigated by the new economic geography (Moreno et al., 2005). There is also a consensus in the literature that this behavior additionally rewards innovators, who tend to cluster, enhancing each other's innovative efforts, which has been confirmed by numerous empirical studies (for example Audreths, Feldman, 1996 or Jaffe et al., 1993).

Complementary to geographical proximity, Jaffe (1986) suggests that the spillovers occur additionally in so-called technological proximity. In other words, the nature of R&D activity may significantly affect the strength of knowledge spillovers, as it tends to be industry-specific. In line with several empirical studies (Jaffe et al., 1993; Jaffe, Trajtenberg, 1998) the spillovers are a function of both, technological and spatial proximity. At the same time, both types of proximity tend to reinforce each other – sectors, where knowledge externalities are more important, tend to cluster to a larger extent (Audreths, Feldman, 1996).

The negative impact of geographical distance on innovations and technology flow can be leveled by different channels of diffusion, such as trade or foreign direct investments, both extensively discussed in the recent economic literature (Kwiatkowski, 2021). For example, Coe and Helpman (1995) indicate that R&D spillovers and international trade are strictly related. Similarly, Bayoumi et al. (1999) consider trade as the main channel of knowledge transfer and argue that trade with economies with a large stock of knowledge promotes productivity and contributes to economic growth. This aspect of a trade is also analyzed in Grossman and Helpman's (1991) growth model which assumes that the stock of a country's knowledge depends on domestic R&D and foreign knowledge absorption. In the model, trade allows for accessing foreign knowledge and innovations, while the extent of foreign knowledge absorption is a function of trade intensity.

From the empirical perspective, the conceptual relation between R&D activity and patented innovation output was established in the seminal paper by Grillihes (1979) within the Knowledge Production Function (KPF). In the initial setting, the linkage between innovation inputs and outputs was describing the process of technological progress at the country or industry level rather than the firm level (Moreno et al., 2005). The spatial context of the KFP was established by Jaffe (1989) who investigated the existence of spillovers between

universities and firms in the US using patent and R&D expenditures data. The results show statistically significant impact of university research, especially in high-tech industries, such as pharmaceuticals/medicine, electronics, optics, or nuclear technology. Moreover, Jaffe (1989) shows that it induces industrial R&D spendings locally. These effects seem to occur only one-way as business R&D expenditures do not impact university research according to the results. In a similar manner, Anselin et al. (1997) investigate spillovers between universities and high-tech innovations at the state and metropolitan statistical areas in the US and suggest that university research positively impacts the local innovative activity of companies directly and indirectly through private R&D expenditures.

At the micro level, the intensity of spillovers may depend on the size of an entity. For example Acs et al. (1994) show that the spillover effects differ between small and large companies. Namely, small companies exploit spillovers from universities to a larger extent than large companies, while large companies' R&D expenditures play a key role in the innovativeness of the latter. The study shows that the total number of innovations at the firm level is positively related to the R&D expenditures of both universities and large corporations. Other studies show that large firm productivity growth can be intensified by geographic and technological proximity between firms (Aldieri, 2009).

In recent years the classical KPF was often modified or extended. For example, Ó hUallacháin and Leslie (2007) verified the regionalization of the production function for the U.S., proving that human capital, flows of specialized knowledge, the degree of urbanization, and the presence of high technology sectors significantly increase the number of patents in the region. Co (2002) takes into account income per capita as a proxy of the quality of human capital in the region. In the European context, Bilbao-Osorio and Rodriguez-Pose (2004) recognize the socio-economic characteristics of European regions as a filter for the relationship between R&D and generating patents. However, when analyzing the regional production function, one should remember the possibility of numerous interactions existing between the characteristics of a given region (Charlot et al., 2015).

From the European perspective, Maurseth, Verspagen (2002) investigate patterns of patent citations across Europe based on patenting data at the regional level. The study shows that knowledge flows between regions in Europe are subject to significant barriers. The spillover is likely to occur primarily between regions in the same country, especially in geographic proximity and within the same or connected industries. Similarly, Bottazzi (2003) that R&D spillovers can be observed within 300 km only. Additionally, Moreno et al. (2005) investigated spillovers at the regional level in developed countries in Europe at the industry level and argue that spillover effect was observed – the innovative activity of a given region was affected by other regions' innovativeness, however the effect was constrained by the borders of a country.

Fritsch and Franke (2003) investigate cross-regional knowledge spillovers in Germany. The study suggests that the efficiency (productivity) of R&D activity differs significantly between regions which can be attributed to intra-regional spillovers from other R&D active

entities within the region – both private companies and public institutions. Gumbau-Albert and Maudos (2009) who investigates differences in patenting activity among Spanish regions. First of all, the study finds a positive impact of human capital and R&D expenditures on regional patenting activity. Moreover, the spillover effects have been confirmed – the impact of innovative activity of neighbouring regions on particular region is stronger than more distant ones. From an intra-regional trade perspective, trade spillovers seem to occur.

Theoretical postulates of trade as a crucial element of a local stock of knowledge was confirmed by Xu and Chiang (2005) who analyze the differences between technology diffusion in countries at different stages of development. The study shows that the source of technology transfer in high-income countries are primarily domestic R&D and imports of foreign capital goods. In the case of middle-income economies, foreign patents and imported goods play a crucial role, while for the low-income countries, the most important source of technology are foreign patents.

As noted above, the empirical studies for non-developed countries are rather scarce, yet the spillovers may be expected also in economies at the lower level of development. For example Chen and Yang (2005) utilized R&D expenditures and patent data to estimate the impact of technology and spillovers on productivity of Taiwanese manufacturing companies. The results suggest that both technological progress measured by R&D and patents as a measure of knowledge stock, as well as spillover effects within industry play key roles in firm-level productivity growth.

From Emerging European perspective, Ćudić (2021) finds that small and medium firms domiciled in West Balkans have low propensity to patent due to perceived level of costs and complexity related to the patenting process.

Given limited studies of non-developed countries and subject to available data, three hypotheses were formulated based on the above literature:

H1: The R&D expenditures have statistically significant impact on the patenting propensity in Polish regions.

H2: Internationalization measures are positively associated with the patenting propensity in a specific region.

H3: Regional economy characteristic measures are positively associated with the patenting propensity in a specific region.

3. Data and Methodology

In the following study, the primary source of data utilized was the Local Data Bank, collected by Statistics Poland. It enables the analysis of regional trends in patenting activity in 16 Polish voivodeships (NUTS-2 regions) from 2009 to 2022. It should be noted that some

series were available over the longer horizon, however, for transparency reasons, balanced panel data were chosen over unbalanced one. We follow Feldman and Florida (1994) assuming that the distribution of innovation can depend on various factors, such as R&D expenditure, but also size of the region, or the presence of international firms within the region. At the same time, it should be highlighted that the economic literature finds patents as a measure of innovative activity output to be suboptimal proxy. Among several arguments, the most important is the fact that not all inventions are patented (software for example). Additionally, patents differ in terms of their quality and may take the form of defensive patenting behaviour, aiming rather in blocking competition rather than reflecting innovation (Cincera, 1997; Grilihes, 1991). Despite this critique, we follow Acs et al. (2002) who finds that given similar drawbacks of alternative measures of innovative activities' output, patents remain the most sound measure. Therefore, the dependent variable representing the number of inventions in the region are patents granted by Polish Patenting Office per 100 thousand inhabitants.

The independent variables can be divided into two groups. The first covers inputs of innovative activity. Specifically, we include internal R&D expenditures and internal R&D expenditures per capita as well as number of employees in R&D per 1000 professionally active inhabitants.

The second group represents regional structure conditions associated with knowledge externality effects. First of all, the number of enterprises per thousand of working age inhabitants to reflect the level of regional entrepreneurship. Second, to account for international knowledge transfer, which is specifically important in the case of non-developed countries (Xu, Chiang, 2005), the number of entities with foreign capital participation per 10 thousand inhabitants was considered. Finally, the number of university graduates per 10 thousand inhabitants as a measure of human capital as well as percentage of foreign students reflecting internationalization/academic networking within a region were taken into account.

Therefore, the final data sample consists of 14 yearly observations for 16 Polish NUTS-2 regions implying 224 observations per each variable. To verify the above stated hypotheses, the ordinary least squares (OLS) regression is utilized in the following study. To account for unobserved, time-invariant region characteristics, a fixed effects (FE) model was chosen over other frameworks, which was supported by highly significant outcome of the Hausman test (1978).

4. Results

The results of estimated coefficients are presented in Table 1 below. All of the obtained coefficients are statistically significant at the 0.1 level. The overall model fit can be considered satisfactory, explaining nearly half of the variation in the count of patents granted per

100 thousand inhabitants, which is acceptable for panel data. Surprisingly, the impact of R&D expenditures is statistically significant, but negative, which is counterintuitive. There are two possible explanations of such outcome. First, per capita relativisation may not properly reflect the relationship between the variables. To account for this, the second specification of the model was estimated (the right column of the table) where relative R&D expenditures were replaced with absolute R&D expenditures. Given no change of the coefficient's sign, another possible explanation is a non-linear relationship between variables, which seems to be confirmed by the plot (fig. 1). Finally, it is reasonable to assume that the relationship between both variables is more complex in nature[1].

The potential of the regional entrepreneurship, measured by enterprises per thousand of working age inhabitants impacts positively patenting activity in a given region, which is in line with Feldman and Florida (1994), and general economic intuition. Similarly, the coefficient related to number of entities with foreign capital participation per 10 thousand inhabitants is statistically significant and positive, which supports the concept of internationalization as a channel of technology transfer (Xu, Chiang, 2005; Kwiatkowski, 2021; Keller, 2021).

Additionally, the measure of academic networking (share of foreign students) is statistically significant and positive, which is generally in line with knowledge spillover literature. On the other hand, the results did not find support for the positive impact of human capital on innovative activity, opposite to numerous studies (Maudos, 2009; Ó hUallacháin, Leslie, 2007).

Finally, GDP changes, a proxy for productivity/technological changes, are positively and statistically significantly affecting patenting in regions, which supports the postulates of new growth theory. It should be noted that the effect can be to some extent endogenous – changes in productivity can impact innovative activity in a region or result in increase of patents per se, but on the other hand, innovative activity results in productivity growth and technological progress.

Table 1.
The results of estimated model

	R&D expenditures (relative)			**R&D expenditures (absolute)**		
	Estimate	**SE**	**p-value**	**Estimate**	**SE**	**p-value**
	Independent Variable: patents granted per 100 th inhabitants					
rd_exp	-0.003	0.001	0.000	-0.000	0.000	0.000
Entn	0.044	0.014	0.002	0.028	0.012	0.020
for_ent	1.003	0.156	0.000	0.982	0.156	0.000
Grad	-0.0217	0.009	0.019	-0.024	0.009	0.011
for_stud	0.157	0.077	0.042	0.152	0.077	0.050
Gdp	0.158	0.036	0.000	0.156	0.036	0.000
Adj R2	0.45			0.44		

Source: Own elaboration.

[1] Due to high correlation between R&D expenditures and employees in R&D per 1000 professionally active inhabitants, the second variable was introduced in a separate specification of the model, replacing R&D expenditures. The coefficient related to employment remained negative and therefore, given lower model fit, not presented in the body of the article, yet available upon request.

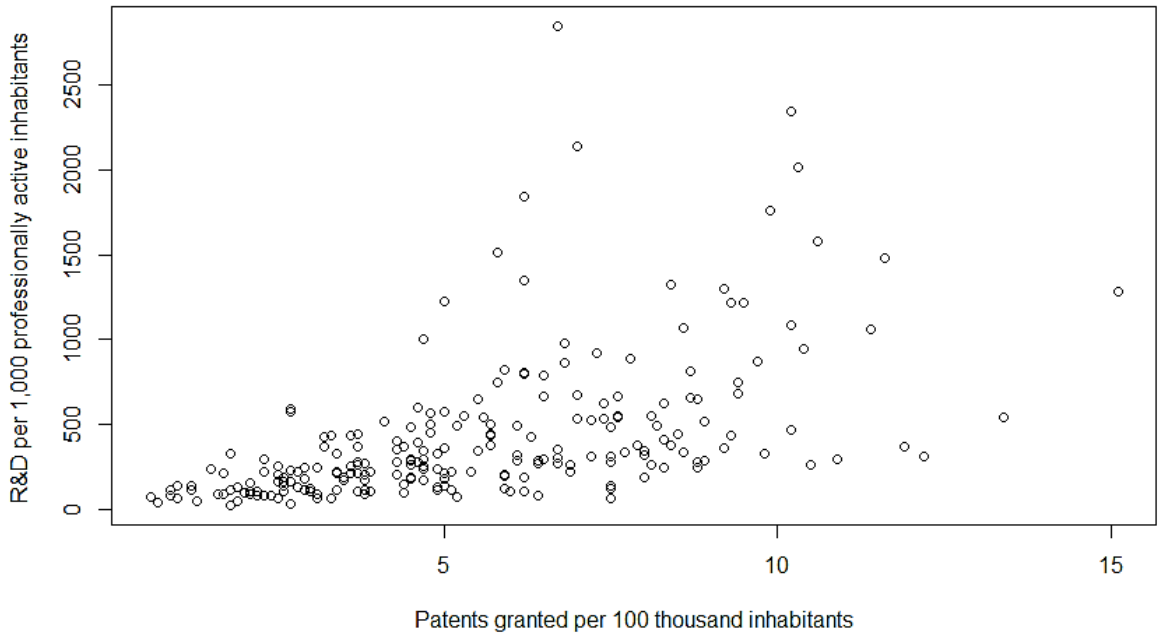

Figure 1. Scatterplot of patents and R&D expenditures.
Source: Own elaboration.

5. Discussion and conclusions

The main aim of this article was to explore the drivers of patenting activity of Polish regions, where patents granted were regressed on various standard, as well as non-orthodox measures of innovative activity. We conclude that determinants of innovative activity utilized in country-level studies are effective in explaining patenting activity on the regional (NUTS-2) level in the case of non-developed country (Poland) with nearly 50% variation explained. Specifically, we demonstrated statistically significant relationship between dependent variable (patents granted per 100 thousand inhabitants) and various independent variables. First of all, region's economy's size, measured by GDP per capita and number of firms show positive impact on the number of patents granted by the Polish Patenting Office, similarly to utilized internationalization measures (firms with foreign capital, foreign students). On the other hand, the number of university graduates is negatively related to the number of patents granted, which remains slightly less intuitive. At the same time, the impact of R&D and expenditures on patenting appears to be more complex and non-linear.

The obtained results in general can be considered robust, as changes to independent variables, as in the case of R&D expenditures, do not impact to a large extent model's performance. Furthermore, the obtained results support the postulates of the new growth theory and knowledge spillover-related literature. The role of knowledge spillovers is likely to remain key at the regional level regardless of the level of regions/country development. However,

the character of its impact could in fact be more nuanced than in classical, country level studies, as in the discussed case of R&D expenditures and patents granted relationship.

At the same time, the presented study has certain limitations. First of all, the patenting activities should be preferably conducted on the firm or industry level data. Second, a comparison between determinants of patenting activity in developed and non-developed economies would benefit the field, however, given the choice of independent variables, was subject to data availability. Finally, given ambiguous results of the impact of R&D expenditures on patenting in both, absolute and relative terms, different types of R&D expenditures should be compared, once available. All limitations mentioned above should be considered as potential areas for further studies. Specifically, a multi-country analysis of developing and developed countries (i.e. EU, OECD) should be modelled using international patent data at the industry and regional level to verify underlying relationships between patenting activity of firms.

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