



Kondratiuk-Nierodzińska, M. (2016). New Knowledge Generation Capabilities and Economic Performance of Polish Regions. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 11(3), 451-471. DOI: <http://dx.doi.org/10.12775/EQUIL.2016.021>

**Monika Kondratiuk-Nierodzińska\***

*University of Białystok, Poland*

## **New Knowledge Generation Capabilities and Economic Performance of Polish Regions**

**JEL Classification:** *O11; O31; O34*

**Keywords:** *knowledge creation; innovation capabilities; regional development*

**Abstract:** *Economic growth is a process of long-term transformation shaped by complex interactions between technology, economy, institutions and social factors. A considerable number of studies have shown that among these factors technological advancement and particularly new knowledge generation capabilities may be one of the most important determinants of economic growth and development.*

*Significant disparities in development levels can be observed between Polish regions. The aim of this paper is to look for the sources of these disparities in regional capacity for new knowledge creation. The research method adopted in this paper is based on statistical analysis of the relationship between variables describing new knowledge generation capabilities and GDP per capita in two periods: 2003–2004 and 2012–2013 in 16 Polish regions. Correlation and regression analysis results show that there is a strong positive relationship between regional differences in new knowledge generation capabilities and variations in GDP per capita. The relationship is very strong when one considers three aspects of these capabilities: R&D employment and R&D expenditures denoting inputs to the new knowledge generation process and patenting activity representing its output. These results may serve as an indication for innovation policy at regional level.*

---

© Copyright Institute of Economic Research

Date of submission: November 20, 2015; date of acceptance: June 16, 2016

\* Contact: [monika.mkn@gmail.com](mailto:monika.mkn@gmail.com), Department of Economic Systems, Economics and Management Faculty, University of Białystok, ul. Warszawska 63, 15-062 Białystok, Poland

## Introduction

Over the last 30 years, the innovation system concept has diffused quite rapidly among both researchers and policy makers. The origins of the concept can, in fact, be traced back to both academia and policymaking, as major contributors to the concept seem to agree (see Sharif, 2006). It has been intended to help develop an alternative analytical framework to standard economics and to criticize its neglect of dynamic processes related to innovation and learning when analysing economic growth and development (Lundvall, 2007, p. 96). The innovation system concept was introduced by Lundvall (1985, 1988) and Freeman (1987), and further developed also by Nelson (1993) and Edquist (1997). The concept was first applied to the national level and the term “National System of Innovation” was used. Other authors took a slightly different approach to the systemic determinants of the knowledge production processes and thus the concepts of Triple Helix (Etzkowitz & Laydesdorff, 1997), technological systems (Carlsson & Stankiewicz, 1991), sectoral innovation systems (Breschi & Malerba, 1997) and regional innovation systems (Cooke, 1995) emerged, giving rise to a considerable body of literature and debates on the theme of innovation systems.

One of the first international organisations to adopt the national innovation system concept as an integral part of their analytical perspective was the Organisation for Economic Cooperation and Development (OECD), with others following afterwards: UNCTAD, European Commission, World Bank and IMF (Lundvall *et al.*, 2002, p. 214). The OECD’s activities in the 1960s and 1970s led to a growing interest in the reasons for the disparity in national growth rates, and one of the explanations taken into consideration was the difference in research systems among countries (Lundvall *et al.*, 2002, p. 215). The early contribution to the understanding that technological advancement may be one of the most important determinants of economic growth and development is attributed to historically oriented economists (see: Castellacci, 2003; Fagerberg & Srholec, 2008). They have stressed the fact that economic growth is a process of long-term transformation shaped by the complex interactions between technology, economy, institutions and social factors (see: Fagerberg, 1994; Castellacci, 2003; Fagerberg & Godinho, 2005 for overviews). Since then, and most of all since 1980s, a lot of studies on the nature and measurement of innovation capabilities and cross-country differences in levels of development and growth performance inspired by this perspective have emerged. A part of the work in this area focused mostly on comparing the impact which technological and other factors have on economic performance of nation states,

thus on searching for and in most cases finding a proof of a positive relationship between technological advancement and economic development (Freeman *et al.*, 1982; Fagerberg, 1987; 1988a; 1994; 2000; Dosi *et al.*, 1990; Verspagen, 1991; Freeman, 2002; Fagerberg & Verspagen, 2003; Goo & Park, 2007; Fagerberg *et al.*, 2007; Fagerberg & Srholec, 2008; Hasan & Tucci, 2010). The line of research included looking for reasons behind the existence of technological differences (technology gaps) and falling behind rather than catching up in case of certain groups of countries (Fagerberg, 1987; 1988a; 1988b; Verspagen, 1991; Fagerberg & Verspagen, 1996; 2002; 2003; Fagerberg *et al.*, 2007; Fagerberg & Srholec, 2008, Filippetti & Payrache, 2011, Fagerberg & Srholec, 2013), as well as investigating factors influencing countries' potential for technology/innovation adoption and development (Furman *et al.*, 2002; Furman & Hayes, 2004; Faber & Heslen, 2004; Cerulli, 2014).

According to Lundvall (2010, p. 1), knowledge is considered to be the most fundamental resource in the modern economy, and acquiring it through learning is the most important process. Therefore, creation of new knowledge is usually placed at the heart of innovation systems and considered one of the most important capabilities determining economic development. The main aim of this paper is to draw from the innovation capabilities concept and determine the relationship between knowledge creation capabilities and economic development in Polish regions. The main assumption is that differences in knowledge creation capabilities of Polish regions have a good explanatory value of regional variations in GDP *per capita*. The paper is structured as follows: Section 2 contains an overview of past research on innovation capabilities and their impact on economic development. In Section 3, a description of the adopted methodology for statistical data analysis is provided, including the choice of variables. Section 4 contains a description of results on the relationship between variations in new knowledge creation capability and economic performance of 16 Polish regions. Conclusions follow in the last section.

## **Innovation/Technological Capabilities as Drivers of Economic Development: Overview of Recent Studies**

Technological capability of a country may be defined as “the ability to make effective use of technological knowledge in efforts to assimilate, use, adapt and change existing technologies” (Kim, 1997, p. 4 cited in Fagerberg & Srholec 2008, p. 1419). This concept draws from the idea of Co-

hen's and Levinthal's "absorptive capacity" of firms (1990, p. 128) and includes not only organized R&D, but also other capabilities needed for the commercial exploitation of technology. In this sense it also relates to a systemic view of innovation, where a wide range of factors influencing innovation generation and diffusion processes are taken into account. National innovative capacity, a term used by Furman, Porter and Stern, has the same connotations and is defined as "the ability of a country – as both a political and economic entity – to produce and commercialize a flow of new-to-the world technologies over the long term" (Furman *et al.*, 2002, p. 900). Therefore, the term "technological capability" may be used interchangeably with the term "innovation capability" or "innovation capacity".

The literature on the subject offers different views on the composition of technological/innovation capabilities of nations. The abovementioned concept of "absorptive capacity" seems to have a lot of bearing on the understanding of factors influencing technological output and economic development of nations. According to Abramovitz (1986; 1994), absorptive capacity may refer to "technological congruence", meaning "resource availabilities, factor supplies, technological capabilities, market scales and consumer demands", as well as "social capability" defined as "countries' level of education and technical competence, the commercial, industrial and financial institutions that bear on their abilities to finance and operate modern, large-scale business, and the political and social characteristics that influence the risks, the incentives and the personal rewards of economic activity" (Abramovitz, 1994, p. 24). Verspagen (1991), on the other hand, spoke about "intrinsic" learning capability, which he defined as depending on such variables as the education of the labour force and the quality of the infrastructure. Keller (1996) also adopted the view that the absorptive capacity of an economy has considerable influence over its performance but his definition of the term was narrower as he defined it as specific skills and knowledge accumulated in domestic human capital. These notions of absorptive capacity suggest that knowledge creation and accumulation are inseparable from human capital.

The concept is also present in Fagerberg's and Verspagen's work (2002; 2003) who distinguished between three sets of factors, which in their opinion help explain economic growth: (1) innovation understood as creation of new knowledge in the country, (2) diffusion, i.e. potential for exploiting knowledge developed elsewhere and (3) absorptive capacity understood as complementary factors that contribute to the exploitation of diffusion potential. Here, however, it relates to a broad set of factors creating an environment conducive to exploiting accumulated knowledge.

The importance of human capital, among other factors influencing creation and diffusion of new technologies, has also been emphasised by other authors. Benhabib and Spiegel (1994), Papageorgiou (2002) and Stokke (2008) focused on human capital and learning capability as the most important factors of economic development, responsible for a country's ability to imitate and absorb foreign advanced technologies. Lall (1992) also mentioned human capital as one of the aspects of national technological capabilities. He indicated three such aspects: (1) physical investment, (2) human capital and (3) technological effort (domestic and imported), which are strongly interlinked. The author emphasised that the quantity of resources is even less important than their quality: what matters is not only plant and equipment, but mainly the efficiency with which physical capital is utilised, and not only human skills generated by formal education and training, but also the expertise gained during on-the-job training and through experience. National technological effort, according to the author, it is to be associated with a broad spectrum of production, design and research work within firms, backed up by a technological infrastructure that provides information, standards, basic scientific knowledge and various facilities too large to be owned by private firms, but is also the result of the extent and nature of a country's reliance on foreign technology. Archibugi and Coco (2004), who proposed a new measure of technological capabilities of countries, also considered three dimensions of technological capabilities, among which they included characteristics of nation's human resources: (1) creation of technology, (2) technological infrastructures and (3) development of human skills.

Fagerberg and Srholec (2008), continuing research on the subject of specific national capabilities as factors influencing economic development, took a broader view and identified four types of capabilities/factors: (1) the development of the innovation system, (2) the quality of governance, (3) the character of the political system and (4) the degree of openness of the economy. In this case innovation capabilities of countries were "summarised" by the term "development of the innovation system", which were measured using a relatively broad spectrum of indicators associated with different aspects of both technological and social capabilities of nation states. Among the variables used to describe this capability, they used the number of patents and scientific articles, which are in fact measures of the output of new knowledge generation process. In their 2013 paper (Fagerberg & Srholec, 2013) they used indicators related to innovation activities to describe broadly defined "social capabilities" of countries, since they found through factor analysis that there exists a strong interdependence between technological, social and cultural factors in the process of devel-

opment. However, the abovementioned variables denoting the results of new knowledge creation, were also present and showed high correlation with the “social capabilities index”.

Broad perspective on national innovation capabilities was shared by Furman *et al.* (2002) and Furman and Hayes (2004), who introduced the concept they termed a “national innovation capacity” (Furman *et al.*, 2002) and described it as a result of three building blocks: (1) presence of a strong common innovation infrastructure, which includes a country’s overall science and technology policy environment, the mechanisms in place for supporting basic research and higher education, and the cumulative “stock” of technological knowledge upon which new ideas are developed and commercialised, (2) specific innovation environments present in a country’s industrial clusters, meaning microeconomic environment in which firms compete, (3) strength of the linkages between the common innovation infrastructure and specific clusters, depending on mechanisms or institutions, such as a domestic university system or established funding sources for new ventures, which encourage the commercialisation of new technologies in particular clusters. Similarly, Faber and Hesen (2004) who also approached the subject of innovation capabilities from the perspective of factors influencing production of innovative output of an economy, argued that the concept of National Innovation Systems comprises two broad categories of variables: (1) related to innovation processes within and among firms, and (2) related to the innovation infrastructure surrounding and enabling innovations by firms, comprising economic, institutional and contextual conditions.

Castellaci and Natera (2013) also adopted a broad view on innovation capabilities. They discerned between two main factors influencing a country’s level of economic development: (1) innovative capability, and (2) absorptive capacity. Innovative capability was described by them as: (a) innovative input representing total efforts and investments carried out by each country for R&D and innovative activities, (b) scientific output denoting results of research and innovation activities carried out by the public S&T system and (c) technological output defined as total output of technological and innovative activities carried out by private firms. Absorptive capacity, on the other hand, was considered to be determined by (a) international trade, which represents the openness of the national system, which in turn influences a country’s capability to imitate foreign advanced knowledge, (b) human capital and its characteristics, (c) level and quality of infrastructures, which increases a country’s capability to absorb, adopt and implement foreign advanced technologies, (d) quality of institutions and governance system and (e) level of social cohesion and economic inequali-

ty which influences the pace of diffusion and adoption of advanced knowledge within the country.

**Table 1.** Knowledge creation as one of innovation capabilities – an overview of different approaches

Author/s	Capability	Context of inclusion of knowledge creation capability or its aspects
Verspagen (1991)	Absorptive capacity	Absorptive capacity is defined as “intrinsic” learning capability, implying the importance of knowledge accumulated during the learning process.
Lall (1992)	Technological effort	National technological effort is associated with a broad spectrum of activities and assets, basic scientific knowledge being one of them.
Keller (1996)	Absorptive capacity	Absorptive capacity is defined as specific skills and knowledge accumulated in domestic human capital, so the author directly refers to the importance of knowledge creation.
Fagerberg & Verspagen (2002; 2003)	Innovation	Innovation is understood as creation of new knowledge in the country.
Furman <i>et al.</i> (2002)	Common innovation infrastructure	Common innovation infrastructure includes the cumulative “stock” of technological knowledge upon which new ideas are developed and commercialised.
Archibugi & Coco (2004)	Creation of technology	Their “creation of technology” index is in fact based on measures of new knowledge creation process output, i.e. patents and scientific articles.
Faber & Hesen (2004)	Innovation processes within and among firms	Patents are used as one of the measures of output of innovation processes within firms.
Fagerberg & Srholec (2008)	Development of innovation system	Authors include a broad spectrum of indicators to describe a level of development of innovation systems, using variables related to the results of new knowledge creation process such as number of patents and scientific articles.
Archibugi & Coco (2005); Archibugi <i>et al.</i> (2009)	Generation/diffusion of knowledge	Authors refer directly to the generation of new knowledge opposite its diffusion.
Castellacci & Natera (2013)	Innovative capability	Innovative capability includes scientific output denoting results of research and innovation activities carried out by the public S&T system, which include new knowledge.

Source: own work based on Verspagen (1991); Lall (1992); Keller (1996); Fagerberg & Verspagen (2002; 2003); Furman *et al.* (2002); Archubugi & Cocco (2004; 2005); Faber & Hesen (2004); Fagerberg & Srholec (2008); Archibugi *et al.* (2009); Castellacci & Natera (2013).

Archibugi and Coco (2005) and Archibugi *et al.* (2009) point out that different views on technological/innovation capabilities of nations agree on the fact that they are composed of heterogeneous elements, which can be

summarised in three contrasts: (a) embodied (i.e. capital good, infrastructure etc.) /disembodied (human skills and technological expertise), (b) codified (blueprints, patents etc.) /tacit (learning processes), and (c) generation (creation of new knowledge)/diffusion (assimilation of new knowledge generated elsewhere).

The above overview allows to conclude that knowledge creation remains one of the most important factors taken into account when analysing the impact of different national capabilities on economic development. Table 1 contains a summary of different approaches to innovation and technological capabilities with description of context in which knowledge creation is included amongst other capabilities. It appears that all the analysed studies referred to some form of knowledge creation or accumulation capability, either in a direct form or indirectly, through inclusion of variables measuring the output of knowledge generation process.

## **Research Methodology**

In order to study the impact of knowledge creation capability on economic development of Polish regions a set of five variables describing the former has been chosen. The choice of variables is based on past practices adopted in studies outlined in the previous section but also with data availability in mind. Definitions of the variables are presented in table 2, along with description of data sources.

Statistical data analysis in this paper is partly based on construction of composite indicators of new knowledge generation capability (KnowCap) for 16 Polish regions. Composite indicators are not a new tool for analysing innovation system performance. The most recent, and probably the most widely recognised, examples of the implementation of this tool are the Innovation Union Scoreboard<sup>1</sup> (see for example Hollanders & El-Sadki, 2013) and its counterpart: the Regional Innovation Scoreboard (see for example Hollanders *et al.*, 2012) that have been regularly measuring innovative performance of EU national and regional economies for over 10 years. Other examples may include the European Competitiveness Index (Huggins & Davies, 2006) or the Global Competitiveness Report (see for example Schwab, 2012).

---

<sup>1</sup> Formerly: European Innovation Scoreboard.



**Table 2.** Definitions of variables measuring new knowledge generation capabilities in Polish regions and data sources

No.	Definition	Data sources
1.1	Units with research and development (R&D) activity per 100 thousand entities of the national economy	LDB 2003-2013
1.2	UPRP patent applications per million inhabitants	own calculations based on NiT 2004-2008 (number of patent applications) and LDB 2004-2008 (population statistics) plus LDB 2009-2013
1.3	UPRP utility model applications per million inhabitants	own calculations based on NiT 2004-2013 (number of utility model applications) and LDB 2004-2013 (population statistics)
1.4	Employment in research and development per thousand economically active persons (full time equivalent)	LDB 2002-2013
1.5	Total R&D expenditures in PLN per one economic entity registered in REGON system	own calculations based on LDB 2000-2013 (total R&D expenditures and number of economic entities registered in REGON system)

Notes: UPRP – Polish Republic Patent Office, NiT – Nauka i technika w ... roku – a series of Polish Central Statistical Office publications (GUS 2006; 2007-2014), LDB – Local Data Bank of Central Statistical Office in Poland.

Source: author.

Saisana and Tarantola (2002, p. 5) are of the opinion that: “Indicators are pieces of information that summarise the characteristics of a system or highlight what is happening in a system. They are often a compromise between scientific accuracy and the information available at a reasonable cost”. They propose a definition of composite indicators as “based on sub-indicators that have no common meaningful unit of measurement and there is no obvious way of weighting these sub-indicators” (Saisana & Tarantola, 2002).

Construction of composite indicators requires data standardisation in order to permit calculation of a sum of the chosen variables. The method chosen in this study additionally imposes normal distribution of the data and simultaneously allows to eliminate the influence of extreme values as they might prove to be unreliable outliers and distort the model estimation results:

$$x = \frac{\text{actual value} - \text{mean value}}{\text{standard deviation}}.$$

The analysis is conducted for two two-year periods: 2003–2004 and 2012–2013, for which the values of most of the variables<sup>2</sup> have been available. A two-year average has been calculated for each of the analysed variables in each period. The inclusion of two periods of analysis makes it possible to test for any changes in the relationship between regional variations in performance within the two areas being the subject of this study and also conclude whether past performance related to new knowledge generation has had any influence over current results pertaining to the level of economic development.

New knowledge generation capability indicators (KnowCap) are calculated as an average of standardised value of variables in each period of analysis. Thus all the variables measuring the capabilities are assigned equal weights.

Regional performance within new knowledge generation capability is tested against economic performance measured by GDP *per capita*, which is one of the most common variables used to describe the level of economic development. The aim of this approach is to recognise to what extent regional differences in new knowledge generation capability may be responsible for variations in economic performance of Polish regions. Correlation coefficients are calculated and regression analysis is performed to determine the relationship between these variations. Positive linear relationship between them is sought, signifying that better performance in the field of new knowledge generation is characteristic for regions with better economic performance. Additionally, correlation and regression results are used to indicate which of the variables describing new knowledge generation capabilities are most important from the point of view of GDP *per capita* level.

## Research Results

Poland's territory is divided into 16 regions which correspond to the NUTS-2 level of the administrative divisions of countries for statistical purposes. There are significant disparities in economic performance between these regions: GDP *per capita* in 2012<sup>3</sup> ranged from 66,755 PLN (Mazowieckie voivodeship) to 29,333 PLN (Podkarpackie). The economic predominance of a few regions over other parts of Poland is evident, with

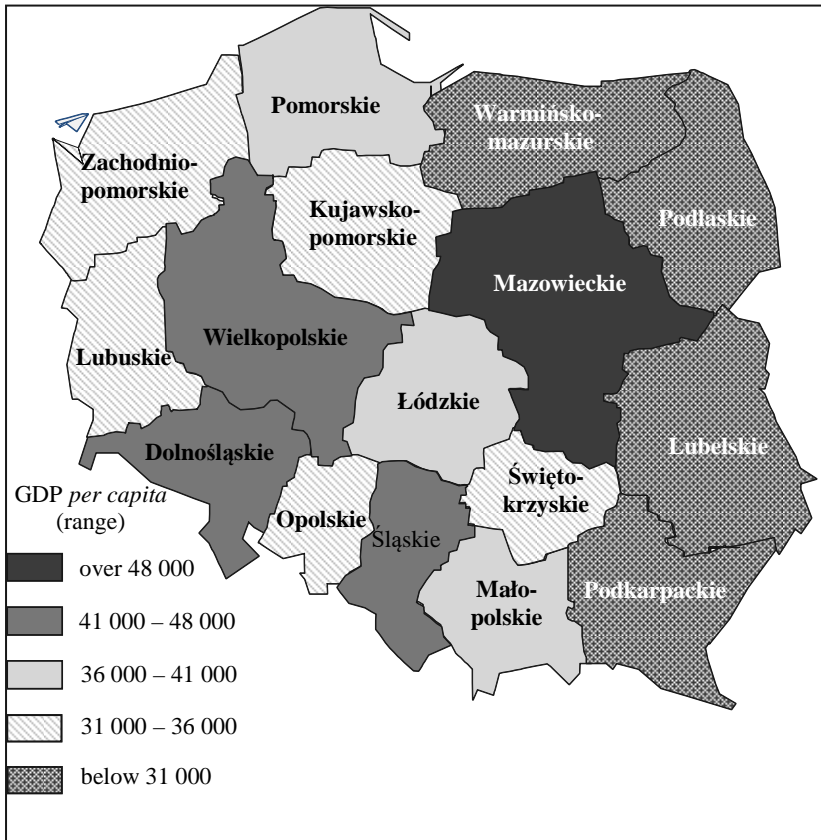
---

<sup>2</sup> Variable no. 1.3 and GDP *per capita* are the only exceptions.

<sup>3</sup> Latest available data.

significantly lower values of economic indicators in the eastern part of the country (Figure 1). What is more troubling is the fact that these disparities have not diminished over time – variation coefficient of GDP *per capita* in 2000–2012 period has grown from 21,6% to 25,2%, although it needs to be mentioned that its accelerated growth has been observed since 2009 – after the world financial and economic crisis (Figure 2).

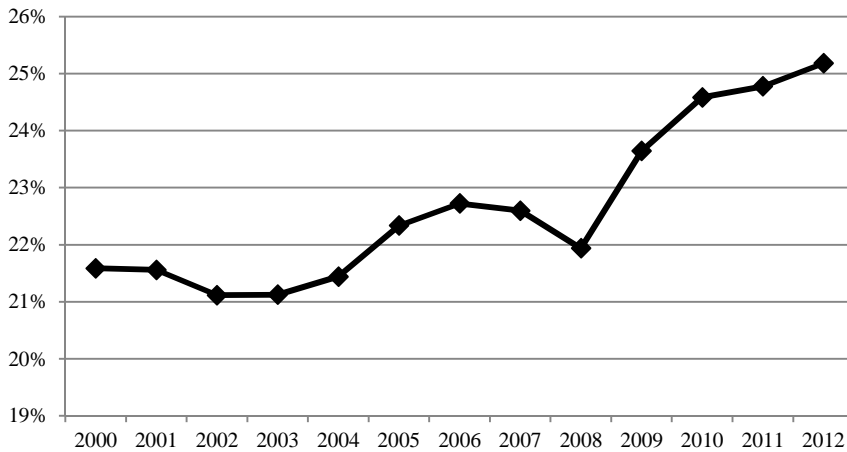
**Figure 1.** Spatial distribution of GDP *per capita* in Poland in 2012 (NUTS-2 level)



Source: Local Data Bank of Central Statistical Office in Poland (Regional accounts/Gross Domestic Product (current prices) – PKD 2007 (NACE rev. 2) - ESA 2010/ Gross domestic product per capita (NTS-2, 2000–2014)).

Since innovation can be a strong disequilibrating factor in the processes of economic growth, triggering the pervasive differential growth rates between geographical areas (Fagerberg & Verspagen, 1996; Verspagen, 1999; Howells, 2005), it is the aim of this paper to look for the sources of indicated disparities in the regional performance within capability of generating new knowledge for innovative activity.

**Figure 2.** Variation coefficient of GDP *per capita* for 16 Polish regions in 2000-2012 period

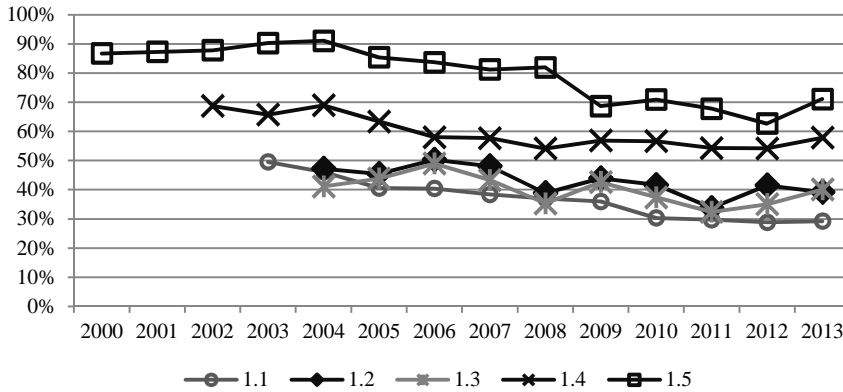


Source: own calculations based on: Local Data Bank of Central Statistical Office in Poland (Regional accounts/ Gross Domestic Product (current prices) – PKD 2007 (NACE rev. 2) - ESA 2010/ Gross domestic product per capita (NTS-2, 2000–2014)).

A look into regional disparities in the level of the five variables used in this paper to describe new knowledge generation capabilities allows to conclude that they remain high or very high for all the analysed indicators (Figure 3).

The biggest differences between regions can be observed in R&D expenditures (1.5) and employment in R&D (1.4). Regional variations in intellectual property rights protection activity (1.2, 1.3) seem to remain quite constant while disparities in the number of units conducting research and development diminish.

**Figure 3.** Variation coefficients of five variables describing new knowledge generation capabilities for 16 Polish regions in 2000-2013 period



Source: own calculations based on data sources indicated in Table 1.

Correlation results, however, suggest that the factors which differentiate regions the most do not necessarily have the strongest bearing on variations in their development level (Table 3).

**Table 3.** Results of correlation analysis between variables describing new knowledge generation capability and GDP per capita

Variable no.	2003-2004					2012-2013				
	1.1	1.2	1.3	1.4	1.5	1.1	1.2	1.3	1.4	1.5
2003-2004	1.1	1.000								
	1.2	0.589	1.000							
	1.3	0.596	0.461	1.000						
	1.4	0.746	0.742	0.636	1.000					
	1.5	0.875	0.661	0.663	0.949	1.000				
2012-2013	1.1	0.932	0.678	0.580	0.691	0.787	1.000			
	1.2	0.682	0.900	0.618	0.857	0.807	0.708	1.000		
	1.3	0.560	0.590	0.870	0.677	0.645	0.609	0.667	1.000	
	1.4	0.813	0.739	0.542	0.954	0.916	0.763	0.838	0.645	1.000
	1.5	0.911	0.570	0.540	0.824	0.918	0.828	0.691	0.592	0.886
GDP per capita 2003-2004	0,623	0,866	0,493	0,806	0,776	0,630	0,802	0,554	0,740	0,624
GDP per capita 2012	0,662	0,894	0,466	0,832	0,801	0,677	0,854	0,536	0,791	0,663

Source: own calculations based on data sources indicated in Table 1.

Regional variations in GDP *per capita* show the highest correlation with differences in number of patent applications per million inhabitants. A strong relationship is also evident between regional variations in employment in R&D as well as R&D expenditures and regions' economic development levels, while differences in economic units' engagement in R&D and number of utility model applications show much weaker correlation.

Regional variations in values of composite indicator of new knowledge generation capabilities (KnowCap indicator), calculated as an average of all five variables in standardised form, show a high correlation with regional differences in GDP *per capita*: correlation coefficient of 0.794 for 2003–2004 period and 0.753 for 2012–2013, which means that there is a strong positive relationship between regional performance in new knowledge creation and regional development. A slightly higher correlation has been observed between values of new knowledge generation composite indicator calculated for the period of 2003–2004 and GDP *per capita* in 2012: coefficient of 0.816, signifying an even stronger positive relationship between past new knowledge generation effort and present value of GDP *per capita*. Such results are understandable, since creation of new knowledge is an important but nevertheless only a first step in a time consuming innovation process which needs to result in implementation of new products and processes and later in their diffusion, to have economic impact (OECD, 2005, p. 17).

A closer look at the results of correlation analysis in Table 3 and regression analysis presented in Table 4, especially regarding the values of coefficients of determination ( $R^2$ ), allow to conclude that variations in the level of development between Polish regions are most strongly determined by differences in three areas: two related to input to the new knowledge generation process – R&D employment (1.4) and R&D expenditures (1.5) and one representing its output – number of patent applications (1.2).

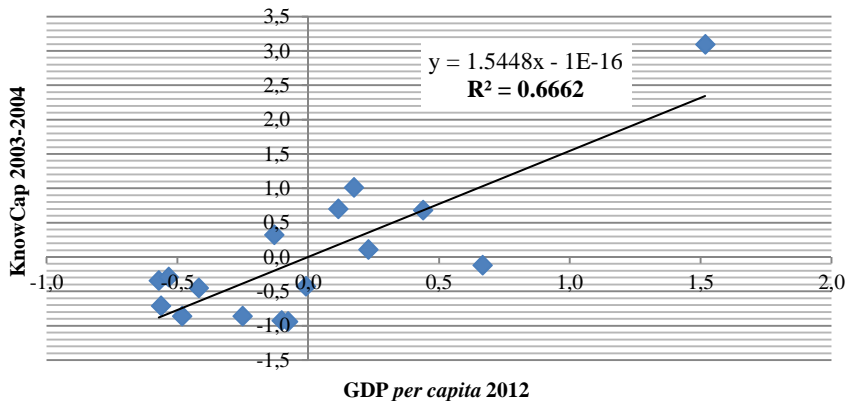
**Table 4.** Regression results for the relationship between new knowledge generation capabilities composite indicator (KnowCap) and GDP *per capita*

KnowCap (average of five variables)				KnowCap (average of three variables)					
KnowCap 2003-2004 and GDP <i>per capita</i> 2003-2004									
Parameters	Stand. error	p	R <sup>2</sup>	Parameters	Stand. error	p	R <sup>2</sup>		
β <sub>0</sub>	-1,22E-16	0,1621	1	0,6311	β <sub>0</sub>	1,13E-16	0,1188	1	0,8018
β <sub>1</sub>	1,5012	0,3067	< 0,001		β <sub>1</sub>	2,0722	0,2753	< 0,001	
KnowCap 2012-2013 and GDP <i>per capita</i> 2012									
Parameters	Stand. error	p	R <sup>2</sup>	Parameters	Stand. error	p	R <sup>2</sup>		
β <sub>0</sub>	-5,55E-17	0,1760	1	0,5665	β <sub>0</sub>	1,87E-16	0,1541	1	0,6674
β <sub>1</sub>	1,7229	0,4028	< 0,001		β <sub>1</sub>	2,3680	0,4467	< 0,001	
KnowCap 2003-2004 and GDP <i>per capita</i> 2012									
Parameters	Stand. error	p	R <sup>2</sup>	Parameters	Stand. error	p	R <sup>2</sup>		
β <sub>0</sub>	-9,80E-17	0,1544	1	0,6662	β <sub>0</sub>	1,44E-16	0,1024	1	0,8533
β <sub>1</sub>	1,5448	0,2923	< 0,001		β <sub>1</sub>	2,1410	0,2373	< 0,001	

Source: own calculations based on data sources indicated in Table 1.

Figures 4 and 5 report the relationships between synthetic measures of new knowledge generation capabilities (KnowCap) in 16 Polish regions and their GDP *per capita* – while in Figure 4 composite indicator is calculated as an average of all five analysed variables, in Figure 5 only three variables mentioned above have been used in its composition.

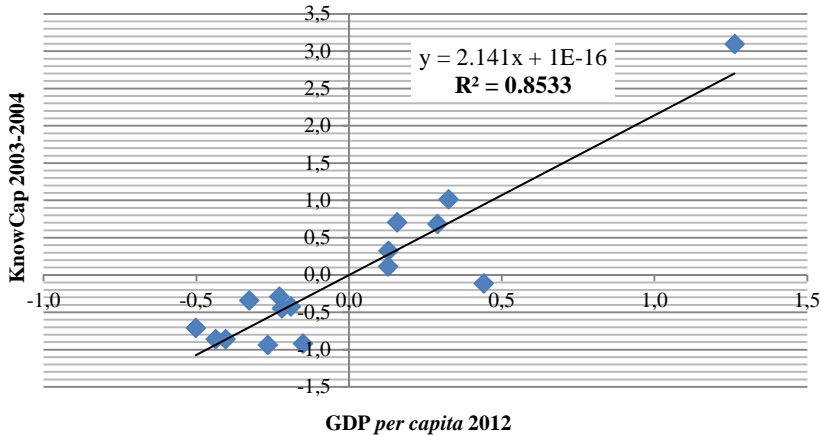
**Figure 4.** New knowledge generation capability composite indicator (average of five variables) and GDP *per capita* in 16 Polish regions



Source: own calculations based on data sources indicated in Table 1.

In both figures, only the cases which represent the relationship between past new knowledge creation activity characteristics and present level of development have been shown, since, according to  $R^2$  values, they represent a better goodness of fit of a relationship model analysed in this paper.

**Figure 5.** New knowledge generation capability composite indicator (average of three variables) and GDP per capita in 16 Polish regions



Source: own calculations based on data sources indicated in Table 1.

The analysis of the relationship between new knowledge generation capabilities and GDP *per capita* conducted separately for each of the periods: 2003–2004 and 2012–2013, has also returned higher  $R^2$  scores when composite indicators consisting of three instead of five variables have been used to measure the former. These results allow to conclude that the relationship between GDP *per capita* and new knowledge generation capabilities characterised by the level of R&D employment, R&D expenditures and number of patent applications, is most likely linear in nature.

## Conclusions

Economic growth is a process of long-term transformation shaped by the complex interactions between technology, economy, institutions and social factors. However, a considerable number of studies have shown that technological advancement may be one of the most important determinants of economic growth and development and the term “innovation capabilities” became widely used both in innovation research and policy.



According to one of the first contributors to the national innovation systems concept (Lundvall, 2010, p. 1), knowledge is considered to be the most fundamental resource in the modern economy, and acquiring it through learning the most important process. Therefore, creation of new knowledge should be considered the most crucial element of innovation capabilities of countries or regions.

Significant disparities in development levels can be observed between Polish regions. The aim of this paper was to look for the sources of these disparities in one of the aspects of regional innovation capabilities – capacity for new knowledge creation. Analysis results show that there is a strong positive relationship between regional differences in new knowledge generation capabilities and variations in GDP *per capita*. The relationship is stronger when one considers three aspects of new knowledge creation: R&D employment and R&D expenditures denoting inputs to the process and patenting activity representing its output. The share of units with R&D activity and number of utility model applications per million inhabitants has proven to have a lesser significance from the point of view of regional development level.

Also a time lag can be observed in the relationship between the regional differences in efforts to create new knowledge and the level of economic development. The observed relationship turned out to be stronger when past new knowledge generation effort and present regional economic performance was considered.

## References

- Abramovitz, M. (1986). Catching-up, Forging Ahead and Falling Behind. *Journal of Economic History*, 46(2). DOI: <http://dx.doi.org/10.1017/S0022050700046209>.
- Abramovitz, M. (1994). The Origins of the Postwar Catch-up and Convergence Boom. In J. Fagerberg, B. Verspagen & N. von Tunzelmann (Eds.). *The Dynamics of Technology, Trade and Growth*. Aldershot: Edward Elgar.
- Archibugi, D., & Coco, A. (2004). A New Indicator of Technological Capabilities for Developed and Developing Countries (ArCo). *World Development*, 32(4). DOI: <http://dx.doi.org/10.1016/j.worlddev.2003.10.008>.
- Archibugi, D., & Coco, A. (2005). Measuring Technological Capabilities at the Country Level: A Survey and a Menu for Choice. *Research Policy*, 34(2). DOI: <http://dx.doi.org/10.1016/j.respol.2004.12.002>.
- Archibugi, D., Denni, M., & Filippetti, A. (2009). The Technological Capabilities of Nations: The State of the Art of Synthetic Indicators. *Technological Forecasting & Social Change*, 76(7). DOI: <http://dx.doi.org/10.1016/j.techfore.2009.01.002>.

- Benhabib, J., & Spiegel, M. (1994). The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-country Data. *Journal of Monetary Economics*, 34(2). DOI: [http://dx.doi.org/10.1016/0304-3932\(94\)90047-7](http://dx.doi.org/10.1016/0304-3932(94)90047-7).
- Breschi, S., & Malerba, F. (1997). Sectoral Systems of Innovation: Technological Regimes, Schumpeterian Dynamics and Spatial Boundaries. In C. Edquist (Ed.). *Systems of Innovation*. London: Pinter Publishing.
- Carlsson, B., & Stankiewicz, R. (1991). On the Nature, Function and Composition of Technological Systems. *Journal of Evolutionary Economics*, 1(2). DOI: <http://dx.doi.org/10.1007/bf01224915>.
- Castellacci, F. (2003). A Neo-Schumpeterian Approach to Why Growth Rates Differ. *University of Oslo, Strategic University Programme – Globalisation as a Transformative Force. Working paper*, 04/03. August
- Castellacci, F., & Natera, J. M. (2013). The Dynamics of National Innovation Systems: A Panel Cointegration Analysis of the Coevolution Between Innovative Capability and Absorptive Capacity. *Research Policy*, 42(3). DOI: <http://dx.doi.org/10.1016/j.respol.2012.10.006>.
- Cerulli, G. (2014). The Impact of Technological Capabilities on Invention: An Investigation Based on Country Responsiveness Scores. *World Development*, 59. DOI: <http://dx.doi.org/10.1016/j.worlddev.2014.01.019>.
- Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, 35(1). DOI: <http://dx.doi.org/10.2307/2393553>.
- Cooke, P., Heidenreich, M., & Braczyk, H.-J. (Eds.) (1995). *Regional Innovation Systems: The Role of Governance in a Globalized World*. Routledge.
- Dosi, G., Pavitt, K., & Soete, L. (1990). *The Economics of Technical Change and International Trade*. London: Harvester Wheatsheaf.
- Edquist, C. (Ed.) (1997). *Systems of Innovation: Technologies, Institutions and Organisations*. London: Pinter.
- Faber, J., & Hesén, A. B. (2004). Innovation Capabilities of European Nations. Cross-national Analyses of Patents and Sales of Product Innovations. *Research Policy*, 33.
- Fagerberg, J. (1987). A Technology Gap Approach to Why Growth Rates Differ. *Research Policy*, 16(2-4). DOI: [http://dx.doi.org/10.1016/0048-7333\(87\)90025-4](http://dx.doi.org/10.1016/0048-7333(87)90025-4).
- Fagerberg, J. (1988a). International Competitiveness. *Economic Journal*, 98(391). DOI: <http://dx.doi.org/10.2307/2233372>.
- Fagerberg, J. (1988b). *Why Growth Rates Differ*. In G. Dosi, C. Freeman, R. R. Nelson, G. Silverberg, & L. Soete (Eds.). *Technical Change and Economic Theory*. London: Pinter.
- Fagerberg, J. (1994). Technology and International Differences in Growth Rates. *Journal of Economic Literature*, 32.
- Fagerberg, J. (2000). Technological Progress, Structural Change and Productivity Growth: a Comparative Study. *Structural Change and Economic Dynamics*, 11(4). DOI: [http://dx.doi.org/10.1016/s0954-349x\(00\)00025-4](http://dx.doi.org/10.1016/s0954-349x(00)00025-4).

- Fagerberg, J., & Godinho, M. M. (2005). Innovation and catching-up. In J. Fagerberg, D. Mowery, & R. Nelson (Eds.). *The Oxford Handbook of Innovation*. Oxford: Oxford University Press.
- Fagerberg, J., Srholec, M., & Knell, M. (2007). The Competitiveness of Nations: Why Some Countries Prosper While Others Fall Behind. *World Development*, 35(10). DOI: <http://dx.doi.org/10.1016/j.worlddev.2007.01.004>.
- Fagerberg, J., & Srholec M. (2008). National Innovation Systems, Capabilities and Economic Development. *Research Policy*, 37(9). DOI: <http://dx.doi.org/10.1016/j.respol.2008.06.003>.
- Fagerberg, J., & Srholec, M. (2013). Knowledge, Capabilities and the Poverty Trap: The Complex Interplay Between Technological, Social and Geographical Factors. In P. Meusburger, J. Glückler, & M. el Meskioui (Eds.). *Knowledge and the Economy*. Springer.
- Fagerberg, J., & Verspagen, B. (1996). Heading for Divergence? Regional Growth in Europe Reconsidered. *Journal of Common Market Studies*, 34(3). DOI: <http://dx.doi.org/10.1111/j.1468-5965.1996.tb00580.x>.
- Fagerberg, J., & Verspagen, B. (2002). Technology-gaps, Innovation-diffusion and Transformation: an Evolutionary Interpretation. *Research Policy*, 31(8-9). DOI: [http://dx.doi.org/10.1016/s0048-7333\(02\)00064-1](http://dx.doi.org/10.1016/s0048-7333(02)00064-1).
- Fagerberg, J., & Verspagen, B. (2003). Innovation, Growth and Economic Development: Why Some Countries Succeed and Others Don't. Paper prepared for the First GLOBELICS Conference: Innovation Systems and Development Strategies for the Third Millennium, Rio, 2-6 November.
- Filippetti, A., & Peyrache, A. (2011). The Patterns of Technological Capabilities of Countries: A Dual Approach using Composite Indicators and Data Envelopment Analysis. *World Development*, 39(7). DOI: <http://dx.doi.org/10.1016/j.worlddev.2010.12.009>.
- Freeman, C., Clark, J., & Soete, L. (1982). *Unemployment and Technical Innovation: A Study of Long Waves and Economic Development*. London: Frances Printer.
- Freeman, C. (1987). *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter.
- Freeman, C. (2002). Continental, National and Sub-national Innovation Systems – Complementarity and Economic Growth. *Research Policy*, 31(2). DOI: [http://dx.doi.org/10.1016/s0048-7333\(01\)00136-6](http://dx.doi.org/10.1016/s0048-7333(01)00136-6).
- Furman, J. L., & Hayes, R. (2004). Catching up or Standing Still? National Innovative Productivity among “Follower” Countries, 1978–1999. *Research Policy*, 33(9).
- Furman, J. L., Porter, M. E., & Stern, S. (2002). The Determinants of National Innovative Capacity. *Research Policy*, 31(6). DOI: [http://dx.doi.org/10.1016/s0048-7333\(01\)00152-4](http://dx.doi.org/10.1016/s0048-7333(01)00152-4).

- Goo, Y., & Park, H. (2007). Economic Growth and Convergence with International Differences in Technology. *Journal of Macroeconomics*, 29(1). DOI: <http://dx.doi.org/10.1016/j.jmacro.2005.04.007>.
- GUS (2006). *Nauka i technika w 2004 roku. Informacje i opracowania statystyczne*. Warszawa: GUS.
- GUS (2007). *Nauka i technika w 2005 roku. Informacje i opracowania statystyczne*. Warszawa: GUS.
- GUS (2008). *Nauka i technika w 2006 roku. Informacje i opracowania statystyczne*. Warszawa: GUS.
- GUS (2009). *Nauka i technika w 2007 roku. Informacje i opracowania statystyczne*. Warszawa: GUS.
- GUS (2010). *Nauka i technika w 2008 roku. Informacje i opracowania statystyczne*. GUS, US w Szczecinie. Warszawa: GUS.
- GUS (2011). *Nauka i technika w 2009 rok. Informacje i opracowania statystyczne*. GUS, US w Szczecinie. Warszawa: GUS.
- GUS (2012a). *Nauka i technika w 2010 roku. Informacje i opracowania statystyczne*. GUS, US w Szczecinie. Warszawa: GUS.
- GUS (2012b). *Nauka i technika w 2011 roku. Informacje i opracowania statystyczne*. GUS, US w Szczecinie. Warszawa: GUS.
- GUS (2013). *Nauka i technika w 2012 roku. Informacje i opracowania statystyczne*. GUS, US w Szczecinie. Warszawa: GUS.
- GUS (2014). *Nauka i technika w 2013 roku. Informacje i opracowania statystyczne*. GUS, US w Szczecinie. Warszawa: GUS.
- Hasan, I., & Tucci, C. L. (2010). The Innovation–economic Growth Nexus: Global Evidence. *Research Policy*, 39(10). DOI: <http://dx.doi.org/10.1016/j.respol.2010.07.005>.
- Hollanders, H., & El-Sadki, N. (2013). *Innovation Union Scoreboard 2013*. European Commission, Enterprise and Industry.
- Hollanders, H., Rivera, L., & Roman, L. (2012). *Regional Innovation Scoreboard 2012*. European Commission, Enterprise and Industry.
- Huggins, R., & Davies W. (2006). *European Competitiveness Index 2006-07*. Robert Huggins Associates Ltd.
- Keller, W. (1996). Absorptive Capacity: On the Creation and Acquisition of Technology in Development. *Journal of Development Economics*, 49(1). DOI: [http://dx.doi.org/10.1016/0304-3878\(95\)00060-7](http://dx.doi.org/10.1016/0304-3878(95)00060-7).
- Kim, L. (1997). *Imitation to Innovation: The Dynamics of Korea's Technological Learning*. Harvard: Harvard Business School Press.
- Lall, S. (1992). Technological Capabilities and Industrialization. *World Development*, 20(2). DOI: [http://dx.doi.org/10.1016/0305-750x\(92\)90097-f](http://dx.doi.org/10.1016/0305-750x(92)90097-f).
- Lundvall, B.-Å. (1985). *Product Innovation and User–Producer Interaction*. Aalborg: Aalborg University Press.
- Lundvall, B.-Å. (1988). Innovation as an Interactive Process: From User-producer Interaction to the National Systems of Innovation. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, & L. Soete (Eds.). *Technical Change and Economic Theory*. London: Pinter.

- Lundvall, B.-Å., Johnson, B., Andersen, E. S., & Dalum, B. (2002). National Systems of Production, Innovation and Competence Building. *Research Policy*, 31(2). DOI: [http://dx.doi.org/10.1016/s0048-7333\(01\)00137-8](http://dx.doi.org/10.1016/s0048-7333(01)00137-8).
- Lundvall, B.-Å. (2007). National Innovation Systems – Analytical Concept and Development Tool. *Industry and Innovation*, 14(1). DOI: <http://dx.doi.org/10.1080/13662710601130863>.
- Lundvall, B.-Å. (Ed.) (2010). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishing.
- Nelson, R. R. (Ed.) (1993). *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.
- OECD (2005). *Oslo Manual, Guidelines for Collecting and Interpreting Innovation Data*. European Commission, OECD.
- Papageorgiou, C. (2002). Technology Adoption, Human Capital and Growth Theory. *Review of Development Economics*, 6(3). DOI: <http://dx.doi.org/10.1111/1467-9361.00160>.
- Saisana, M. & Tarantola, S. (2002). *State-of-the-art Report on Current Methodologies and Practices for Composite Indicator Development*. European Commission, Joint Research Centre.
- Schwab, K. (Ed.) (2012). *The Global Competitiveness Report 2012-2013*. World Economic Forum.
- Sharif, N. (2006). Emergence and Development of the National Innovation Systems Concept. *Research Policy*, 35(5). DOI: <http://dx.doi.org/10.1016/j.respo.1.2006.04.001>.
- Stokke, H. (2008). Productivity Growth and Organizational Learning. *Review of Development Economics*, 12(4). DOI: <http://dx.doi.org/10.1111/j.1467-9361.2008.00445.x>.
- Verspagen, B. (1991). A New Empirical Approach to Catching up or Falling Behind. *Structural Change and Economic Dynamics*, 2(2). DOI: [http://dx.doi.org/10.1016/s0954-349x\(05\)80008-6](http://dx.doi.org/10.1016/s0954-349x(05)80008-6).