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Research and Development and Economic Growth: EU Port Regions[*1]

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Abstract

Investment in research and development (R&D) creates preconditions for the implementation of more advanced and better technologies. It enables the introduction of new products or production processes which can result in higher earnings and potential economic growth. Even though research and development is a catalyst for the genesis of aggregate economic activity, its importance is not widely researched at regional levels. The European Union has defined strategies which view innovation as an essential element in stimulating growth and job creation. The aim of this paper is to establish and measure the impact of investment in R&D on economic growth of port regions. The data used in this research were panel data of the European Union's port regions for NUTS 2 classification for the period from 2005 to 2015. The results of the two-step Generalized Method of Moments (GMM) indicate that investment in R&D has a significant impact on the economic growth of the port regions in European Union. However, in order for innovations to be accepted and implemented, it is also necessary for regions to have specific economic structure which was further analyzed in this paper. Regions

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with high innovation capacity create greater economic benefits and are considered to grow faster than other regions.

Key words: *economic growth, investment in R&D, port regions, European Union*

JEL classification: *R11, O31*

1. Introduction

Investment in research and development (R&D) is mostly associated with the development of new technologies; however, it can also be associated with small discoveries that improve a business process or society in general. It allows the introduction of new products or processes which consequently lead to higher revenues and growth. The European Union puts innovation in the center of its strategies for encouraging growth and job creation and has thus developed a special strategy called the Innovation Union. The strategy encourages member states to invest 3% of their GDP in research and development by 2020. An investment of 1% is expected from the public sector and 2% from the private sector, envisaging the creation of 3.7 million jobs and a higher GDP of the European Union by 800 billion Euros (European Union, 2019).

Endogenous growth theory based on R&D highlights the importance of investment in research and development as a driver of economic growth. This theory forms the basis of the research in this paper. Furthermore, the endogenous growth theory advocates that changes in some variables of economic policy permanently affect long-term economic growth rates. The main motive for researching long-term growth is to find out why some regions are richer and some poorer. In general, very small changes in the long-term rate of economic growth can cause significant differences in the standards of living. The purpose of this paper is to find new evidence on what stimulates economic growth of port regions. The main hypothesis of the research is: Investment in R&D affects the growth of the regional economies of port regions. The rest of the paper is organized as follows: Section 2 gives literature review, Section 3 discuses used methodology, Section 4 describes the empirical data and variables and explains the model formulation. Section 5 discuses results and Section 6 gives concluding remarks.

2. Literature review

Traditional economic approach connects economic growth with investments in transport infrastructure. It suggests that the services provided by the transport infrastructure positively affect the productivity of the industry in various ways. The main positive effects include smaller transportation costs and shorter time of transportation which in turn may lead to many other positive effects such as

growth in trade, competitiveness, better access to foreign goods, lower production costs and exploitation of economies of scale (Aschauer, 1989; Bottasso *et al.*, 2014). Furthermore, lower transportation costs and better transport availability may increase the market potential of different regions (Niebuhr, 2006; Condeço-Melhorado *et al.*, 2011). Recent papers argue that the relationship of investment in transport infrastructure and economic growth is not so strong (Crescenzi and Rodríguez-Pose, 2012).

Song and van Geenhuizen (2014) researched the impact of port infrastructure investments on China's regional economic growth. In their research they demonstrated that the good location of Chinese seaports showed that China had invested heavily in seaport infrastructure. They concluded that investment in seaport infrastructure, the spillover effects from adjacent regions and international connectivity had a positive impact on China's regional economic growth. Park and Seo (2016) researched the economic impacts of seaports on Korean regions using an augmented Solow model. The research showed that seaports with insufficient freight traffic hinder regional economic growth (mostly small seaports), whereas those with sufficient freight traffic, contribute to regional economic growth. Furthermore, they showed that container port activities had a positive effect on regional economic growth, and that port investments indirectly lead to economic growth, i.e. it is necessary to invest in ports that are successful and that have sufficient freight traffic, otherwise these investments do not lead to improvement. Bottasso *et al.* (2014) researched the impact of port activity on regional GDP of European regions, with an emphasis on its spillover effects on neighboring regions. Empirical findings indicate that ports tend to increase the GDP in their area and that there are large and positive spillovers on the GDP of nearby regions. Furthermore, the impact of seaports on the host city's economic development was researched by Shan et al. (2014). They concluded that freight traffic at a seaport significantly affects the economic growth of the city in which it is located. In addition to this, they found that containerized freight traffic in larger seaports had greater impact on the economy than that of smaller seaports and, counter-intuitively, that freight traffic from competing seaports had a positive impact on the city's economy.

Crescenzi and Rodriguez-Pose (2012) researched the extent to which transport infrastructure affected regional economic growth in the European Union between 1990 and 2004. The research was partly based on the endogenous growth theory. The results of the two-step GMM indicate that the infrastructure (represented by the road network) is a relatively poor predictor of economic growth and that the European Union's regional economic growth came about as a result of a combination of an adequate social filter, sufficient investment in R&D, and the region's ability to attract migrants. The authors concluded that there is no significant relationship between investment in infrastructure and regional economic growth, and that the funds should be redirected towards investment in human capital and R&D.

Bilbao-Osorio and Rodriguez-Pose (2004) researched the impact of investment in R&D on the development of innovations and the impact of innovations on economic growth of European Union's regions. They explained that along with the investment in R&D, certain socio-economic preconditions should be met for a successful implementation of new ideas. The preconditions encompass a relatively high employment of the population, since the unemployed are less prone to innovating, a high level of human capital, i.e., good educational achievements and a certain economic structure of the region. The economic structure refers to the predominant activity of the region, that is, agricultural regions will be less prone to innovations than regions that deal with specific service and production activities. The results indicate a significant relationship between investment in R&D and innovation, although there is a difference among the various research sectors (private, public and higher education). More specifically, the private sector's research activities are a more significant predictor of innovation than that of other sectors. The link between innovation and economic growth is present in peripheral regions, but does not exist in non-peripheral ones. The authors concluded that in addition to investments in R&D, other factors should also be considered to understand the process of economic growth in the European Union's regions.

Crescenzi (2005) proposed a model showing the relationship between innovation and growth in the regions of the European Union. In the theoretical part, the author set the hypothesis that different innovation activities lead to different economic effects. He calculated his own innovation index and introduced it into the regression analysis. The results showed that innovation activities play an important role in defining regional growth. It was also concluded that innovative activities in peripheral areas must be supported by large investments in human capital for them to be as productive as those in central areas. The importance of investment in R&D is becoming more and more important; therefore, in this paper the impact of investment in R&D on the economic growth was examined on the sample of port regions of the European Union, a topic which has not been previously researched and aims to give new insights into the specific characteristics of the port regions.

3. Methodology

The endogenous growth theory based on R&D serves as a theoretical framework for researching the factors encouraging economic growth. The theory's development began with the model proposed by Paul Romer (1990) founded on Schumpeter's (1942) ideas and it advocates the importance of investment in R&D, as the main driver of economic growth. After Romer, similiar models were also developed by Grossman and Helpman (1990 and 1991) and Aghion and Howitt (1992). The theory rejects assumptions about diminishing returns and convergence, which form the core of neoclassical models; namely, it considers that convergence does not

have to occur at all, i.e. rich countries can continually improve their standard of living, while poor countries can remain poorly developed forever. This is caused by constant development of new ideas.

The economic impact of investment in R&D on regional economies is researched using panel data analysis, which is an increasingly used method in economic research since it allows for testing more complex econometric models and greater data coverage. For model testing purposes, the two-step GMM is applied. This method was created by Arellano and Bond (1991) and then modified by Blundell and Bond (1998). The gross domestic product per capita, expressed in purchasing power standard (PPS), is used as the indicator of regional economies' growth. As the growth of GDP per capita is strongly related to its previous values, it is necessary to apply a dynamic panel data analysis. Expressing GDP in purchasing power standards eliminates differences in price levels between regions while per capita values allow for comparisons of economies and regions that are significantly different in size (European Commission, 2018e).

In order to investigate the relationship between regional economic growth and R&D as well as the other factors described above, a dynamic panel analysis model is introduced with the basic form as follows:

$$Regional\ Growth_{it} = \beta_0 + R\&D_{it} + Control_{it} + \lambda_t + u_{it} \tag{1}$$

where *Regional Growth* is an indicator of the regional economic growth of the European Union's port regions, *R&D* the main independent variable that involves investment in R&D in each particular region over the years, and *Control* representing the set of previously described control variables. λ_t represents the time effects, u_{it} the error term, while i represents each region and t the time period.

A more detailed specification of the model reads:

$$\begin{aligned} \ln GDPpc_{it} = {} & \beta_0 + \beta_1 \ln GDPpc_{it-1} + \beta_2 RD_{it} + \beta_3 Unempl_{it} + \beta_4 Pop_{it} + \\ & + \beta_5 Open_{it} + \beta_6 Transport_{it} + \lambda_t + u_{it} \end{aligned} \tag{2}$$

where $\ln GDPpc_{it}$ is the logarithm of the gross domestic product per capita for the region i and time t, $\ln GDPpc_{it-1}$ is the logarithm of the gross domestic product per capita for the region i and time t–1, RD_{it} is the value of investment in R&D for the region i and time t, $Unempl_{it}$ is an indicator of unemployment for the region i and time t, Pop_{it} is an indicator of the population change for the region i and time t, $Open_{it}$ is an indicator of trade openness for the region i and time t, and $Transport_{it}$ is an indicator of investment in transport infrastructure for the region i and time t. λ_t represents the time effects, u_{it} is the error of the relation, and β_1, β_2, β_3, β_4, β_5 and β_6 are the coefficients.

The logarithmic transformation of variables is a routine process in business and economic literature, including literature on maritime economics (Cheung and Yip, 2011; Bottasso *et al.*, 2014; Shan *et al.,* 2014; Song and van Geenhuizen, 2014). It takes into account the possibility of a nonlinear relationship between economic growth and explanatory variables.

4. Empirical data and analysis

4.1. Data

For the purposes of this research, secondary panel data were collected from Eurostat (European Commission, 2018a, 2018b, 2018c, 2018d, 2018e, 2018f) for the period from 2005 to 2015, enabling the authors to define 107 port regions based on quantified freight transport data. The port regions have been chosen as a sample because it is assumed that in the operation of seaports it is necessary to invest in new technologies. Data aggregation level is NUTS 2 classification. Countries whose regions were included in the research are as follows: Belgium, Bulgaria, Denmark, Germany, Estonia, Ireland, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Malta, Netherlands, Poland, Portugal, Romania, Finland, Sweden and the United Kingdom. Greece and Slovenia are excluded from the research because their data on R&D investment is not available.

4.2. Variables

In order to research the impact of R&D on regional economies, a regression model is formulated. The dependent variable of the regression model is the economic growth of European Unions's port regions. Following the literature (Bilbao-Osorio and Rodriguez-Pose, 2004; Crescenzi and Rodríguez-Pose, 2012; Bottasso *et al.*, 2014; Shan *et al.*, 2014; Jouili, 2016; Park and Seo, 2016), GDP per capita (GDPpc) is used as a dependent variable. Independent variables include investment in R&D (RD), as the main independent variable, and a set of control variables that are linked to regional economic growth. The control variables include the unemployment level (Unempl), population change (Pop), trade openness (Open) and investment in transport infrastructure (Transport). The list of all variables can be seen in the following table.

Table 1: List and explanation of variables

Dependent variable	Description	Formulation
GDPpc	Gross domestic product per capita	Expressed in purchasing power standards – PPS (in EUR)
Independent variable	Description	Formulation
RD	Investment in research and development	% of GDP
Control variables	Description	Formulation
Unempl	Unemployment rate	% of unemployed in total work force
Pop	Population change	% of total population change per 1000 persons
Open	Trade openness	% of imports and exports in GDP
Transport	Investment in transport infrastructure	% of GDP

Source: Summarized by the authors

All of the data required for model testing were available at NUTS 2 level, with the exception of trade openness and investment in transport infrastructure that were self-executed. Namely, trade openness in Eurostat is only available at country level, therefore, in order to calculate its values for individual regions, the first step was to determine the share of GDP per capita for each NUTS 2 region in the total GDP per capita and then multiply the share of GDP per capita with the value of a country's trade openness. The same principle was applied for data on investment in transport infrastructure. Eurostat data on investment in R&D are data for which relatively many values are missing, hence some missing values (where methodologically possible), have been calculated by linear interpolation.

4.3. Descriptive statistical analysis

The following table presents descriptive statistics for each individual variable.

Table 2: Descriptive statistics of variables

Variable	No of observations	Mean	Standard deviation	Minimum	Maximum
GDPpc	1,175	25,269.19	7,617.80	7,100.00	59,500.00
RD	1,136	1.39	1.02	0.06	5.44
Unempl	1,161	9.26	5.55	2.00	37.00
Pop	1,167	4.27	7.35	-28.90	54.80
Open	1,175	14.67	37.31	0.82	325.86
Transport	1,173	0.28	0.50	0.03	3.70

Source: Authors' calculations

Since data are observed for 107 regions over a period of 11 years (from 2005 to 2015), the maximum number of observations is 1,177. Looking at the number of observations for each variable separately, it can be seen that most variables have almost all data available with some missing values. The least amount of data was found for investment in R&D (1,136), i.e. 41 observations are missing. The standard deviation shows higher variations in GDP per capita, suggesting that there are significant differences between the development of the various port regions. Some of the observed European Union's port regions are more or less economically developed compared to others. Trade openness has a relatively high standard deviation as well, which points to the differences between the percentage of imports and exports in GDP in different port regions. The smallest number of standard deviations are reported for the investment in R&D variable and the investment in transport infrastructure variable, which was expected since investment ratios do not change drastically over the years and within regions. Before formulating and testing the model, the correlation between the variables was verified. The table below shows the correlation coefficients of variables.

Table 3: Correlation coefficients

	ln GDPpc	RD	Unempl	Pop	Open	Transport
ln GDPpc	1					
RD	0.53	1				
Unempl	-0.36	-0.25	1			
Pop	0.30	0.15	-0.16	1		
Open	-0.07	-0.07	-0.02	-0.07	1	
Transport	-0.14	-0.04	0.02	-0.22	0.76	1

Source: Authors' calculations

As a threshold for the presence of correlation, the positive or negative correlation higher than 0.80 was used (Lovrić, 2005). None of the correlation coefficients were greater than 0.80 nor lower than -0.80, which indicates the absence of multicollinarity. The higher correlation between the Transport and Open variables (0.76) indicates a medium strong correlation between these variables, which was expected due to the high interconnection between foreign trade and transport infrastructure.

4.4. Empirical analysis

Before carrying out the regression analysis, the tests for autocorrelation and the validity of the instruments were conducted. The test results are shown in the lower part of Table 4. The Arellano-Bond test on the serial correlation in the first-difference residuals rejects the hypothesis of the absence of serial correlation of the first order, which is desired. However, the hypothesis cannot be rejected for higher orders, which is desired as well. This allows excluding the presence of residual serial correlation errors. The null hypothesis of the Hansen's test states that the instruments are valid or that the instruments are uncoordinated with the stochastic error of the model, which is confirmed by a p-value greater than 0.05.

Investment in R&D is expected to have a positive impact on economic growth. In terms of control variables, it is expected that unemployment will negatively affect economic growth, as well as the population change because the dependent variable in the model is GDP per capita; therefore, if population increases, GDP per capita will decrease. When it comes to the openness of the economy and investment in transport infrastructure, as well as for GDP per capita from the previous year, a positive impact is expected. The testing of the model was performed in the program package STATA. The model results are shown in the following table.

Table 4: The test results of the model

Variables	*ln* GDPpc	*ln* GDPpc	*ln* GDPpc
L.*ln* GDPpc	0.957***	0.956***	0.959***
	(0.0152)	(0.0145)	(0.0149)
RD	0.00832**	0.00906**	0.00837***
	(0.00338)	(0.00365)	(0.00322)
Unempl	-0.00182***	-0.00176***	-0.00174***
	(0.000317)	(0.000324)	(0.000317)
Open	0.000113**	0.000108**	9.58e-05**
	(5.05e-05)	(4.39e-05)	(4.04e-05)
Pop	-0.000612***	-0.000653***	-0.000634***
	(0.000206)	(0.000231)	(0.000240)

Variables	*ln* GDPpc	*ln* GDPpc	*ln* GDPpc
Transport	-0.00208		
	(0.00421)		
L.Transport		-0.00186	
		(0.00348)	
L2.Transport			-0.000823
			(0.00399)
Time effects included	Yes	Yes	Yes
Constant	0	0	0
	(0)	(0)	(0)
Observations	1035	1034	1031
Number of regID	107	107	107
Hansen test (p-value)	1.000	1.000	1.000
AR (1) test (p-value)	0.000	0.000	0.000
AR (2) test (p-value)	0.739	0.761	0.810

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Source: Authors' calculations

From the perspective of endogenous growth theory, creating new knowledge and ideas is considered a key driver of long-term growth, productivity and revenue. The variable that proxies research and development is investment in R&D. As with any other proxy variables, there are limitations to be considered when describing the results of the research. Investment in R&D can have a heterogeneous impact over time. For example, large investments in new areas can become profitable only after a long period of time. On the other hand, investment in existing products and processes, that are not necessarily linked to formal research and development, can produce significant economic effects (Crescenzi and Rodríguez-Pose, 2012: 14). These effects limit the possibility of a full assessment of the impact of R&D investment on regional economic growth.

The results indicate that investments in R&D have a positive impact on economic growth with a 5% statistical significance. If investment in R&D increases by 10 percentage points, regional economic growth will increase, on average, by 0.0832%. All control variables are statistically significant and carry expected signs except the investment in transport infrastructure variable. Consideration should be given to the time lag needed for an investment in transport infrastructure to have an impact on the growth of the economy. Therefore, lag variables with one and two lags were introduced to the model; however, even with this improvement, the variable that represents transport infrastructure remained insignificant. The obtained results failed to identify solid evidence on the relationship between transport infrastructure

and economic growth at regional level. The reason behind this, might be in the possibility that a good infrastructure level is the result of a successful economy, and not its cause. Or in other words, a good transport infrastructure can be a factor that follows the process of regional growth; therefore, it is not its driver.

5. Results and discussion

Through innovation processes, resources gain new features, new activities are generated and new values are created. This process transforms knowledge into a new value, and new value becomes a source of competitiveness in dynamic markets (Sundać *et al.,* 2016: 123). It is considered that economies that create new ideas will not reach the point of saturation in which economic growth stagnates. Technology improves rapidly and becomes a fundamental catalyst for economic growth. The regions with the highest technological capacity create greater economic benefits associated with changes in production methods and market demand. Therefore, it is considered that the regions that are intensively investing in research and development will grow faster than other regions, not only because of high technology-related yields, but also because of the effects of multipliers created by innovation centers and their assimilation capabilities for new technological achievements (Rodríguez-Pose, 1999: 76). Technological knowledge does not disappear after use; it is accumulated and serves as a foundation for creation of yet new knowledge. It can also cause spillovers from areas where it is created to other nearby areas.

An example of the implementation of new technologies into port regions and seaports is the usage of cloud technology in seaport business operations. Ports and terminals are mostly connected and are trying to find the most efficient ways to automatize their processes; therefore, one of the solutions could be the usage of clouds. A platform for planning routes that is cloud-based enables users to share information in real time. Cloud connectivity also provides a platform for Internet of Things (IoT) operating systems, enabling communication within ports as well as between ports (Port Technology, 2018). Furthermore, seaports and logistics are considered eligible for implementation of blockchain technology due to the large number of participants involved in logistic processes. Blockchain technology can be used for storing and transmitting freight documentation, thereby ensuring accurate and consistent information about freight documentation across the logistics chain. It could ensure visibility of all processes that can lead to better coordination among all participants. This would be especially important for third parties located outside seaports like banks and insurance companies who would have better insight into logistics processes and could reduce bottlenecks resulting from sequential activities such as commercial approvals (Francisconi, 2017). The use of drones is another example of implementation of new technologies into seaport business. Drones

are primarily used to monitor and control gas emissions, since it is easier to reach vessels at sea with drones (Xia e*t al.* 2019:174). However, they can be used in the logistics process as well as to perform smaller logistical operations of package delivery and warehouse management.

Creating new ideas and technological development largely depends on cultural and organizational factors. Not all areas are prone to innovation. Furthermore, there are certain social characteristics that are favorable for encouraging and accepting innovations. Rodríguez-Pose (1999:80) explains that there are different "social filters" in different regions that create different prerequisites for implementing innovation in economic activity. Some of the prerequisites include demographic and educational achievements, unemployment and the economic structure of areas that have different, positive or negative impacts on the development and implementation of innovations. Educational achievements are closely connected to R&D because regions need to have a qualified human capital that will accept and implement innovations. The low level of employment is negatively linked to the readiness to innovate because the employed population is more willing to learn and introduce change than the unemployed (Rodríguez-Pose, 1999:96). The predominantly agricultural regions will have a smaller tendency to innovate since the agricultural sector, as a whole, does not show tendencies towards innovation as do some other sectors (Bilbao-Osorio and Rodriguez-Pose, 2004:438). Contrary to this, regions engaged in specific manufacturing and service sectors are more prone to innovation, particularly regions relying on technologically advanced sectors such as the maritime sector.

6. Conclusions

Innovation is a collective learning and a socially integrated process; therefore, there is a relationship between innovations and the regions in which they take place. Social, cultural and institutional preconditions of regions are an important element of a successful innovation process. At the same time innovations are the key source of competitive advantage for the respective regions. The development of new ideas is in accordance with the endogenous growth theory, which considers it as the main factor encouraging economic growth. It avoids the diminishing returns and leads to constant growth of the economy. Regions should put in efforts in developing new ideas but, at the same time, should create a proper climate for the development and implementation of new ideas. The main hypothesis of this research was confirmed since a significant relationship between investment in R&D and economic growth in port regions was found. Therefore, the empirical research shows the importance of developing new ideas and provides new findings about what generates growth in European Union port regions. However, there are some research limitations to this study, foremost, the available data where, in general, the data on aggregate level

are more complete opposed to data on regional level. Research limitations can also be defined within the used variables that form the research model. For example, innovation can be represented by different proxy variables such as the number of patents in a region or by calculating a new innovation index, if data availability allows it. The success of seaports largely depends on implementation of up-to-date technologies and adaptation to new trends; therefore, further research could be more focused on the operations of the seaports themselves and the impact they have on regional economic growth from the perspective of endogenous growth theory based on R&D.

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Istraživanje i razvoj i gospodarski rast: lučke regije EU[1]

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Sažetak

Ulaganje u istraživanje i razvoj stvara preduvjete za primjenu naprednije i bolje tehnologije. Omogućuje uvođenje novih proizvoda ili proizvodnih procesa koji mogu rezultirati većom zaradom i potencijalnim ekonomskim rastom. Istraživanje i razvoj katalizator su za generiranje agregatnih ekonomskih aktivnosti, no njihova važnost nije široko istražena na regionalnoj razini. Europska unija definirala je strategije u kojima se inovacije smatraju bitnim elementom za poticanje rasta i otvaranje novih radnih mjesta. Cilj ovog rada je utvrditi i mjeriti utjecaj ulaganja u istraživanje i razvoj na gospodarski rast lučkih regija. Podaci korišteni u ovom istraživanju su panel podaci lučkih regija Europske unije za klasifikaciju NUTS 2 u razdoblju od 2005. do 2015. Rezultati generalizirane metode momenata (GMM) i njenog procjenitelja u dva koraka pokazuju da ulaganja u istraživanje i razvoj imaju značajan utjecaj na gospodarski rast lučkih regija u Europskoj uniji. Međutim, kako bi se inovacije usvojile i primijenile, također je potrebno da regije imaju određenu ekonomsku strukturu koja je dodatno analizirana u ovom radu. Regije s velikim inovacijskim kapacitetom stvaraju veće ekonomske koristi i smatra se da rastu brže od ostalih regija.

Ključne riječi: *ekonomski rast, ulaganja u istraživanje i razvoj, lučke regije, Europska unija*

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