

Olejnik, Alicja; Olejnik, Jakub

Conference Paper

Labor productivity growth in EU28: Spatial panel analysis

55th Congress of the European Regional Science Association: "World Renaissance: Changing roles for people and places", 25-28 August 2015, Lisbon, Portugal

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Olejnik, Alicja; Olejnik, Jakub (2015) : Labor productivity growth in EU28: Spatial panel analysis, 55th Congress of the European Regional Science Association: "World Renaissance: Changing roles for people and places", 25-28 August 2015, Lisbon, Portugal, European Regional Science Association (ERSA), Louvain-la-Neuve

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Labour Productivity Growth in EU28

- Spatial Panel Analysis

Alicja Olejnik
olejnika@uni.lodz.pl
University of Lodz

Jakub Olejnik
jakubo@math.uni.lodz.pl
University of Lodz

Working Paper

September 2015

Labour Productivity Growth in EU28 - Spatial Panel Analysis ¹

Alicja Olejnik
olejnika@uni.lodz.pl
University of Lodz

Jakub Olejnik
jakubo@math.uni.lodz.pl
University of Lodz

Abstract

This paper is an attempt to explain variations across EU regions in productivity growth and takes into consideration the important structure of the age-productivity relation of Human Capital. The study is fundamentally based on the theory of Fingleton's model which analyses the spatial process of productivity growth on the foundations of the theory of New Economic Geography. The applied specification links manufacturing productivity growth to the growth of manufacturing output by the means of Verdoorn's law. The model incorporates productivity-adjusted human capital understood as Total Human Capital Productivity corrected with age structure with the use of productivity as a function of age. The model has been tested through implemented methodology, namely a spatial panel model with fixed effects.

The model presented provides evidence of the importance of increasing returns to scale for regional economic growth, which lead to divergence effects for EU regions. Similar implications can be observed in the case of regionally differentiated human capital. Furthermore, the country fixed effects turned out to be significant.

Key words: spatial panel, productivity growth, Verdoorn's law, age-productivity curve

JEL: O40, J24, C21, C23

1. Introduction

New Economic Geography (NEG) presented mainly in Fujita, Krugman and Venables (1999) has significantly influenced the regional analysis of the concentration of economic

¹ Project financed by The National Science Centre grant, number: 2011/03/D/HS4/04305

activity, and in particular placed increasing returns processes in the mainstream of economics. However, the NEG theory is more a theoretical description of the real world than a ready formula for application. Nevertheless, recently the number of papers which take the new theory as a point of departure for their analysis is increasing (cf. Combes and Lafourcade 2001 and 2004, Combes and Overman 2003, Redding and Venables 2004, Fingleton 2005a, 2005b, 2006).

The aim of this paper is to analyse the spatial process of productivity growth in the European Union (EU) on the foundations of the theory of New Economic Geography. The presented model is based on the study of NUTS 2 regions and applies Fingleton's model of productivity growth which, in turn, is essentially founded on the NEG theory. Our work also takes into consideration a spatial weights matrix in order to better describe the spatial structure of the dependencies among the EU regions. Additionally, In our study we introduced productivity-adjusted human capital.

This paper is structured as follows. Section 2 introduces the theoretical background for our study. In Section 3 we present data used in the empirical analysis and variables description. Empirical results and discussion are presented in Section 4. Finally, Section 5 provides a summary and some concluding remarks.

2. The theoretical background

The theoretical background for the study is Bernard Fingleton's model (2001, 2004b) based on the New Economic Geography theory. By employing some simplifications he developed a spatial econometric model based on Verdoorn's Law (see Verdoorn 1949, Kaldor 1957) which links increase in productivity with increase in production. Verdoorn's law seems to be important in regional growth analysis as it embodies scale effects.

According to Fingleton the exponential growth rate of productivity is expressed by the following formula:

$$p = \lambda + [(\gamma - 1)/\gamma]q. \quad (1)$$

where p is the exponential growth rate of productivity (the amount of final good produced for the level of employment), λ is the rate of technical change, and q is the exponential

growth rate of the amount of final good produced. In the above equation the parameter $(\gamma-1)/\gamma$ is called *Verdoorn's coefficient*. According to the assumptions of Verdoorn's law this coefficient should be around 0.5 (cf. Bernat 1996, Fingleton and McCombie 1998, Fingleton 2004b, Fingleton and López-Bazo 2006).

In Fingleton's model the rate of technical progress λ is assumed to be an indication of the presence of technological externalities. The technical progress rate is modelled by the means of a function of socio-economic conditions characteristic for a specific region. Fingleton also assumes that the technical progress affect and is influenced by technical progress in neighbouring regions.

As a result, the technical progress rate varies by region instead of being an unmodelled constant. The technical progress rate (λ) is considered to depend on the terms: Human Capital (C), the Initial Level of Technology (G), the Spillover of Knowledge (S) and an autonomous rate which reflects 'learning by doing' which proceeds regardless of the other factors. On the basis of the above assumptions Fingleton introduced the following specification:

$$\lambda = b_0 + \rho S + b_1 C + b_2 G + \varepsilon. \quad (2)$$

Another assumption is that fast (slow) technical progress in neighbouring regions ($\mathbf{W}\lambda$) affects given region, which as a result, also experiences faster or slower technical progress respectively. Furthermore, the rate of technical progress in distant regions will have less impact, so that the set of neighbouring regions is important due to the spatially impeded knowledge flows. Therefore as notice by Fingleton the spillover of knowledge S is a spatially weighted rate of technical progress $S = \mathbf{W}\lambda$, where \mathbf{W} is an n by n spatial weight matrix reflecting the connectivity structure of the regions. Therefore:

$$\lambda = b_0 + \rho \mathbf{W}\lambda + b_1 C + b_2 G + \varepsilon. \quad (3)$$

In our study we suggest to modify technical progress stimulants. Let us notice that regional Human Capital stocks are determined not only by the Human Capital in a given region but also by the Human Capital in neighbouring regions represented by the spatial lag term $\mathbf{W}H$ embodying an average of neighbouring regions knowledge stocks:

$$C = b_1H + \varphi\mathbf{W}H. \quad (4)$$

This leads to the equation:

$$\lambda = b_0 + \rho\mathbf{W}\lambda + b_1H + \varphi\mathbf{W}H + b_2G + \varepsilon. \quad (5)$$

where $u \propto N(0, \sigma^2)$ is an error term capturing other unmodelled effects.

Combining (1) and the above equation one can obtain:

$$p = b_0 + \rho\mathbf{W}\lambda + b_1H + \varphi\mathbf{W}H + b_2G + [(\gamma - 1)/\gamma]q + \varepsilon. \quad (6)$$

Furthermore, after some basic algebra, since $\lambda = p - [(\gamma - 1)/\gamma]q$, we get:

$$\rho\mathbf{W}\lambda = \rho\mathbf{W}p - \rho\mathbf{W}([(\gamma - 1)/\gamma]q). \quad (7)$$

Finally, the exponential rate of productivity growth can be described by the formula:

$$p = b_0 + \rho\mathbf{W}p + b_1H + \varphi\mathbf{W}H + b_2G + b_3q - \rho[(\gamma - 1)/\gamma]\mathbf{W}q + \varepsilon. \quad (8)$$

The expression in (8) represents what has been dubbed a spatial Durbin Model (SDM) by Anselin (1988). Let us notice the nonlinear restriction on the set of parameters ie. the coefficient in front of $\mathbf{W}q$ is equal $\rho \cdot b_3$.

3. Determinants and Data

The exponential rate of productivity growth will be explained through Equation (8) described in theoretical background presented in section 2. In this final expression the exponential growth of labour productivity is explained by the productivity growth in neighbouring regions, human capital in this region, human capital in in neighbouring regions, the initial level of technology and the output in a given and nearby regions. We have tested a number of alternative proxies however we report the final ones with satisfying statistical properties.

The EU comprises 28 member states and 273 NUTS 2 regions. This study covers 261 regions of those excluding a number of French, Portuguese and Spanish regions due to their isolated position and Croatia because of the lack of comparable data. The eliminated

regions are: Réunion (FR), Guadeloupe (FR), Martinique (FR), Guyane (FR), Região Autónoma dos Açores (PT), Região Autónoma da Madeira (PT), Ciudad Autónoma de Ceuta (ES), Ciudad Autónoma de Melilla (ES), Canarias (ES), Jadranska Hrvatska (HR) and Kontinentalna Hrvatska (HR).

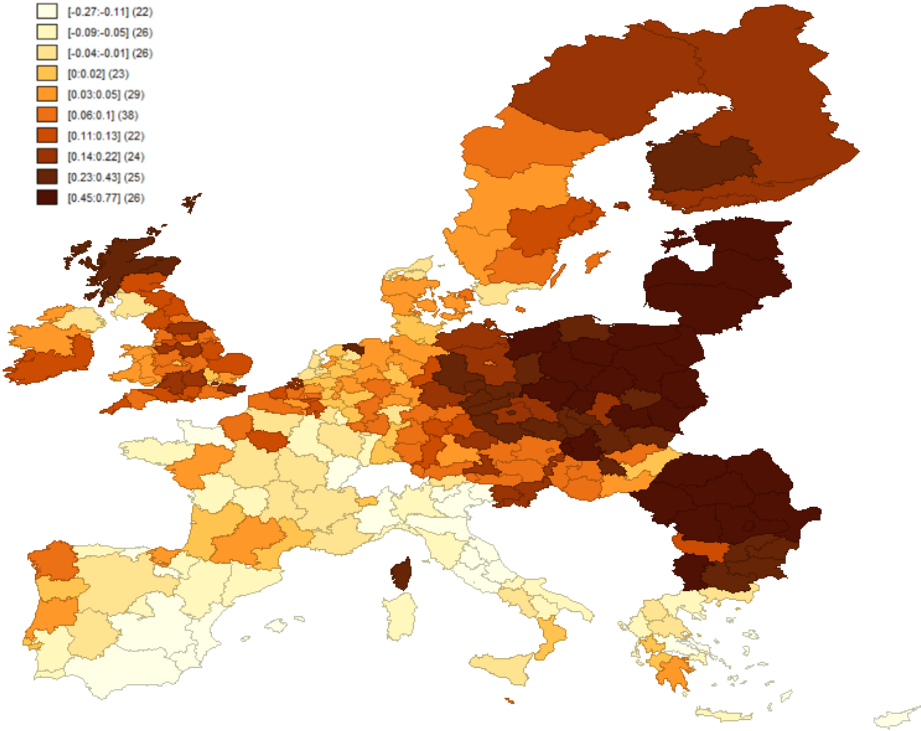
All data used in the empirical part of this study are published by Eurostat² and refer to the years 2000-2013. Some missing information was interpolated from the past trends and from data for NUTS1 level. Table 1 reports the essential description of the variables used in the study.

Table 1. Basic statistics of variables used in the model

<i>Variable</i>	<i>Mean</i>	<i>σ</i>	<i>Min</i>	<i>Max</i>
p	0.0901	0.1477	-0.2681	0.7683
q	0.1348	0.1210	-0.2416	0.7501
H	-0.0925	0.0891	-1.0022	0.5633
Hprod	-0.0583	0.0955	-0.9993	0.5824

² http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database - July 2015

Figure 1. Exponential change of labour productivity in EU NUTS 2 (year 2013/2000)



In our study the regional labour productivity is explained by the quotient of regional production over the number of *Economically Active Population* (L). The productivity growth (p) for the years 2001-2013 is approximated by the exponential change of regional productivity in these years to regional productivity in the initial year 2000: $p = \ln[(GDP/L)_t^i / (GDP/L)_{2000}^i]$, where $t=2001, \dots, 2013$ and $i=1, \dots, 261$.

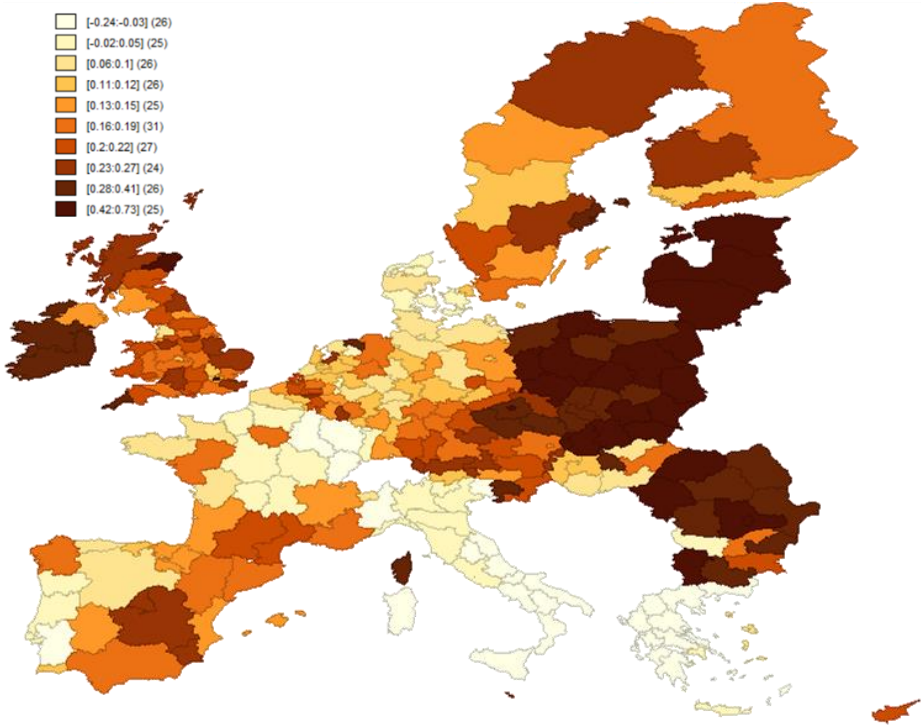
The regional GDP is expressed in millions of Euro in constant prices (year 2000), where *Economically Active Population* is in thousands of people at the age of 15 or over. The map shown in Figure 1 visualizes the distribution of the productivity growth in the European regions in the year 2013 compared to 2000.

It can be seen in the Figure 1 that there is a clear tendency towards clustering regions with similar productivity growth (positive spatial autocorrelation).³ The highest growth can be observed for regions of New European Union countries (after EU enlargement in May 2004) with the exception some regions of Hungary and Bulgaria. Let us notice that Sud-Vest Oltenia and Vest and Sud-Est regions in Romania have the highest productivity growth rate for years 2013/2000. Additionally, within the old EU countries the highest

³ Regions in light colours are close to region in dark colours.

productivity growth is observed for the Highlands and Islands and North Eastern Scotland region in Scotland in UK, Groningen in Northern Netherlands, French Corse, West Finland and some regions of East Germany: like Bayern, Brandenburg, Bremen and Sachsen-Anhalt.

Figure 2. The exponential change of regional production in EU NUTS 2 (year



2013/2000)

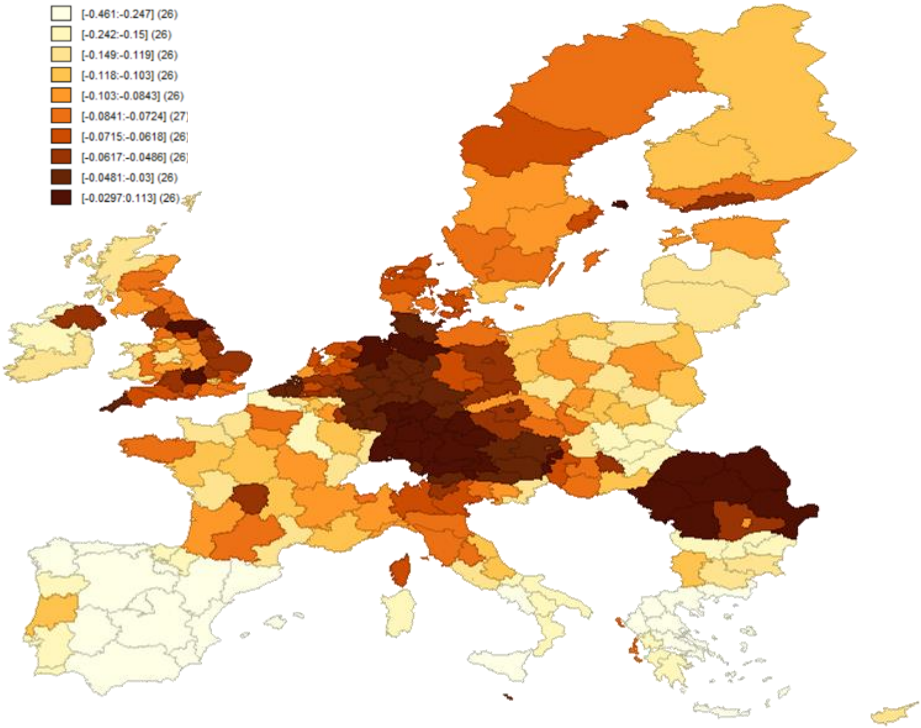
The exponential change of regional output is approximated by regional production in years 2001-2013 to the year 2000: $q = \ln \left[\frac{GDP_t^i}{GDP_{2000}^i} \right]$, where $t=2001, \dots, 2013$ and $i=1, \dots, 261$. Figure 2 presents visualization of the variable for the year 2013 to 2000. We expect positive impact of change of regional output on productivity with corresponding coefficient in our model being less than one (Verdoorn’s law). Furthermore according to the theory presented in Section 2 the effect of change of regional production in neighbouring regions on productivity growth is expected to be negative (expression: $[-\rho[(\gamma - 1)/\gamma]]$ in eq. (8)).

The Initial Level of Technology (G_0) represents the technological gap between the i -th region and the technology leader of the whole economy of EU. Since the assumed theory

is tested through the spatial panel model with spatial fixed effects the initial level of technology is incorporated in individual constants estimated for each region.

For the specification of the structure of the spatial effects we apply a row standardised spatial weights matrix \mathbf{W} (261×261) of the three nearest neighbours (3nn).

Figure 3. Natural logarithm of Human Capital in EU NUTS 2 (year 2013)



The Human capital (C) is explained by the Human Capital in a given region (H) and Human Capital in near locations (\mathbf{WH}). The former is approximated by the Employment in Technology and Knowledge-intensive Sectors (T) as a percentage of Economically Active Population (L): $H = \ln[(T/L)_t^i]$, where $t=2001, \dots, 2013$ and $i=1, \dots, 261$, and the latter by its spatial lag. We expect positive impact of Human Capital on productivity growth as well as positive spillover effect confirming benefits coming from knowledge intensive neighbours.

3.1 Age-Productivity Curve

Keeping in mind importance of knowledge in modern economies, the increasing role of innovations it seems to be reasonable to consider age-productivity relation as a part of

Human Capital which is supposed to describe the productivity process. As noticed by Skirbekk (2008) exceptional achievements do happen at early as well as late ages. For example 82 year old Johann Wolfgang von Goethe published 2nd part of Faust, James Watson made his greatest discovery of the DNA molecule at the age of 25.

As pointed out by Skirbekk (2008) studies of researchers, innovators and artists achievement suggest that productivity peaks in the 30s and 40s, with substantially lower output at younger and older ages, (e.g., journal article citations, Lehman, 1953; Cole, 1979; Simonton, 1988; Miller, 1999; Kanazawa, 2003; Oster and Hamermesh, 1998). Nobel Prize Laureates do their most important contributions in their 30s (Jones, 2005), however in the last century the most innovate age period seem to increase by about 6 years (Skirbekk, 2008). This could be due to a longer training period and due to the economic situation in the last decade, because of which the number of graduates of second and third level increased. At the same time the peak of entrepreneurial activity is between age 25 and 44.

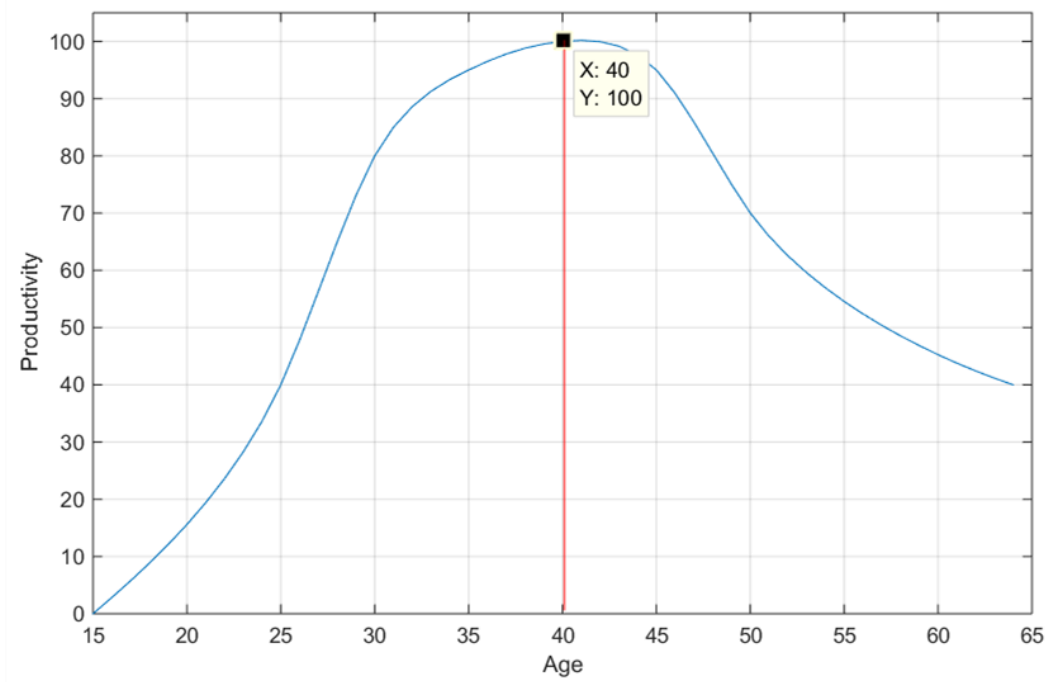
Based on the literature and findings of other studies of employer-employee data sets (i.a. Schneider, 2006; Prskawetz, 2005; Crépon *et al.*, 2002; Grund and Westergård-Nielsen (2005)) we established a set of critical points on a theoretical curve describing relation between age and productivity that constituted a repeating pattern in the suggestion made in above research papers. Then Radial Bases Function interpolation method with thin-plate spline was used. This resulted in the age-productivity curve presented in Figure 4. The age-productivity curve is a function which measures how people are productive at a certain age. It allows to describe how the work performance differs over the life period and thus allows for differences in age structure of employees in regions under research. Most importantly it productivity in jobs requiring problem solving and learning skills reaches a plateau for the 35-45 age bracket and has its peak around the age of 40.

In our study we included productivity-adjusted human capital understood as Total Human Capital Productivity corrected with age structure with the use of productivity as a function of age. Total Human Capital Productivity

$$H_{prod}(i, t) = \int_0^{\infty} H_{it}(A)p(A)dA$$

in a given region and time period, where $H(A)$ is a number of people employed in technology and science-intensive sectors at age A and $p(A)$ is a value of age-productivity function for age A .

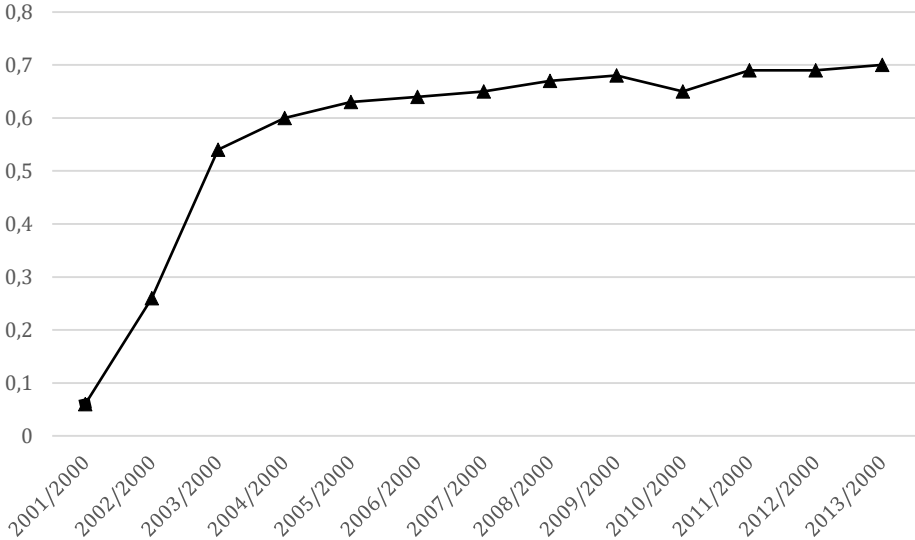
Figure 4. Age-Productivity Curve $p(A)$



4. Empirical results and discussion

The point of departure of the empirical part of the study was the analysis of spatial autocorrelation of the exponential productivity growth rate for all 261 regions for each year of the analysis. Figure 5 reports very strong spatial autocorrelation for the entire period of analysis. This means, that there is no random distribution in the change of productivity growth in the EU regions but regions with high productivity growth tend to have neighbours with comparable high growth, and at the same time regions with low productivity growth also cluster together. Let us notice that there is an increasing trend in the value of Moran's I , but at the same time spatial autocorrelation of the exponential change of labour productivity seems to reach long term stabilisation at a level ca. $I = 0.64$. The reported results are for the three nearest neighbours matrix spatial weights matrix, yet, for contiguity spatial weights matrix the outcomes were not significantly different.

Figure 5. Moran's I for productivity growth for years 2001-2013



NOTE: All (except for the year 2001/2000 - 10% significance level) reported Moran's I statistics are statistically significant at the 1% level.

The starting point of the econometric analysis was the following Spatial Durbin Panel Model:

$$p = b_0 + \rho \mathbf{W}p + b_1 H + \varphi \mathbf{W}H + b_3 q - b_4 \mathbf{W}q + \varepsilon. \tag{13}$$

where p represents the labour productivity growth, H – human capital and q – the growth of production for years 2000-2013. The empirical results covers the estimation of models with local spatial fixed effects (for 261 regions) and country spatial fixed effects (for 26 countries) in order to capture national-specific features.⁴ There were two specifications of each model as they differ according to the measure of human capital as they contain pure human capital and productivity-adjusted human capital. The empirical results of the estimation of the models are presented in Table 2.

Firstly, let us consider the estimation results reported in 1nd column which is the estimation results on the productivity model with local fixed effects. All the variables are highly significant (at 1% level), thus have statistically significant impact on the productivity growth in EU NUTS 2 regions.

⁴ The model was estimated with ML demeaned estimator for spatial panels.

Table 2. SDM estimation results

Models	Local FE 261		Local FE H_{prod}		Country FE 26		CountryFE H_{prod}	
	Coeff.	tstat	Coeff.	tstat	Coeff.	tstat	Coeff.	tstat
ρ	0.574	39.400	0.569	38.806	0.381	21.772	0.379	21.566
q	0.738	53.775	0.736	53.627	0.732	51.593	0.733	51.325
H	0.086	8.567	0.090	9.062	0.081	6.414	0.061	5.026
Wq	-0.420	-22.503	-0.417	-22.388	-0.280	-14.509	-0.276	-14.122
WH	0.127	8.395	0.133	8.855	0.094	4.790	0.077	4.196
Direct effect								
q	0.740	55.117	0.735	56.899	0.732	53.276	0.732	52.283
H	0.119	11.125	0.128	12.155	0.117	5.497	0.073	5.956
Indirect effect								
q	0.011	0.541	0.004	0.200	0.011	0.584	0.007	0.320
H	0.385	11.192	0.389	12.852	0.385	2.179	0.151	5.389
Total effect								
q	0.751	36.154	0.739	38.349	0.744	33.590	0.739	32.88
H	0.505	12.513	0.517	14.387	0.196	5.345	0.224	6.544
<hr/>								
\bar{R}^2	0.947		0.947		0.850		0.849	
pseudo R^2	0.922		0.924		0.823		0.821	
Corr ²	0.727		0.735		0.559		0.555	
φ^2	0.274		0.265		0.442		0.447	

The spatial autoregressive coefficient ρ is significant and equal to 0.57 which indicates that productivity growth in neighbouring regions have significant impact on the productivity growth in a given region. Let us notice that both production growth and relative employment in technology and knowledge-intensive sectors has significant and positive direct effects, therefore they also appear to determine the productivity growth confirming the theoretical assumptions. Moreover, direct effect of output growth is close to 0.74, which is similar to that reported in the literature - 0.5. Therefore, we conclude that increasing returns to scale do exist, and faster output growth induces faster productivity growth ($\gamma = -0,35$). In addition, employment in technology and science intensive sectors also stimulate faster productivity growth. Let us notice that though we did not put the restriction on parameter: $\rho[(\gamma - 1)/\gamma]$, it does fulfil this restriction up to 1% error.

The indirect effect for variable q (output growth) turns out to be insignificant. We can conjecture that this might be a result of two opposing relations present in the model.

Namely, the positive value of $-b_4$ suggests that an increase in output growth in neighbouring regions of a given region coincides with an decrease in productivity growth in the region, on the other hand, by $b_3 > 0$, the same increase in output growth 'results' in increase in productivity growth in the neighbouring regions. This, further results in an increase in productivity growth in the given region ($\rho > 0$). This phenomenon is amplified by the relation $\rho b_3 = b_4$. The significant indirect effect of human capital suggest the inclusion of spatially lagged human capital (as opposed to suggestions of Fingleton) into our model provides additional insight into the process of productivity growth. Region-specific time-invariant effects turned out to be significant for most of the regions.

Similar conclusions may be drawn for the country fixed effect model reported in the 3rd column of Table 3. Country-specific time-invariant effects turned out to be significant which means that national-specific effects are important in explaining the regional productivity growth. In contrast, time period-specific spatial-invariant effects are not significant in any of those models.

Second and fourth column of Table 3 reports models with productivity-adjusted human capital. Let us notice that in both models productivity-adjusted human capital is more significant than the pure human capital. This confirms that the age-structured productivity of economically active population employed in technology and knowledge-intensive sectors has even more significant impact on productivity growth than the initial human capital. Let us notice that the inclusion of productivity-adjusted human capital improved the performance of model estimates.

5. Conclusions

This paper is an attempt of assessing the productivity growth in EU regions for the period 2000-2013. The empirical model is fundamentally based on Fingleton's model which analyses the spatial process of productivity growth on the foundations of the theory of New Economic Geography and Endogenous Growth Theory. We have investigated the spatial productivity growth within the spatial setting provided by the spatial fixed effects panel model. Moreover, a new approach to defining the human capital, namely productivity-adjusted human capital has been presented and tested showing the improvement in the empirical model.

Concluding, the model presented provides evidence of the importance of increasing returns to scale for regional economic growth, which lead to divergence effects for EU regions. Similar implications can be observed in the case of regionally differentiated human capital. The significance of cross regional spillovers implies that the impact of policy instruments on the productivity growth in one region may effect productivity growth in neighbouring regions. We believe that more accurate description of driving forces of productivity growth plays important role in providing the information to put better policy recommendations and policy making leading to right economic decisions.

Let us notice that some data on the Economically Active population for Romania does not seem to be reliable. Therefore in further research they should be corrected or if it's not possible excluded from the study.

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