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Returns to Scale for EU Regions – evidence from the spatial panel model[1]

Abstract: Recent findings emphasise the importance of localised returns to scale for the regional growth as well as for the agglomeration processes. However, it is still not well established whether returns to scale are constant or increasing, and to what extent. Therefore, in this study we apply specification which describes the productivity growth with the growth of output through the Verdoorn's law. This study aims to provide some new estimates of the degree of returns to scale for EU regions. Our findings show that the hypothesis of increasing returns to scale is still valid in today's EU economy. To test the hypothesis, we have employed the Multidimensional Spatial Panel Durbin Model with Spatial Fixed Effects. The research is conducted for 261 regions of the EU 28. The paper concludes that increasing returns to scale in EU regions are substantial.

Keywords: increasing returns to scale, productivity growth, Verdoorn's law, spatial panel

JEL: O40, J24, R11, C23

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1. Introduction and theoretical background

In economic and statistical analysis of regional development of the European Union (EU), labour productivity modelling is recognised as a very important research direction. It is considered, among others, as a dynamic measure of economic growth and standard of living as well as competitiveness. Furthermore, it explains the principal economic foundations that are necessary for economic upswing as well as social development.

In the last years, the reception of New Economic Geography (NEG) (Fujita, Krugman, Venables, 1999) has transformed. The regional analysis of concentration of economic activities has pointed to increasing returns processes as one of the most important issues in economics. Returns to scale have been tested mainly by means of cumulative causation modelling as well as Verdoorn's Law (Verdoorn, 1949). In particular, Fingleton and McCombie (1998), Fingleton (2001; 2003) and Angeriz et al. (2006) have tested some of the underlying assumptions of the NEG theory using regional data and the tools of spatial econometrics.

Bernard Fingleton's model of productivity growth (Fingleton, 2001; 2004; 2006; 2007) constitutes the theoretical framework for this research. This model is essentially based on the NEG theory and Verdoorn's law (c.f. Verdoorn, 1949; Kaldor, 1957), in which an increase in production accounts for an increase in productivity. Fingleton's model is a spatial econometric specification of the following formula:

$$p = \alpha_0 + \rho \mathbf{W} p + \alpha_1 H + \alpha_2 G_0 + \alpha_3 q + \varepsilon, \tag{1}$$

where p is the exponential growth rate of productivity – the amount of final goods produced for the level of employment. The matrix $\mathbf{W}$ is the spatial weight matrix of dimension $N \times N$ (cf. Anselin, 1988), variable H embodies Human Capital, and G_0 the Initial Level of Technology. Variable q represents the exponential growth rate of the amount of final goods produced. Parameter α_3, known as *Verdoorn's coefficient*, defines κ by the equation: $\kappa - 1/\kappa = \alpha_3$. According to the literature, *Verdoorn's coefficient* should be around 0.5 (i.e. $\kappa \approx 2$, cf. Bernat, 1996; Fingleton, McCombie, 1998; Fingleton, 2004; Fingleton, López-Bazo, 2006). Essentially, increasing returns to scale are implied by: $\kappa > 1$. Therefore, the first aim of this paper is the revision of the quantitative statement of Verdoorn's law.

According to Paelinck (2013), because of region-specific level of economic activity, transport flows and thus a different spillover effect, a spatial pattern should be adopted for each region. As it seems to be rather difficult, if not impossible, to deal with each EU region separately, it is reasonable to at least assume that each country has its specific (spatial) pattern. Similarly, a spatial spillover may differ for the pre-enlargement EU member states and for the new member states, due to e.g.:

a different initial level of development, or for inside and outside of the Schengen Area, inside and outside of the euro area, or along other historically established or culturally justified divisions.

Following the argument presented above, the second goal of this study is to capture the spatial variation in regional productivity dynamics by investigating the hypothesis about increasing returns to scale and the spatial relation between dynamics of labour productivity and dynamics of output by means of the Multidimensional Fixed Effects Spatial Durbin Panel Model (MSDPM), a special case of the *Multidimensional Spatial Panel Model* – MPSAR (Olejnik, 2014). Namely, (1) is extended to the form of the following MPSAR relation:

$$p = \alpha_0 + \rho \mathbf{W} p + P_1 \mathbf{D} q + P_2 \mathbf{D} H + \gamma G_0, \tag{2}$$

where P_1, P_2 and γ are spatial coefficient vectors, **D** is the multidimensional spatial weight matrix representing the multilevel spatial correlation, and the multiplication employed is the one described in detail in Olejnik and Özyurt (2016).

Concluding, this paper aims to provide multidimensional spatial analysis of productivity growth in the EU in order to retest the quantitative statement of increasing returns to scale, and simultaneously to capture the spatial variation in regional productivity dynamics by employing multilevel spatial fixed effects.

The structure of the rest of this paper is as follows. Section 2 introduces a description of variables and data used in the empirical analysis. Following this, in Section 3, spatial econometric issues in the estimation of Verdoorn's law are discussed. The econometric results are then presented and discussed. Finally, Section 4 offers a summary and some concluding thoughts.

2. Determinants and data

All data used in the study are taken from Eurostat (http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database). Some missing data were interpolated from the past trends and from the data for the NUTS1 level. In the research, we considered 261 EU regions from 28 countries from the year 2000 to 2013.

The regional labour 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, i.e. $p = \ln\left[\frac{(GDP/L)_t^i}{(GDP/L)_{2000}^i}\right]$, where L denotes *Economically Active Population*, $t = 2001, \ldots, 2013$ and $i = 1, \ldots, 261$. The regional *GDP* is expressed in millions of Euro in constant prices for the year 2000, where L is expressed in thousands of people at the age of 15 and over. The distribution of productivity growth (p) for the European regions in the year 2013 compared to 2000 is presented in Figure 1.

The *Human Capital* (C) is explained by the *Human Capital* in a given region (H) and the *Human Capital* in nearby locations ($\mathbf{W}H$). The *Human Capital* in a given region (H) is approximated by the *Employment in Technology and Knowledge-intensive Sectors* (K) as a percentage of *Economically Active Population* (L). The *Human Capital* in nearby locations is represented by its spatial lag ($\mathbf{W}H$). Finally, the exponential change of regional output is approximated by the *Regional Production* (GDP) in the years $t = 2001, \ldots, 2013$ to the year 2000.

The *Initial Level of Technology* (G_0), described in the theoretical background (in the previous section), embodies the technological gap between a given region and the technology leader of the EU economy. As the research is conducted using the methodology of the spatial panel model with multilevel spatial fixed effects, the *Initial Level of Technology* (G_0) is incorporated in individual constant terms which are estimated for each region individually. Thereby, we do not have G_0 *per se* in our empirical model.

The spatial structure in the empirical model is described by the row-standardised spatial weights matrix **W** of dimension 261 × 261. The matrix **W** is the row-standardised spatial weights matrix of the three nearest neighbours (3nn) and is included in the multidimensional spatial lag matrix **D** introduced in equation (1).

Table 1. Basic statistics of variables used in the model

Variable	Description	Mean	σ	Min	Max
p	regional labour productivity growth: $p = \ln\left[\frac{(GDP/L)_t^i}{(GDP/L)_{2000}^i}\right]$	0.090	0.022	–0.268	0.7683
q	exponential change of regional output: $q = \ln\left[\frac{GDP_t^i}{GDP_{2000}^i}\right]$	0.135	0.015	–0.242	0.7501
H	employment in technology and knowledge-intensive sectors as a percentage of economically active population: $H = \ln\left[\left(\frac{K}{L}\right)_t^i\right]$	–0.093	0.008	–1.002	0.5633

Source: own study based on research

3. Empirical analysis

In order to conduct the multidimensional research of productivity growth in the EU which will confirm or reject the hypothesis of increasing returns to scale and to establish the quantitative spatial variations in regional productivity dynamics, we will further develop the MSDPM relation (1), described in Section (1). By further specifying and expanding it, we settle the model form to (13), which is the *Multidimensional Fixed Effects Spatial Durbin Panel Model*. To estimate the model, we employ a version of Quasi-Maximum Likelihood estimation procedure adjusted suitably to accommodate the multidimensionality of fixed effects. The QML procedure will be described in a subsequent paper.

To calculate the numerical value of parameter κ, we employ the fixed effects panel methodology with multiple levels of fixed effects, in order to account for multidimensional diversity of regional characteristics. Thus, the equation (2) for explaining the exponential rate of productivity growth is further adopted and takes the following form:

$$p_{\mathrm{t}} = \alpha_0 + \rho\mathbf{W}p_t + P_q\mathbf{D}q_t + P_H\mathbf{D}H_t + \mu + \varepsilon_t, \qquad \sim N(0, \sigma^2\mathbf{I}_{N\times T}), \qquad (3)$$

where $\mathbf{D} = [\mathbf{I}_N \intercal \mathbf{W}]$ is a $2 \times N \times N$ three dimensional matrix, i.e. $\mathbf{D} = \left(\mathbf{D}_{ij}^{k}\right)_{i,j\le N}^{k=1,2}$ with $\left(\mathbf{D}_{ij}^{1}\right)_{i,j\le N} = \mathbf{I}_N$ and $\left(\mathbf{D}_{ij}^{2}\right)_{i,j\le N} = \mathbf{W}$, further $P_q = [\pi_1, \pi_2]$, $P_H = [\eta_1, \eta_2]$ are parameters with $\pi_1 = (\kappa - 1)\kappa^{-1}$ being Verdoorn's coefficient and π_2 – spatial Verdoorn's coefficient. Furthermore, **W** is the spatial weight matrix, p represents the labour productivity growth, H – the human capital and q – the growth of production, μ – the level-specific spatial variation term, and t – the time period (years 2000–2013).

Table 2. MSDPM estimation results

	Parameters	Regional FE 261	Country FE 26	OLD NEW FE 2			
	ρ	0.574	***	0.381	***	0.548	***
P_q	π_1	0.738	***	0.732	***	0.760	***
	π_2	–0.420	***	–0.280	***	–0.388	***
P_H	η_1	0.086	***	0.081	***	0.084	***
	η_2	0.127	***	0.094	***	0.089	***
	pseudo R^2	0.922	0.823	0.739			

Source: own study based on research.

The level-specific spatial variation term is defined as: $\mu = (\mu_i)_{i \le G}$, $\sum_{i=1}^{G} \mu_i = 0$, where $G = N$ for the regional level, $G = 26$ for the country level, and $G = 2$ for the old vs. new EU member states division. The empirical results of the estimation of the models for level-specific fixed effects are presented in Table 2.

Table 2 shows that all three spatial specifications gave similar results. For all three models, all the variables are highly significant (at 1% level), thus all the variables have a statistically significant impact on the productivity growth in EU NUTS 2 regions. The spatial autoregressive coefficient ($\rho = -0.574$, $\rho = 0.381$, $\rho = 0.548$ – for the regional, country and old-new model, respectively) is highly significant, which indicates that the productivity growth in the neighbouring regions has a significant impact on the productivity growth in a given region.

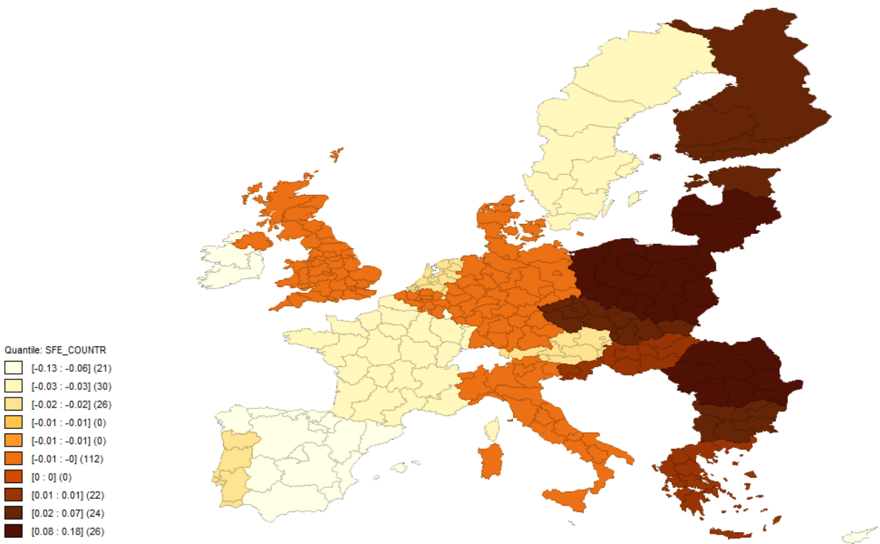

Figure 1. Map of country fixed effects

Source: own study based on research

It should be noted that, due to the values of Verdoorn's coefficients ($\pi_1 = 0.738$, $\pi_1 = 0.732$, $\pi_1 = 0.760$ – respectively), economic performance in all three models has a significant and positive effect on the productivity growth, which confirms the theoretical assumptions. Therefore, we conclude that increasing returns to scale do exist, and faster output growth induces faster productivity growth ($\kappa = 0.262$, $\kappa = 0.268$, $\kappa = 0.240$ – respectively). Moreover, the level of increasing returns to scale is consistent with previous findings. On the other hand, the negative value of spatial Verdoorn's coefficient ($\pi_2 = 0.420$, $\pi_2 = -0.280$, $\pi_2 = -0.388$) suggests that an increase in the output growth in the neighbouring regions coincides with a decrease in the productivity growth in the region. This might be caused by the pull factors to the neighbouring regions which with their growing economic performance present better economic opportunities for individuals.

The human capital, understood as a rate of employment in technology and knowledge-intensive sectors ($\eta_1 = 0.086$, $\eta_1 = 0.081$, $\eta_1 = 0.084$ – respectively), has a highly positive impact on the growth of productivity. It is interesting to note the virtually identical coefficients associated with *H*. However, for its spatial counterpart ($\eta_2 = 0.127$, $\eta_2 = 0.094$, $\eta_2 = 0.089$), we observe that in the regional model this coefficient is about 42% larger than in the old-new model.

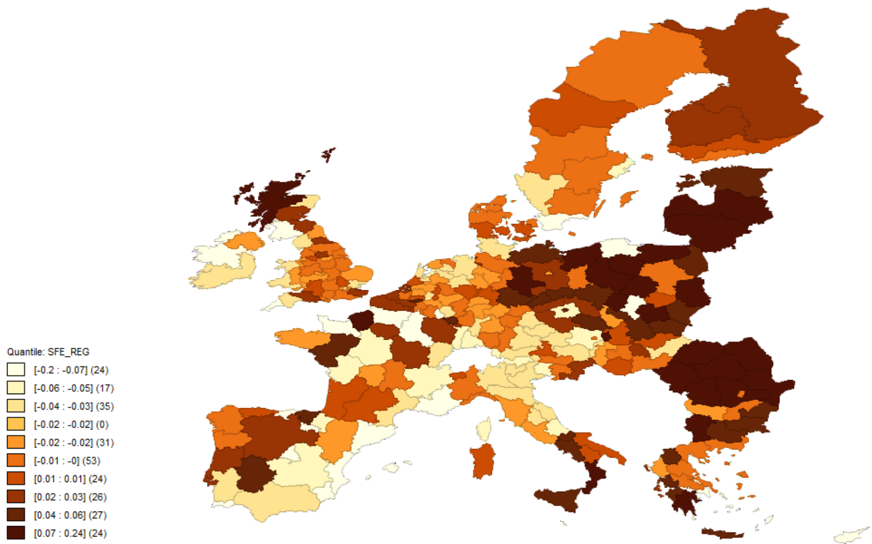

Figure 2. Map of regional fixed effects

Source: own study based on research

Finally, all three levels of analyses of spatially varied fixed effects confirmed the assumptions made. Region-specific time-invariant effects turned out to be significant for most of the regions, confirming that there is significant heterogeneity (diversity) in spatial spillovers captured by the region-specific terms. Similar conclusions may be drawn for the country fixed effect model also reported in Table 2. Country-specific time-invariant effects turned out to be significant, which means that national-specific effects play an important role in explaining the regional productivity growth. The old vs. new EU member states spatial fixed effects are also significant, confirming the assumption about the importance of different initial level of development of each country, its historical and cultural background. Figures 1 and 2 present the graphical illustration of the level-specific spatial variation term. It should be noted that for country-level fixed effects we do not observe individual, national effects but a few specific ones for the whole economy of the EU. For regional-level fixed effects, however, we can clearly observe huge diversity in the values between the individual regions. In contrast, time period-specific spatial-invariant effects are not significant in any of these models.

As a final point, it should be noted that though the Regional Model turned out to be the best model judging by the goodness of fit, the importance of information we gain about the spatial process of productivity growth in EU regions is substantial.

4. Conclusions

The current literature emphasises the importance of localised returns to scale for the regional growth as well as for the agglomeration processes. However, it is still not well established whether returns to scale are constant or increasing, and to what extent. In our research, we have made an attempt to describe the spatial process of productivity growth in EU regions. The analysis was based on the theoretical foundations of New Economic Geography and the Endogenous Growth Theory embodied in Fingleton's model through Verdoorn's law.

The empirical model was estimated within the spatial setting provided by the Multidimensional Spatial Durbin Panel Model with multilevel spatial fixed effects. This study aimed at providing some new estimates of the degree of returns to scale for EU regions. Our findings show that the hypothesis of increasing returns to scale is still valid in today's EU economy. To test the hypothesis, we have employed the Multidimensional Spatial Panel Durbin Model with Spatial Fixed Effects. The research is conducted for 261 regions of the EU 28.

As a novelty and a significant benefit to the empirical form of the model, apart from classic Verdoorn's coefficient, we have also included its spatial counterpart. In our research, the Regional Model turned out to be the best model, however, the goodness of fit shows that all three models describe the phenomenon in question well. Based on our research, we conclude that increasing returns to scale are present in the contemporary EU economy and they are not significantly different from the ones reported in the literature.

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Korzyści skali dla regionów Unii Europejskiej – wyniki przestrzennego modelu panelowego

Streszczenie: Ostatnie wyniki prac naukowych zwracają uwagę na rolę zlokalizowanych korzyści skali zarówno dla wzrostu gospodarczego, jak i dla procesów aglomeracyjnych. Badacze chcą wiedzieć, czy korzyści skali są stałe, czy rosną, i jeśli tak, to do jakiego stopnia. Aby odpowiedzieć na te pytania, w niniejszym artykule oszacowany został przestrzenny model ekonometryczny w oparciu o prawo Verdoorna, opisujące zależność wzrostu produktywności od wzrostu produkcji. Celem artykułu jest prezentacja nowych wyników oszacowań stopnia korzyści skali dla regionów UE. Wyniki te wskazują, że hipoteza o rosnących korzyściach skali jest nadal aktualna. Badania zostały przeprowadzone z zastosowaniem modelu WAMP Durbina (wielowymiarowego autoregresyjnego modelu przestrzennego Durbina) z przestrzennymi efektami stałymi. Z analizy wykonanej dla 261 regionów 28 państw UE wynika, że rosnące korzyści skali dla regionów UE są znaczące.

Słowa kluczowe: rosnące korzyści skali, wzrost produktywności, prawo Verdoorna, panel przestrzenny

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