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Shallow determinants of growth of Polish regions. Empirical analysis with panel data methods[2]

Summary

We derive and then estimate an augmented neoclassical growth model to identify major shallow determinants of growth of Polish NUTS-2 regions and the existence of macroeconomic education and infrastructure-related externalities. The empirical model for 16 NUTS-2 regions over the period 1999–2009 is estimated with various panel data techniques. The simple model explains around 90 per cent of variation in real GDP per capita. Most of results are in line with theoretical predictions. Overall, the return to accumulation of human capital through education and experience for Polish regions is statistically significant, robust and positive. The magnitude of the impact is higher for experience. The macroeconomic infrastructure externality is positive however statistically insignificant. When we separate the impact of quality of roads (iqm) and railway (iqr), only the second term seems to have a statistically significant effect on the dependent variable. Taken at face value, this result could have significant policy implications. Overriding priority should be given to fostering further accumulation of human capital over investments in the transport infrastructure or at least more emphasis should be placed on complementarity between the two.

Key words: regional development, economic growth, panel data analysis

1. Introduction

Economic growth is a complex, sequential and non-linear process affected by a number of shallow as well as deep-rooted determinants[3]. Growth theory has traditionally

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[3] D. Rodrik, *Institutions, integration, and geography: In search of the deep determinants of economic growth*, in: *Modern Economic Growth: Analytical Country Studies*, 2002, https://www.sss.ias.edu/files/pdfs/Rodrik/Research/institutions-integration-geography.pdf.

focused on shallow determinists such as physical and human capital accumulation or technological change, in particular in its endogenous growth or the so-called new growth theory variant. Recent contributions, however, put more attention to deep determinants of growth and development as not all stylized facts can be explained by reference to shallow factors only[4]. Theoretical models are usually applied to countries, however, they can fit the regional setting as well. At high level of spatial disaggregation, however, agglomeration effects are evident and potential spatial interlinkages have to be acknowledged.

According to Crescenzi and Rodriguez-Pose[5] peripheral and backward European regions should follow balanced strategies in which infrastructure development is coordinated with policies aimed at developing human capital and the innovative potential of regions. Improvements in infrastructure endowments obviously increase interregional accessibility, but at the same time contribute significantly to better market integration. This could be particularly important for outward-oriented and thus more open regions. Del, Chiara and Florio conduct similar analysis for European NUTS-2 regions disaggregating infrastructure into its different types and considering spatial dependence[6]. A positive correlation between regional infrastructure endowments, both in aggregate and disaggregated terms, with economic activity is detected controlling for human capital endowment. At the same time the results suggest investment complementarity across regions. Del, Chiara and Florio highlight further the importance of directing public investment to specific disaggregated categories of infrastructure with high return in order to stimulate multiplier effects. We have to stress that infrastructure projects bring about both demand-side and supply-side effects with the later particularly evident over longer spans of time.

Taking into account large infrastructure projects implemented in Poland in recent years that were co-financed from structural funds (financial perspectives 2004–2006, 2007–2013) we would like to assess their impact on growth of Polish regions. Simultaneously we observe a shift in spending priorities with more resource directed to accumulation of human capital and boosting regional innovation potential (this is

[4] Please refer to D. Rodrik, A. Subramanian, F. Trebbi., *Institutions rule: the primacy of institutions over geography and integration in economic development*, “Journal of Economic Growth” 2004, vol. 9(2), pp. 131–165; D. Acemoglu, S. Johnson, J.A. Robinson, *The Colonial Origins of Comparative Development: An Empirical Investigation*, “American Economic Review” 2001, vol. 91, pp. 1369–1401.

[5] R. Crescenzi, A. Rodriguez-Pose, *Infrastructure endowment and investment as determinants of regional growth in the European Union*, “European Investment Bank Papers” 2008, vol. 13(2), pp. 62–101.

[6] B. Del, F. Chiara, M. Florio, *Infrastructure and Growth in a Spatial Framework: Evidence from the EU regions*, “European Planning Studies” 2012, vol. 20(8), pp. 1393–1414. The authors utilize spatial Durbin model.

particularly evident in the new programming period 2014–2020). Complementarity between investments in infrastructure and human capital are of particular interest to us.

We would like to stress that some recent studies utilizing more general approaches found an important impact of infrastructure development on growth of Polish regions (e.g. Cieślik and Rokicki[7]). Surprisingly intraregional infrastructure development seems to bring more benefits than interregional infrastructure projects.

In order to assess the above postulates for the case of Polish NUTS-2 regions (voivodeships) we extend the analysis of Carstensen, Gundlach and Hartmann[8] augmenting the neoclassical model of Solow[9] and Swan[10] in an approach similar to Mankiw, Romer and Weil[11] or Nonneman and Vanhoudt[12] by incorporating Mincerian schooling externalities and infrastructure externalities in a single theoretical framework. Analogously to an earlier article of Brodzicki[13] infrastructure is introduced into the model in a manner similar to exogenous Hicks-neutral technological change thus raising the overall efficiency of an economic system. Basing on the structural equation of our theoretical model we develop an empirical model and apply it in a panel setting to a group of Polish NUTS-2 regions over the period 1999–2009.

The structure of this paper is as follows. In section 2 we develop an augmented neoclassical growth model including infrastructure and human capital. In section 3 we demonstrate the empirical model. Section 4 presents and discusses the principal results. The last section concludes, discusses the limitations of our research as well as gives guidelines for future empirical studies.

[7] A. Cieślik, B. Rokicki, *Wpływ inwestycji drogowych na rozwój polskich regionów*, in: *Spójność ekonomiczno-społeczna regionów Unii Europejskiej*, eds B. Jóźwik, P. Zalewa, Wydawnictwo KUL, Lublin 2010.

[8] K. Carstensen, E. Gundlach, S. Hartmann, *The augmented Solow model with Mincerian schooling and externalities*, "German Economic Review" 2009, vol. 10(4), pp. 448–463.

[9] R. Solow, *A Contribution to the Theory of Economic Growth*, "Quarterly Journal of Economics" 1956, vol. 70(1), pp. 65–94; R. Solow, *Technical Change and the Aggregate Production Function*, "Review of Economics and Statistics" 1957, vol. 39, pp. 312–320.

[10] T. Swan, *Economic Growth and Capital Accumulation*, "Economic Record" 1956, vol. 32, pp. 334–361.

[11] N. Mankiw, D. Romer, D. Weil, *A Contribution to the Empirics of Economic Growth*, "Quarterly Journal of Economics" 1992, vol. 107, pp. 407–437.

[12] W. Nonneman, P. Vanhoudt, *A further augmentation of the Solow model and the empirics of economic growth for OECD countries*, "The Quarterly Journal of Economics" 1996, vol. 111(3), pp. 943–953.

[13] T. Brodzicki, *Augmented Solow Model with Mincerian Education and Transport Infrastructure Externalities*, "Czech Economic Review" 2012, vol. 6(2), pp. 155–170.

2. Augmented neoclassical growth model

Following Brodzicki[14] we assume that at an aggregated level the regional production function takes the Cobb – Douglas form with physical capital K and labour L as the two basic inputs. The labour input is conditioned for the average level of education. The general production function is thus given by:

$$Y = I^{\gamma} K^{\alpha} \left(B\ L\right)^{1-\alpha} \tag{1}$$

where Y is the aggregate output of a region, B an exogenous index of the level of technology and I is an index of the quality of infrastructure that is also exogenous to individual firms. K represents the stock of aggregate physical capital and L the labour force. We do not set any a priori restrictions on parameter γ. The general production function shows constant returns to scale as long as we treat infrastructure as an exogenous efficiency-adjusting parameter having the impact on overall productivity of the regional economic system.

Accumulation of human capital (through education system) generates an externality given by:

$$B = Ah^{\lambda} \tag{2}$$

where h the average level of education and λ represents educational externality.

A is a region-specific technology that grows exponentially over time at an exogenous and positive rate g common to all the regions. Technological progress is labour-augmenting or Harrod-neutral. We take into account heterogeneity of regions along technological dimension by allowing the initial level of technology A (0) to vary between regions.

In accordance with Mincerian tradition the average level of education may be specified as a function of average years of schooling (AYS) and average years of experience (AYS)[15]. Accordingly:

$$h = \mu e^{\beta AYS + \chi AYE} \tag{3}$$

where μ – constant and positive parameter, β and χ – microeconomic – individual private returns from additional year of schooling and additional year of experience respectively.

[14] Ibidem.

[15] M. Bils, P.J. Klenow, *Does Schooling Cause Growth?*, “American Economic Review” 2000, vol. 90, pp. 1160–1183.

In the analysis of the empirical model it would be advisable to take into account the diversity of the quality of education between regions.

The overall production function in the intensive form with income per efficient unit of labour $\tilde{y} \equiv \frac{Y}{AL}$ and capital per efficient unit of labour $\tilde{k} \equiv \frac{K}{AL}$ and takes the following form:

$$\tilde{y} = I^{\gamma} \tilde{k}^{\alpha} \left(\mu e^{\beta AYS + \chi AYE} \right)^{(1-\alpha)\lambda} \tag{4}$$

Adopting the neoclassical rule of physical capital accumulation proposed by Solow (perpetual inventory method) as well as assuming that a constant fraction of output s is saved and invested (s > 0) and a constant fraction of physical capital δ decays every period (δ > 0).

A series of transformations (taking logs and differentiating expression 4 with respect to time, including the expression for evolution of capital and setting a condition for the steady state) allows us to derive the key equation for the level of income per unit of effective work in the steady state. Moreover, thanks to the definition of effective unit of labour, we are able to determine the level of real income per capita in the long-term. Its level is shown by the following equation:

$$y^* = AI^{\frac{\gamma}{1-\alpha}} \left(\mu e^{\beta AYS + \chi AYE} \right)^{\lambda} \left(\frac{s}{g+n+\delta} \right)^{\frac{\alpha}{1-\alpha}} \tag{5}$$

Real income per capita in the steady state is a function of exogenous structural parameters of the model. It is worth noting that in the steady state, all the key parameters of the model such as income, consumption and capital in per capita terms grow at an exogenously determined and constant rate of technological progress g. Taking logs of both sides allows us to obtain the crucial structural equation of the model:

$$\ln y^* = \ln A + \frac{\gamma}{1-\alpha} \ln I + \lambda \ln \mu + \lambda \left(\beta AYS + \chi AYE \right) + \frac{\alpha}{1-\alpha} \ln \left(\frac{s}{g+n+\delta} \right) \tag{6}$$

The level of real income per capita in the steady state is a positive function of the rate of saving (investment), a negative function of the population growth rate and depreciation of capital. Technological progress has generally a positive impact on the level of GDP per capita as shown by A. The direction of impact of infrastructure and human capital depends on the structural parameters λ and γ whose values should not be assumed a priori.

3. The empirical model and its components

In order to estimate an empirical panel model version of the above theoretical model with individual effects for voivodeships (in order to capture the unobservable, region-specific characteristics and to eliminate potential bias) we make a relatively strong simplifying assumption that the observed real GDP per capita is close to the level in the steady state.

Starting from the structural equation (6) assuming that $\lambda \ln \mu = const.$ and allowing for differences in technology to be given by A_i and knowing the average investment rate and average population growth rate we can construct our empirical equation containing the stochastic component. The panel data version of the empirical growth model with individual effects for regions takes the following form:

$$\ln y_{i,t} = const + \ln A_{i,t} + \frac{\gamma}{1-\alpha} \ln I_{i,t} + \lambda\left(\beta AYS_{i,t} + \chi AYE_{i,t}\right) + \\ + \frac{\alpha}{1-\alpha} \ln\left(\frac{\bar{s}_{i,t}}{g + \bar{n}_{i,t} + \delta}\right) + \eta_i + u_{i,t}, \ i = 1,\dots N, \ t = 1,\dots T \tag{7}$$

Equation (7) predicts that the coefficient on the investment share equals in absolute value the coefficient on labour force growth (conditioned by g and δ).

As can be seen from the empirical equation above, fixed individual effects seem to be our preferred choice. However, in the estimation we are not going to assume fixed effects a priori. We implement a standard Hausman test which provides a generally accepted way of choosing between fixed (FE) and random effects (RE) models. The null hypothesis of the test states that the RE estimator is consistent and thus outperforms FE estimator.

Log of real GDP per capita (y) is our dependent variable. This deserves a short comment. In traditional approach to growth econometrics, for instance classic cross-sectional growth regressions a la Barro[16], average growth rate and not the level of income per capita is the explained variable. In our case we have solved the augmented neoclassical

[16] R.J. Barro, *Economic Growth in a Cross Section of Countries*, „The Quarterly Journal of Economics" 1991, vol. 106(2), pp. 407–443.

growth model obtaining the structural equation for the steady-state value of income per capita (lny). Making the simplifying assumption that incomes in regions are close to their steady-state values we can still treat it as a test of the theoretical model. This approach is commonly accepted and utilized in the literature of the subject.

From the estimates of the coefficient on $\ln(s/(g+n+\delta))$ we will be able to calculate the implied value of α. We expect it to be close to one-third. Knowing α and the coefficient on the infrastructure index allows us to calculate the implied value of γ. We expect it to be positive and in the range of 0 to 10 per cent. We will obtain implied macroeconomic return on education λ directly from the coefficient on the fourth term on the right hand sight of the estimated empirical equation. We expect λ to be positive and statistically significant.

In line with the related empirical growth literature, we assume a constant rate of labour-augmenting technological progress $g=0.02$ and a constant decay of physical capital $\delta=0.03$. Thus $g+\delta=0.05$.

In accordance with the theoretical model we allow for variation in the level of technology. It could be relatively large if we take into account the existence of metropolitan and non-metropolitan regions and large difference in the level of development between the western and eastern part of Poland. Since in this case we are dealing with regions of one country constituting a single national innovation system we introduce a variable approximating variation in scientific potential of regional innovation systems – R&D employment (rdemploy)[17].

Sticking to the initial theoretical assumptions we adjust average schooling years for differences in education quality (eduq) – average results of test at secondary level of education. In order to obtain an implied macroeconomic return for human capital accumulation (λ) similarly to Carstensen, Gundlach and Hartmann[18] we impose restrictions on private returns to schooling, thus setting $\beta=0.1$ and private return on experience $\chi=0.03$. The assumed values are based on the results of micro econometric research[19].

In order to obtain average years of experience (aye) we follow Mincer and calculate it as an average age of the cohort (ages 15 to 65) minus the average years of schooling and further deduce 6 years (presumed age of entry into education system). The data on

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[17] In a recent study Ciołek and Brodzicki show that TFP levels in Poland vary significantly with the highest values for metropolitan areas, and the lowest values for South-Eastern region of Poland. Please refer to: D. Ciołek, T. Brodzicki, *Determinants of total factor productivity of Polish districts. The impact of territorial capital*, Instytut Rozwoju, Working Paper no. 001/2015.

[18] K. Carstensen, E. Gundlach, S. Hartmann, op.cit.

[19] G. Psacharopoulos & H. Patrinos offer a large review of results of empirical studies on micro-level returns from education. Please refer to: G. Psacharopoulos, H. Patrinos, *Returns to Investment in Education: A Further Update*, World Bank, Policy Research Working Paper no. 2881, 2002.

population come from the Central Statistical Office of Poland – GUS (Baza Danych Lokalnych, BDL database).

Construction of the crucial index measuring overall quality of infrastructure is based on the methodology proposed by Careijo et al.[20] The index of corrected infrastructure quality (ciiq) relativizes infrastructure endowment by taking into account both population size and land area and compares it to a benchmark. In the present study we take the average for Poland as the respective benchmark. Ciiq is calculated according to the following formula:

$$ciiq_r = \left(\frac{X_r / N_r}{X_{PL} / N_{PL}} \right)^{0,5} \left(\frac{X_r / S_r}{X_{PL} / S_{PL}} \right)^{0,5} \qquad (8)$$

where X_r and X_{PL} gives the infrastructure endowment of a given region and Poland, whereas N and S represents respectively population (in thousands) and land area (in square km).

We consider two types of infrastructure stock as key determinants of an overall accessibility and competitiveness of regions: motorway system and railway network. These are key elements shaping interregional accessibility of regions. We were not able at this stage to account fully for the stock of intraregional infrastructure[21]. Infrastructure indices have been calculated separately for both types of infrastructure (iqm and iqr respectively). The overall index (ciiq) has been calculated as a simple geometric mean of two aforementioned indices. The quality of the proposed index could obviously be questioned by economic geographers or spatial planners who utilize much more elaborated spatial techniques in order to construct regional accessibility indices[22].

In addition to the variables described above, we use a conditioning set of variables as postulated by the literature on growth. These include in particular an openness ratio (open) as well as agglomeration index (a1) which accounts for metropolitan or non-metropolitan character of a given region or the strength of agglomeration process taking place within the region.

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20 E. Cereijo, J.T. Sánchez, F.J.V. Angona, *Indicadores de convergencia real para los países avanzados*, "Estudios de la Fundación FUNCAS", Madrid 2006.

21 At the same time the presence of international airports or seaports (depicted by simple zero-one dummy variables), crucial to international accessibility of regions, cannot be accounted for if we utilize the fixed effect approach. Their impact constitutes a part of the fixed effect for regions.

22 The indices of potential accessibility calculated by IGiPZ PAN are calculated in 5 year intervals which obviously is unsatisfactory for our purposes.

Openness is measured in accordance with the standard approach as a ratio of total trade to GDP[23]. Agglomeration index (a1) is calculated as a ratio of the population of the largest city in the region to region's overall population. As some of provinces have polycentric metropolises we also will test the impact of taking into account of 3 or 5 largest urban centres (a3 and a5 respectively).

4. Results and discussion

The empirical analysis is carried out for a group of 16 Polish NUTS-2 regions within the period 1999 to 2009. We utilize several data sources. The majority of data comes from BDL and HERMIN provided by GUS. EUROSTAT regional database has been utilized in construction of several infrastructure-related variables.

The empirical results are presented in Table 1. In the choice of the preferred specification of the model we have used the Hasuman and Bresuch-Pagan test. The null hypothesis of the Hausman test has been rejected, leading to the choice of the model with fixed effects (FE). The analysis pointed to the use of one-way model considering only region-specific effects and not taking into account the model with temporal effects (two-way approach). Artificial time effects in this setting reflect majority of the actual variation of key economic variables and thus in the two-way model it would be difficult to detect the interaction between the key drivers of growth[24].

Analyses were performed for a number of different specifications of the model with varying selection of explanatory variables. Due to the use of the approach with fixed effects for individual regions, we consider the effect of variation in the initial level of technology to be included in these effects[25].

[23] Data on regional trade were provided by S. Umiński from Instytut Rozwoju and are originally from detailed trade statistics of GUS.

[24] In line with the suggestion of one of the peer reviewers we have tried to test the impact of accession into EU by introducing dummy variable eut taking value 1 for 2004 onwards. It cannot be included in the FE model due to colinearity and thus has to be dropped.

[25] We would like to stress that we have tested for the existence of potential spatial linkages between regions (not shown in the present article because of size limitations) using both SAR and SEM approaches. Spatial linkages proved to be insignificant which to some extents seems surprising. Spatial econometric approaches should be implemented for sure at higher levels of spatial disaggregation (NUTS-3, LAD-4) where spatial agglomeration and diffusion forces dominate and spatial linkages abound.

Table 1. Estimation results

	M1	M2	M3	M4	M5	M6	M7	M8	M9
	lny	lny	lny	lny	lny	lny	lny	lny	lny
Constant	–3.238***	–3.238***	–4.764***	–3.518***	–3.948***	–5.317***	–6.867***	–6.224***	–5.128***
	(0.414)	(0.416)	(1.285)	(0.654)	(0.663)	(1.290)	(1.544)	(1.528)	(1.050)
ln (s/ (n+0.05))	–0.164***	–0.164***							
	(0.0474)	(0.0476)							
Lns			–0.162***						
			(0.0475)						
ln (n+0.05)			–0.290	–0.277**	–0.269**	–0.873**	–0.845**	–0.846**	–0.963***
			(0.365)	(0.107)	(0.104)	(0.365)	(0.363)	(0.368)	(0.253)
Aysaye	19.11***	19.11***	19.34***	17.96***	18.04***	16.76***	17.57***	16.66***	
	(0.603)	(0.606)	(0.633)	(0.600)	(0.592)	(1.035)	(1.123)	(1.101)	
Ays									0.592***
									(0.0346)
Aye									0.225***
									(0.0315)
Ciiq		0.000458	0.00221	0.00992				0.0313	0.00587
		(0.0218)	(0.0218)	(0.0227)				(0.0227)	(0.0157)
Iqm					0.000395	0.000654	0.00468		
					(0.00855)	(0.00839)	(0.00862)		
Iqr					0.383***	0.302***	0.309***		
					(0.111)	(0.109)	(0.109)		
Open						0.135***	0.125**	0.167***	0.145***
						(0.0488)	(0.0488)	(0.0473)	(0.0324)
a1							5.886*	6.591*	0.153
							(3.281)	(3.380)	(2.371)
N	160	160	160	176	176	160	160	160	160
R^2	0.878	0.878	0.879	0.881	0.889	0.887	0.889	0.884	0.946
N	16	16	16	16	16	16	16	16	16

One-way FE with robust standard errors. The table contains estimates of the parameters. In brackets () robust standard errors. Result *** – significant at 1 per cent., ** – 5 percent and * – 10 percent level. R^2 – the value of the coefficient of determination; n – number of regions; N – the total number of observations in the data panel.

Source: Estimation in the STATA 12.

The augmented neoclassical model, taking into account the impact of human capital and the quality of transport infrastructure, seems to suit well the specific nature of the development of Polish regions. Our base model explains approximately 88–90% of the variation in real GDP per capita of Polish NUTS-2 regions.

The impact of ln (s/ (n + 0.05)) on income per capita is statistically significant however its negative both in the base specification of the model (M1)[26] as well the one including overall quality of infrastructure ciiq (M2). For this reason, in the next step (M3) we divide ln (s/ (n + 0.05)) into its components: lns which reflects the process of physical capital accumulation and the denominator ln (n + 0.05). lns turns out to be significantly correlated with the quality of the infrastructure index ciiq. With reference to the theoretical assumptions of the model, it was noted that it is not possible to separate the effect of the rate of investment (accumulation of fixed assets) from the impact of infrastructure quality. For this reason, in the following specifications (M4 and further) we drop the lns. Effect of ln (n + 0.05) on the dependent variable in these cases is negative and statistically significant – in accordance with theoretical postulates.

The impact of aysaye on the level of development of Polish regions in all specifications (M1 to M8) is positive and statistically significant. It indicates key significance of human capital endowment for boosting development of Polish regions. With the on-going transition from extensive (based on a simple catching-up processes) to more intensive stage of growth its role in the growth of Poland is likely to increase even further. Separation of the overall impact on the education component (ays) and experience (aye) does not substantially change the situation (M9). The influence of both elements is positive and statistically significant, the magnitude of impact of the experience, however, is higher. It is worth noting that the results obtained are robust to the introduction of additional explanatory variables (not shown in Table 1, available upon request) capturing the quality of the education system (eduq) and scientific research potential of regions – the logarithm of employment in R&D (rdemploy). The impact of these variables turns out to be statistically insignificant.

The impact of relative quality of infrastructure (ciiq) on the dependent variable is positive but statistically insignificant (models M3–M4). When we break it down in the following two specifications (M5 to M7) into subcomponents associated with the quality of roads (iqm) and railways (iqr), only the second term seems to have a statistically significant effect on the level of GDP per capita of Polish voivodeships. The result is to some extent surprising. It can reflect the fact that at the spatially aggregated level of voivodeships the variation in regional endowment in railway infrastructure is larger than

[26] For the same specification of the model (M1) estimated for a longer data-set (1995–2009) the coefficient on ln (s/ (n+0.05)) is positive (0.184) and statistically significant (not shown in the Table 1).

it is the case of road system. It is also often said that density of railway system in Poland still fits the borders of former partitions of Poland which could point to the problem of path-dependency in economic development. It is worth noting that the result does not disappear when we control for openness (open) and metropolization of regions (a1) (M7)[27]. In this context, it is worth noting that more open regions achieve on average, a higher level of real GDP per capita in the long-run. At the same time, at the 10% significance level, the positive impact of agglomeration forces on the dependent variable is clear. Regions with strong metropolitan areas attain ceteris paribus a higher level of GDP per capita in the long term and there are clear growth poles in the polycentric cores-peripheries set up of spatial economic system of Poland.

5. Conclusions

The aim of the paper was to identify shallow determinants of growth of Polish regions as well the existence of macroeconomic education and infrastructure-related externalities. In order to do so we developed an augmented neoclassical growth model incorporating a Mincerian approach to human capital accumulation. We further assumed infrastructure to have a direct effect on overall productivity of an economic system. We derived a specific structural equation of the theoretical model which, after inclusion of stochastic element, became our empirical model. The panel version of the model was estimated with fixed effects estimator.

Our simple panel model explains nearly 90 per cent of observed variation in GDP per capita of Polish voivodeships. Overall, the return to accumulation of human capital through education and experience for Polish regions is statistically significant, robust and positive. The magnitude of the impact is higher for experience. The macroeconomic infrastructure externality is positive however statistically insignificant. When we separate the impact of quality of roads (iqm) and railway (iqr), only the second term seems to have a statistically significant effect on the dependant variable. Taken at face value, this result could have significant policy implications. Overriding priority should be given to fostering further accumulation of human capital over investments in the transport infrastructure or at least more emphasis should be placed on complementarity between the two.

[27] Other proxies for agglomeration effect – a3 and a5 have statistically insignificant impact on the dependant variable (not shown in the Table 1).

Nonetheless, good quality of basic interregional infrastructure still seems to be fundamental to growth. In order to boost economic growth further, when an economy goes from extensive (resource or efficiency-driven) to intensive (innovation-driven) growth phase, we require an accelerated accumulation of human capital as well as increased gross expenditures on R&D and innovation. It seems that the central role of capital-deepening has to be replaced by human capital accumulation and knowledge creation[28].

We see several limitations of our analysis. Our theoretical model should preferably incorporate both direct and indirect effects of infrastructure on economic growth. We agree with Straub[29] that dynamic NEG models could outperform economic growth models in this respect, as they allow for agglomeration effects, non-linear impact of infrastructure on development due to reduction in transport costs, and the role of sequencing and infrastructure types (interregional and intraregional). The period analysed is rather short while the impact of infrastructure and human capital investments on growth has mainly a medium or long – run nature. Last but not least, there could be a measurement error in key variables which could potentially bias the estimates.

We see several potential extensions of our analysis. First of all, more effort has to be given to constructing better indices of infrastructure quality including various types of infrastructure (e.g. ICT infrastructure said to be of prime importance for a knowledge-based economy, intraregional and interregional infrastructure). The use of more elaborate accessibility indices could bring interesting results, however, this is difficult due to the lack of data at yearly intervals. Secondly, the robustness of our results should be further tested at more disaggregated spatial levels, preferably powiats, where spatial interactions and externalities become crucial and cannot be neglected in empirical analysis. This would also require the use of more sophisticated spatial econometric approaches (SAR, SEM or spatial Durbin models). The lack of GDP per capita estimates at the LAD-4 level has been solved recently by a new methodology of D. Ciołek[30] and this should be utilized as extension of our study. The analysis could be further broadened to include regions at NUTS-2 level from other countries such as Visegrad group or EU28 as a whole. Last but not least, other potential theoretical frameworks could be utilized including more elaborated multi-sector growth models as well as dynamic NEG models. From a theoretical perspective polycentric core-periphery model seems to suit the Polish framework conditions. This is also stressed by economic geographers[31].

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28 P. Aghion, P. Howitt, *The Economics of Growth*, MIT Press, Cambridge 2009.

29 S. Straub, *Infrastructure and Growth in Developing Countries: Recent Advances and Research Challenges*, World Bank, Policy Research Working Paper no. 4460, 2008.

30 D. Ciołek, T. Brodzicki, op.cit.

31 M. Tarkowski, *Centra i peryferie rozwoju społeczno-gospodarczego Polski w okresie transformacji ustrojowej*, Wydawnictwo Bernardinum, Gdynia–Pelplin 2008.

References

Acemoglu, D., Johnson S., Robinson J.A., *The Colonial Origins of Comparative Development: An Empirical Investigation*, "American Economic Review" 2001, vol. 91, pp. 1369–1401.

Aghion P., Howitt P., *The Economics of Growth*, MIT Press, Cambridge Mass. 2009.

Barro R.J., *Economic Growth in a Cross Section of Countries*, "The Quarterly Journal of Economics" 1991, vol. 106(2), pp. 407–443.

Bils M., Klenow P.J., *Does Schooling Cause Growth?*, "American Economic Review" 2000, vol. 90, pp. 1160–1183.

Brodzicki T., *Augmented Solow Model with Mincerian Education and Transport Infrastructure Externalities*, "Czech Economic Review" 2012, vol. 6(2), pp. 155–170.

Carstensen K., Gundlach E., Hartmann S., *The augmented Solow model with Mincerian schooling and externalities*, "German Economic Review" 2009, vol. 10(4), pp. 448–463.

Cereijo E., Sánchez J.T., Angona F.J.V., *Indicadores de convergencia real para los países avanzados*, "Estudios de la Fundación FUNCAS", Madrid 2006.

Cieślik A., Rokicki B., *Wpływ inwestycji drogowych na rozwój polskich regionów*, in: *Spójność ekonomiczno-społeczna regionów Unii Europejskiej*, eds B. Jóźwik, P. Zalewa, Wydawnictwo KUL, Lublin 2010.

Ciołek D., Brodzicki T., *Determinants of total factor productivity of Polish districts. The impact of territorial capital*, Instytut Rozwoju, Working Paper no. 001/2015.

Crescenzi R., Rodriguez-Pose A., *Infrastructure endowment and investment as determinants of regional growth in the European Union*, "European Investment Bank Papers" 2008, vol. 13(2), pp. 62–101.

Del Bo, Chiara F., Florio M., *Infrastructure and Growth in a Spatial Framework: Evidence from the EU regions*, "European Planning Studies" 2012, vol. 20(8), pp. 1393–1414.

Mankiw N.G., Romer D., Weil D.N., *A Contribution to the Empirics of Economic Growth*, "Quarterly Journal of Economics" 1992, vol. 107, pp. 407–437.

Nonneman W., Vanhoudt P., *A further augmentation of the Solow model and the empirics of economic growth for OECD countries*, "The Quarterly Journal of Economics" 1996, vol. 111(3), pp. 943–953.

Ottaviano G., *Infrastructure and economic geography: An overview of theory and evidence*, "European Investment Bank Papers" 2008, vol. 13(2), pp. 8–35.

Psacharopoulos G., Patrinos H.A., *Returns to Investment in Education: A Further Update*, World Bank, Policy Research Working Paper no. 2881, 2002.

Rodrik D., *Institutions, integration, and geography: In search of the deep determinants of economic growth*, in: *Modern Economic Growth: Analytical Country Studies*, 2002, https://www.sss.ias.edu/files/pdfs/Rodrik/Research/institutions-integration-geography.pdf.

Rodrik D., Subramanian A., Trebbi F., *Institutions rule: the primacy of institutions over geography and integration in economic development*, "Journal of Economic Growth" 2004, vol. 9(2), pp. 131–165.

Solow R., *A Contribution to the Theory of Economic Growth*, "Quarterly Journal of Economics" 1956, vol. 70(1), pp. 65–94.

Solow R., *Technical Change and the Aggregate Production Function*, "Review of Economics and Statistics" 1957, vol. 39, pp. 312–320.

Straub S., *Infrastructure and Growth in Developing Countries: Recent Advances and Research Challenges*, World Bank, Policy Research Working Paper no. 4460, 2008.

Swan T., *Economic Growth and Capital Accumulation*, "Economic Record" 1956, vol. 32, pp. 334–361.

Tarkowski M., *Centra i peryferie rozwoju społeczno-gospodarczego Polski w okresie transformacji ustrojowej*, Wydawnictwo Bernardinum, Gdynia–Pelplin 2008.

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Płytkie determinanty wzrostu polskich regionów. Analiza empiryczna z wykorzystaniem metod panelowych

Streszczenie

Celem niniejszego artykułu jest empiryczna identyfikacja płytkich determinant rozwoju polskich województw, w tym zwłaszcza makroekonomicznych efektów zewnętrznych inwestycji w kapitał ludzki i infrastrukturę. W tym celu został opracowany rozszerzony neoklasyczny model wzrostu uwzględniający podejście Mincera do akumulacji kapitału ludzkiego oraz założenie o bezpośrednim wpływie jakości infrastruktury na ogólną wydajność systemu gospodarczego. Na podstawie równania strukturalnego modelu teoretycznego opracowano panelowy model empiryczny, który został oszacowany dla panelu 16 województw Polski w okresie 1999–2009.

Słowa kluczowe: infrastruktura, kapitał ludzki, poszerzony model neoklasyczny, wzrost gospodarczy

JEL: O41, R10, R11, C23