10.2478/v10103-012-0023-9

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The Determinants of Total Factor Productivity in Polish Subregions. Panel Data Analysis

Abstract

The significant role of TFP in stimulating the long-run economic development induces researchers to seek for the sources of the TFP growth.

The mail goals of the paper are: to estimate the level of TFP in the years 2003-2009 at the level of subregions, and to define the factors which determine this estimated TFP level. The first hypothesis being verified is, that the role of the quality of human capital in stimulating long-run economic growthis crucial and can be measured by the model. The second hypothesis is, that there are some factors affecting the TFP level which are common in all subregions.

1. Introduction

Division into subregions has been introduced in the research conducted by GUS [*Polish Central Statistical Office*] in connection with the necessity to adjust the Polish economy to the requirements of the European Union law regarding regional statistics. On the basis of the *Nomenclature of Territorial Units for Statistics* (*NUTS*), legally binding in the EU countries, in the year 2000 the Polish statistics was altered to include the Nomenclature of Territorial Units for Statistical Purposes [*pl. Nomenklatura Jednostek Terytorialnych do Celów Statystycznych*] (NTS) and a five-level hierarchical grouping of data (country,

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provinces – regions, subregions – groups of districts, districts, communes). The NUTS system is based on the binding administrative division of the member countries. In exceptional cases, in order to improve comparability with regional levels within the EU, for statistical purposes new units are created which have no equivalents in the territorial division. In case of Poland, this pertains to subregions (NTS 3).

The economic and spatial analysis of subregions, performed using the synthetic indicators developed by GUS (gross domestic product - GDP and gross value added - GVA), characterizes the diversification of the level of development and the sector structure of the economy better than in case of the arrangement of 16 provinces.

The presented article sets two fundamental aims. The first of these is to estimate the level of TFP in the years 2003-2009 at the level of subregions, whereas the second one is to define the factors which determine the level of TFP in Polish subregions in the considered period, with particular attention paid to the role of human capital.

2. Methodology applied to measure TFP

In order to estimate the value of TFP we have taken advantage of the method applied in Tokarski's paper (2008), which consists in determining the estimation of parameter *α* on the basis of a two/double/bi-factor function by Cobb-Douglas: $Y = \alpha_0 K^{\alpha} L^{1-\alpha} e^{\varepsilon_t}$. This function is converted into an efficiency model in the form of:

$$\ln\left(\frac{Y_{it}}{L_{it}}\right) = \ln A + gt + \alpha \ln\left(\frac{K_{it}}{L_{it}}\right) + \varepsilon_{it} \qquad (1)$$

where *Y* – gross value added in million of PLN, *L* – amount of labour (expressed in thousands of working people), *K* – gross outlays on property, plant and equipment in million of PLN, $\alpha_0 = Ae^{gt} > 0$ – total productivity of production factors (TFP) *t* – a time variable, *g* – rate of technological progress in the sense of Hicks, *α* – flexibility *Y* in relation to capital*K*.

After estimating model (6) the TFP values specific to individual subregions and years were calculated according to the following formula:

$$TFP_{it} = \frac{(Y_{it} / L_{it})}{(K_{it} / L_{it})^{a}} \qquad (2)$$

where *a* is the estimate of parameter *α* of model (6).

In order to estimate the efficiency model and models which describe the shaping of TFP, alternative specifications were applied in case of panel data: fixed effects (FEM), random effects (REM), Swamy random-coefficients, Hausman-Taylor models. It appears that the first two constructions are commonly known, and therefore below we provide a brief description of the idea behind the last two approaches.

Random-coefficients models are more general than fixed- and random-effects models in that they allow each panel to have its own vector of slopes randomly drawn from a distribution common to all panels. A random-coefficients model has the form (Swamy, 1970)

$$y_{it} = \boldsymbol{x}_{it}^T \boldsymbol{\beta}_i + \varepsilon_{it} \tag{3}$$

where $\boldsymbol{\beta}_i$ is a k×1 vector of parameters specific to group i. The error term vector $\boldsymbol{\varepsilon}_i=[\varepsilon_{it}]_{Tx1}$ is distributed with mean zero and variance $\sigma_{ii}^2\mathbf{I}$. Each group-specific $\boldsymbol{\beta}_i$ is related to an underlying common parameter vector $\boldsymbol{\beta}$: $\boldsymbol{\beta}_i = \boldsymbol{\beta} + \mathbf{v}_i$ where $E[\mathbf{v}_i] = 0$, $E[\mathbf{v}_i\mathbf{v}_i^T] = \Sigma$, $E[\mathbf{v}_i\mathbf{v}_j^T] = 0$ for $j \neq i$, and $E[\mathbf{v}_i\boldsymbol{\varepsilon}_j^T] = 0$ for all i and j. The estimate of $\hat{\boldsymbol{\beta}}$ is a weighted average of the panel-specific OLS estimates of $\hat{\boldsymbol{\beta}}_i$.

Hausman and Taylor (1981) developed a method of estimation of models which contain variables that explain both the constants and the variables in time. In addition, irrespective of the above diversification, the method permits part of the variables not to be correlated, and part – to be correlated with group effects α_i. This means a combination of the assumptions of FEM and REM regarding the correlations between the group effects and explanatory variables. The estimation method is based on the Method of Instrumental Variables (IV).

3. Estimating the value of TFP according to subregions

Among all the 66 subregions there are eight specific ones, being large urban agglomerations. They have been isolated before commencing the analysis.They include: Warszawa, Poznań, Kraków, Wrocław, Trójmiasto, Łódź, Szczecin, Katowice. Model (6) has been estimated separately for the abovementioned urban subregions and others.

Table 1 presents the results obtained using the most optimal method for each subgroup, from the point of view of the subject matter and the statistical quality of the model. For urban subregions this involved the specification random effects model, while for the group of the remaining subregions – Swamy random-coefficients model.

Table 1. Results of the estimation of the model (1)

	Subgroup	
	Urban subregions	Remaining subregions
	Estimation method	
	Random effects model (REM)	Swamy random-coefficientsmodel
$\ln(K_{it}/L_{it})$	0.3489 [0.000]	0.1784 [0,039]
t	0.0252 [0.000]	0.0275 [0.000]
$\ln A$	-1.6683 [0.000]	-2.0186 [0.000]
R^2	within = 0.8136 between = 0.8789 overall = 0.8259	-
Test of parameter constancy	-	chi2(171) = 11862.24 Prob> chi2 = 0.0000
Number of observations	56	406

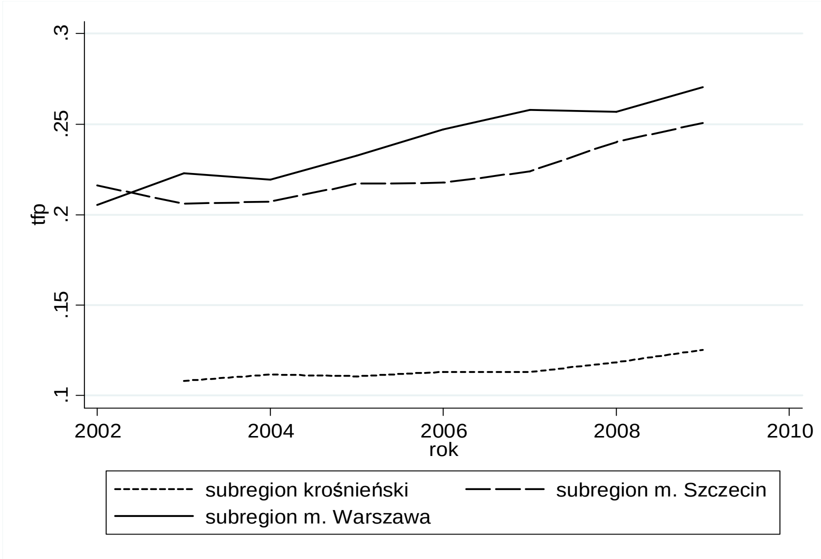
Note: In square brackets *p-values* have been given.

Source: author's calculations.

The results of the estimation of the efficiency model appear to be satisfactory. The rate of technological progress in the understanding of Hicks, annually amounts to: 2.5% for urban subregions and 2.7% for the remaining ones. The flexibility of productivity in relation to the technical armament of work is significantly higher in case of urban subregions (0.35) than in case of the remaining ones (0.18), which may be due to a better utilization of capital in these subregions.

The next stage of the analysis involved calculating the total productivity of production factors for subregions. To this end, we have applied formula (7) with the value a equal to 0.3489 or 0.784, for "urban" subregions and the remaining ones respectively (see Table 1). The obtained values differ in a significant way. Overall, we have found that the TFP values for "urban" subregions are higher than for the remaining ones. A graphical representation of TFP values for all the subregions would render the graph illegible. Therefore, Graph 1 presents, as an illustration of the rate of TFP diversification, the shaping of this variable in subregions of extreme values.

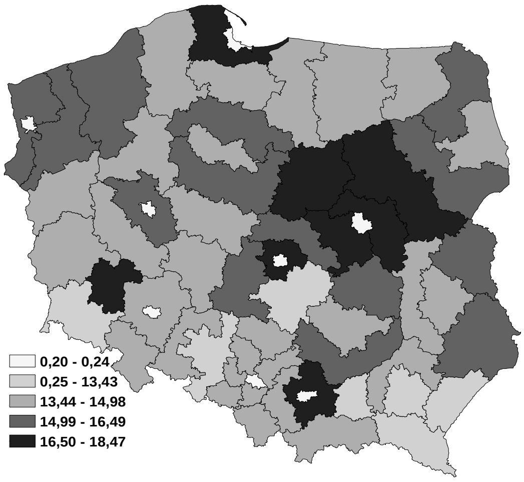
Graph 1. A comparison of the extreme values of TFP in subregions



Source author’s calculations.

On the basis of graph 1 one can find a considerable diversification of TFP values between subregions. For this reason we have decided to perform the analysis of the determinants of this variable in smaller groups of subregions. Apart from the group of “urban” subregions, isolated at the previous stage of research, from among the 58 remaining subregions we have isolated four subgroups. The grouping criterion involved the average value of TFP for each subregion, calculated for the entire sample period: $\overline{TFP}_i = (\sum_t TFP_{it})/T$. In the first stage, on the basis of the obtained values we have calculated the national average: $\overline{TFP} = (\sum_i \overline{TFP}_i)/N$. The subregions have been divided into those in which $TFP_{it} > \overline{TFP}$ and those in which $TFP_{it} < \overline{TFP}$. For each of the two groups obtained in such a manner, procedure from stage one has been repeated, ultimately yielding four groups of regions (the fifth group includes “urban” subregions).

Graph 2. TFP level in subregions (TFP*100)



Source author's calculations.

4. Potential determinants of TFP in Polish subregions

Greater and greater interest of theoreticians and practitioners is aroused by the role of human resources in developing competitiveness of economies. Human capital is considered to be an important factor in regional and local development (Herbst 2009).

As regards the influence of human capital on the growth of the economy, two approaches are noticeable (Aghion, Howitt 1992). In the first of these, human capital is defined as an argument of the function of production. In the second approach, it is treated as a factor which has influence on developing innovations and assimilating new technologies – a factor which is indispensable for technological development. In accordance with the last of the approaches, human capital affects the growth of the economy in an indirect manner - by means of the total productivity of production factors.

The set of indicators which characterize the quality of human capital is extremely vast. Since they comprise the level of education, skills, health and migration opportunities (Herbst 2009; Kunasz 2010). Not all information is available at the level of NUTS3. The choice of variables has been dictated by the possibility to obtain data which ensure comparability with respect to space and time.

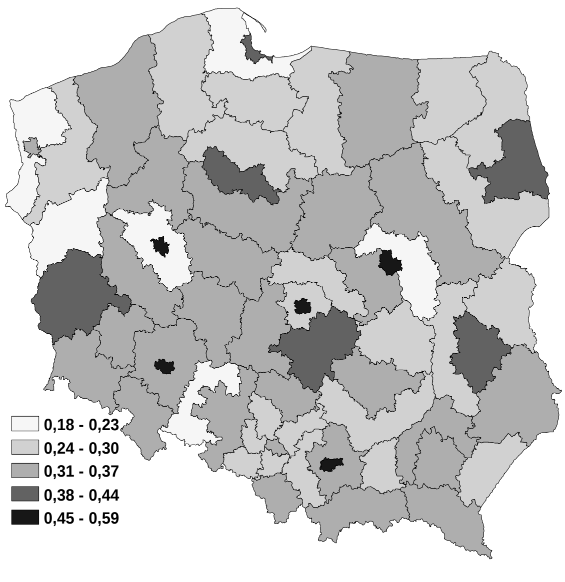
Therefore, the following indicators were selected to account for various human capital aspects:

- computer with Internet access per 10 thousand people,
- number of students per 10 thousand inhabitants,
- number of graduates of schools of higher education per 10 thousand people,
- gross scholarization coefficient in case of postsecondary schools (age: 19-21 years old),
- owing to the lack of information about the state of health (e.g. life expectancy) at the level of subregions, as an indicator of the state of health, we have used outlays on health measured in the number of consultations with physicians per 10 thousand inhabitants.

On the basis of selected indicators (diagnostic variables) we have created the synthetic variable *Z*. The aggregate variable Z_i^t for object *i* at time *t*is an unweighted sum of individual diagnostic characteristics after normalization (Panek 2009). The higher value of the variable Z_i^t, the better human capital level.

The average level of human capital (average value of the synthetic variable Z_i^t) in Polish subregions in the years 2003-2009 is illustrated by the map.

Graph 3. The average values of human capital measure in Polish subregions in the years 2003-2009



Source: Author's calculations.

Subregions with the highest level of human capital in the vast majority include urban subregions. On average, in the considered period the subregions with the highest level of human capital included: the city of Warszawa, city of Poznań, city of Łódź, city of Kraków. In the last year of the period, it was the most favourable in the city of Warszawa, city of Poznań, city of Kraków, city of Wrocław, city of Łódź. Whereas, the lowest average value of human capital in the considered period is observed in the following subregions: elbląskie, oświęcimskie, radomskie, skierniewickie.

Apart from the assessment of the role of human capital, one of the targets of the analysis involved examining the influence exerted on the shaping of TFP through research and development activity. The only available variable which measures the level of this last factor includes outlays on research and development (R&D). However, GUS does not provide its value at the level of subregions, but merely at the level of provinces. Despite this, we have made an attempt to include this indicator in the model. We have constructed an interactive variable, being the product of the estimated value of human capital in a subregion and the value of outlays on research and development in the province, to which the given subregion belongs. It appears that including a variable constructed in such a way in the model allows us to take into consideration the diversification of the effects of the R&D activity between subregions, in which the possibilities of their absorption are varied due to the unequal level of human capital.

Among the factors which can determine TFP investments are also taken into consideration. Such a variable has also been used in the presented study.

Research methodology and obtained results

This analysis uses a static panel model

$$\ln TFP_{it} = \mathbf{x}_{it}^{T}\boldsymbol{\beta} + \sum_{j=1}^{15} \alpha_j d_j + \varepsilon_{it} \tag{4}$$

where *i*is an object indicator and *t* is a time indicator,

$\boldsymbol{x}_{it} = [x_{kit}]_{K\text{x}1}$ – a K-coordinate vector of explanatory variables,

β – a vector of parameters (*K*x1), identical for all *i*and *t*

d_j – a dummy variable indicating a voivodeship containing the subregion

The reason for including binary variables in the model is to examine whether the fact of belonging to a given province, and what follows from this, the influence of the directly superior economy, has influence on the level of TFP in the subregion.

In the analysis we have applied alternative specifications for panel data: fixed effects (FEM), random effects (REM), Hausman-Taylor models (HT). The tables below present the results yielded by the models with the best statistical properties and correct from the standpoint of economic theory.

Table 1 shows results of the estimation of TFP models for all the subregions along with urban subregions. Table 2 presents the results of estimation of TFP models in the remaining subgroups isolated due to the observed level of TFP.

Table 2. Results provided by the ln*TFP* models for 66 subregions and city-subregions

	66 subregions RE model	*City-subregions RE model*
	Parameter estimate [p-value]	
investment outlays per capita (in form of logarithm)	0.0649 [0.000]	0.054 [0.003]
interactive variable (in form of logarithm	0.1109 [0.000]	0.0746 [0.002]
dolnośląskie	-0.2107 [0.000]	-
kujawsko-pomorskie	-0.1678 [0.000]	
lubelskie	-0.2299 [0.000]	
małopolskie	-0.2870 [0.000]	-
pomorskie	-0.1377 [0.000]	
śląskie	-0.3069 [0.000]	-
wielkopolskie	-0.2848 [0.000]	-
łódzkie	-0.1872 [0.000]	
mazowieckie	-0.2887 [0.000]	-
podkarpackie	-0.2545 [0.000]	
const	1.2034 [0.000]	1.1905 [0.000]
R-sq within	0.4296	0.4296
R-sq between	0.462	0.462
R-sq overall	0.4561	0.4561
Breusch-Pagan test [*p*-value]	893.809 [0.000]	23.91 [0.000]
number of units	462	56

Note: a) all explanatory variables are given as the logarithms

Source: author's calculations.

Table 3. Selected results provided by the ln*TFP* models in isolated subgroups

	Group I RE model	*Group II HT model*	*Group III RE model*	*Group IV HT model*
investment outlays per capita (in form of logarithm)	0.0516 [0.001]	0.0564 [0.000]	0.0664 [0.000]	0.0534 [0.085]
interactive variable (in form of logarithm	0.1985 [0.000]	0.0961 [0.000]	0.0599 [0.000]	0.2260 [0.000]
kujawsko-pomorskie		0.0596 [0.000]	0.0679 [0.000]	
lubelskie		0.0774 [0.000]	0.0979 [0.000]	
lubuskie		0.2686 [0.000]		
łódzkie			0.0423 [0.000]	
małopolskie				-0.218 [0.000]
podlaskie		0.1889 [0.000]	0.1998 [0.000]	
pomorskie		0.0650 [0.000]		
mazowieckie				-0.476] [0.000]
opolskie	0.5951 [0.000]	0.3329 [0.000]		
podkarpackie	0.2736 [0.000]			
świętokrzyskie		0.2778 [0.000]	0.2417 [0.000]	
warminsko-mazurskie	0.4477 [0.000]	0.2348 [0.000]		
zachodniopomorskie			0.1443 [0.000]	
const	-0.1415 [0.000]	1.1010 [0.000]	1.5428 [0.000]	-0.0928 [0.000]
R-sq within	0.6477		0.413	
R-sq between	0.4483		0.811	
R-sq overall	0.5243		0.486	
Breusch-Pagan test [*p*-value]	55.41 [0.000]		2.17 [0.070]	
number of units	105	161	84	56

Note: a) all explanatory variables are given as the logarithms: group I- the highest level of TFP, group IV – the lowest level of TFP

Source: author's calculations.

In all the considered models the variable which has a significant influence on TFP includes investment outlays (for group IV at the significance level of 0.1). The effect of the influence of investments in the urban subregions and the subregions which belong to the four remaining groups is similar.

The interactive variable which is the product of the level of human capital and the outlays on R&D, is also of significant. It means, that in all the selected subgroups, the influence of the R&D absorption on the TFP level, measured by the parameter estimates, is important (and positive). The strength of this influence is greatly diversified and is the weakest in the subregions of urban nature).

5. Conclusions

The conducted study allows us to conclude that the diversified level of TFP values in the subregions is, to some extent, conditioned by the differences in the human capital. The impact of human capital on the level of TFP is observed both in the subregions with the highest level of this variable, as well as in those in which the level of TFP is relatively low. Thus, the investments in human capital can stimulate the competitiveness of the region.

Inclusion of the interactive variable into the model of human capital additionally allows one to estimate the possibility of using provincial outlays on research and development activities in subregions, depending on the level of human capital.

Investments constitute yet another factor which determines the shaping of TFP in subregions, where the strength of influence is similar for all subregions. The binary variables which determine the provincial membership are partially significant; however, it appears that the influence of the situation in the superior region is more significant in the provinces considered to be slightly worse developed with respect to the economy.

It seems that the results of the presented research can be helpful to the practitioners, especially in the field of social policy (mainly educational and health).

The conducted study allows us to conclude that the level of TFP in subregions is greatly diversified. The highest value of TFP characterizes the subregions of urban nature. In urban subregions we can also observe the highest level of human capital. The applied econometric models confirm the speculation about the positive role of human capital in the shaping of TFP, both in the subregions with the highest level of this variable, as well as in those in which the level of TFP is relatively low. Inclusion of the interactive variable into the model of human capital additionally allows one to estimate the possibility of using provincial outlays on research and development activities in subregions, depending on the level of human capital.

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References

Aghion P., Howitt P. (1992), *A model of growth through creative destruction*, 'Econometrica', vol. 60(2), pp. 323-351

Hausman J.A., W.E.Taylor (1981), *Panel data and unobservable individual effects*, 'Econometrica', 49(6), pp. 1377–1398

Herbst M. (2009), *Tworzenie i absorpcja kapitału ludzkiego w polskich miastach akademickich w kontekście realizacji narodowej strategii spójności*, http://www.mrr.gov.pl/aktualnosci/fundusze_europejskie_2007_2013/Documents/3_8_M_Herbst_Tworzenie_i_absorpcja_kapitalu_ludzkiego_w_pols.pdf [access: 21.05.2012]

Kunasz, M. (2010), *Indeks gospodarowania kapitałem ludzkim*, raport przygotowany na zlecenie Centrum Badań Socjologicznych, VOLUMINA, Szczecin

Panek T. (2009), *Statystyczne metody wielowymiarowej analizy porównawczej*, Oficyna Wydawnicza SGH, Warszawa

Statistical Data of GUS: http://www.stat.gov.pl

Swamy P.A.V.B. (1970), *Efficient Inference in a Random Coefficient Regression Model*, 'Econometrica', vol. 38, pp. 311-323

Tokarski T. (2008), *Oszacowanie regionalnych funkcji produkcji*, 'Wiadomości Statystyczne', vol. 10, pp. 38-53

Streszczenie

DETERMINANTY ŁĄCZNEJ PRODUKTYWNOŚCI CZYNNIKÓW PRODUKCJI W PODREGIONACH W POLSCE

Znaczącą rolę TFP w stymulowaniu długookresowego rozwoju gospodarczego skłania badaczy do poszukiwania źródeł jej wzrostu.

Główne cele badań prezentowanych w artykule są następujące: oszacowanie wartości TFP w latach 2003-2009 w podregionach, a następnie określenie czynników determinujących łączną produktywność czynników produkcji. Z zastosowaniem modelu ekonometrycznego podjęto próbę weryfikacji hipotezy, iż jakości kapitału ludzkiego odgrywa istotną rolę w stymulowaniu długookresowego wzrostu gospodarczego. Zgodnie z kolejną hipotezą istnieją czynniki wpływające na poziom TFP, wspólne dla wszystkich podregionów.