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Determinants of industry-level production capacity in Poland

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Abstract

The paper deals with the production capacity – innovation nexus. It focuses on development of total factor productivity (TFP), which is one of the determinants of production capacity of the economy. The analysis is carried out using 2-digit NACE rev. 2 level Polish manufacturing data covering the most recent period of 2008-2012. TFP is estimated using theoretical framework based on a Cobb-Douglas production function and an attempt is made to identify the role of innovation activities in forming TFP in case of economy of an emerging country under recent economic crisis. The findings suggest that the non-R&D innovation activities are of more importance in determining TFP of Polish manufacturing divisions than R&D expenditures.

Keywords: TFP, R&D expenditures, non-R&D expenditures, Poland, manufacturing, panel data

1. Introduction

The paper provides estimates of the TFP values in the Polish manufacturing industries using the most recent data available, covering the period of 2008-2012. It tries to answer the question whether innovation expenditures play an important role in forming TFP in case of emerging country economy under recent economic crisis.

TFP is the amount of production that can be obtained using unit inputs of the production factors. TFP growth is interpreted in terms of technological progress – it represents part of output growth which does not result from the growth of production factors (Dańska-Borsiak, 2011; Tomaszewicz and Świeczewska, 2008).

As little is known about the non-input determinants of economic growth, TFP (Solow's residual) is often called a "measure of our ignorance" of growth process (Abramowitz, 1956). In a narrower sense it stands for output growth related to technological and efficiency improvements, while in a wider view it covers output growth due to all sorts of factors (cf. resource endowment, climate, institutions, corruption etc.) (Eberhardt and Teal, 2010 as cited in Gehringer et al., 2014).

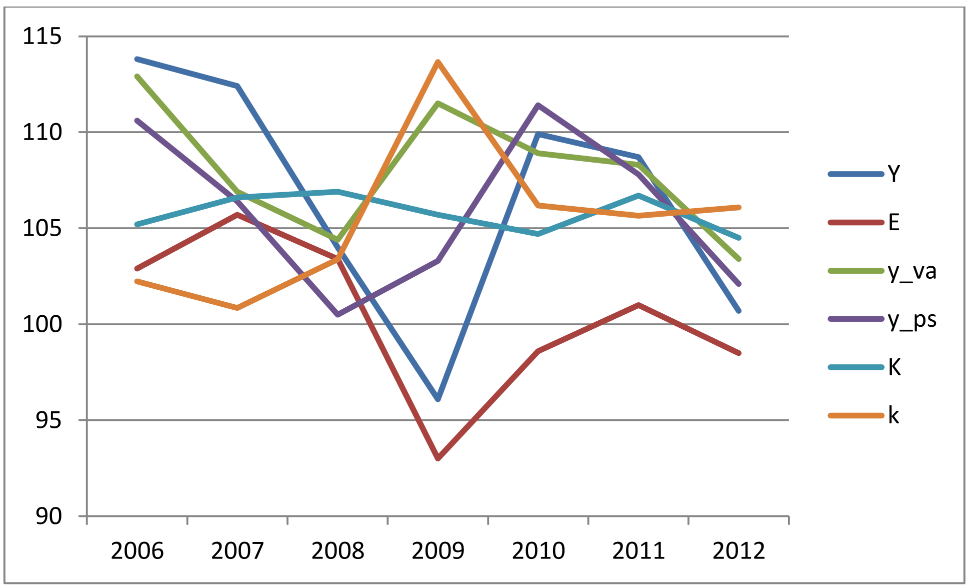
This paper is structured as follows. Section 2 reports briefly changes in key variables in Polish manufacturing sector in the period 2006-2012. Section 3 presents methodology and estimation results of total factor productivity for Polish manufacturing divisions using the most recent available data of 2-digit NACE rev. 2 level (2008-2012). In Section 4 determinants of TFP are analyzed using the estimated series obtained in Section 3. Finally, Section 5 provides some concluding remarks.

2. Data overview

The starting point of the study is the preliminary analysis of changes in production sold, net value of fixed assets, paid employment, labour productivity and capital-labour ratio in the Polish manufacturing sector[1].

The years 2008-2009 were a period of global crisis. Polish economy was largely resistant to this phenomenon, and there was only a slowdown of its development observed. Poland was the only country out of the 27 European Union member states which reported a positive value of the GDP index in all the four quarters during the financial crisis (i.e. between Q4 2008 and Q3 2009) (Tworek, 2012). This may serve as the evidence that Polish economy remained relatively stable during the crisis, without excessive shocks.

Figure 1. *The rate of change of production sold, average paid employment, gross value of fixed assets, labour productivity and capital-labour ratio in manufacturing section in 2006-2012 (compared to the previous period in %, constant prices)*



Notes: Y – index of production sold,
E – index of average paid employment,
y_va – index of labour productivity measured by gross value added per paid employee,
y_ps – index of labour productivity measured by production sold per paid employee,
K – index of gross value of fixed assets,
k – index of capital-labour ratio measured by gross value of fixed assets per paid employee.

Source: Statistical Yearbook of Industry (2013).In the years 2006-2012, the average paid employment in the manufacturing sector showed some fluctuations. Until 2009 average number of paid employees had been increasing (with the rates of 2.9%, 6.6% and 3.4 % in the years 2006, 2007 and 2008 respectively as compared to the previous year). From 2009 onwards employment had been decreasing (with exception of 1% rise in 2011), with the most significant rate of fall in 2009 (7%) and decreases of about 1.5% in 2010 and 2012.

[1] Time span of analysis is determined by availability of comparable data. The data for manufacturing divisions are available from 2008.

Similar pattern can be observed when analyzing indices of production sold. After a period of relatively high growth in 2006 and 2007, the growth rate decreased to 4% in 2008, reaching minimum of -3.9% (decrease of production sold) in 2007. Following years brought rise of 9.8% in 2010 and 9.3% in 2011. In 2012 volume of production sold rose only by 0.7% compared to 2011.

As a result, labour productivity measured by production sold per paid employee was improving during the whole analyzed period with the 11.4% growth peak in 2010. Index of labour productivity measured by gross value added per paid employed person showed similar pattern with exception for a peak of 11.5% in 2009.

The gross value of fixed assets in manufacturing showed a stable growth with rates of growth of 4.5-6.9% compared to the previous year. As a consequence, capital-labour ratio was rising over the whole analyzed period.

3. Estimation of total factor productivity (TFP)

Total factor productivity is an unobserved economic variable and it is measured using other available data series. Standard Solow-type equation is used to estimate TFP values in the Polish manufacturing sector.

The starting point is the Cobb-Douglas production function in its most standard form with two production factors:

$$Y_{i,t} = TFP_{i,t} K_{i,t}^{\beta} L_{i,t}^{1-\beta} \qquad (1),$$

which can be written in intensive form as

$$y_{i,t} = TFP_{i,t} k_{i,t}^{\beta} \qquad (2),$$

where $y_{i,t} = \frac{Y_{i,t}}{L_{i,t}}$ and $k_{i,t} = \frac{K_{i,t}}{L_{i,t}}$.

Equation (2) can be written in a log form as

$$\ln y_{i,t} = \ln TFP_{i,t} + \beta \ln k_{i,t} \qquad (3).$$

Taking first differences on both sides of equation (3) we get

$$\Delta \ln y_{i,t} = \Delta \ln TFP_{i,t} + \beta \Delta \ln k_{i,t} \qquad (4).$$

The estimation model takes the form

$$\Delta \ln y_{i,t} = \sum_{i=10}^{33} \alpha_i d_i + \beta \Delta \ln k_{i,t} + \varepsilon_{i,t} \qquad (5),$$

where d_i is a dummy variable taking the value of 1 for the i-th division, and $y_{i,t}$ is measured using the value of production sold in millions of zlotys[2] ($Y_{i,t}$) per unit of labour ($L_{i,t}$) (the latter proxied by average paid employment in thousands), $k_{i,t}$ is measured by inputs of physical capital (in terms

[2] Estimation of model with Y proxied by gross value added in millions of zlotys was also performed, but the results were not satisfactory from a statistical point of view, therefore they are not presented.

of gross value of fixed assets, millions of zlotys – $K_{i,t}$ per unit of labour), β *(1- β)* is the output elasticity of capital (labour)[3].

The values of the variables are observed for the *i*-th division (*i=10,…,33*) in the year *t* (*t=2008,…,2012*). The statistical data used in the investigation were derived from the Statistical Yearbooks of Industry published by the Central Statistical Office in Poland. They describe 24 divisions in section C (manufacturing) numbered in the Polish Classification of Activities (PKD NACE Rev. 2) from 10 to 33. The main advantage of division level analysis over aggregate analysis is that it provides more reliable results as sectoral data have less noise than aggregate data (Ulku, 2007). Table 1 lists manufacturing divisions covered by the study and their codes.

Table 1. *Manufacturing divisions (2-digit NACE codes)*

Divisions (NACE Rev. 2)	
10	*Manufacture of food products*
11	*Manufacture of beverages*
12	*Manufacture of tobacco products*
13	*Manufacture of textiles*
14	*Manufacture of wearing apparel*
15	*Manufacture of leather and related products*
16	*Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials*
17	*Manufacture of paper and paper products*
18	*Printing and reproduction of recorded media*
19	*Manufacture of coke and refined petroleum products*
20	*Manufacture of chemicals and chemical products*
21	*Manufacture of basic pharmaceutical products and pharmaceutical preparations*
22	*Manufacture of rubber and plastic products*
23	*Manufacture of other non-metallic mineral products*
24	*Manufacture of basic metals*
25	*Manufacture of fabricated metal products, except machinery and equipment*
26	*Manufacture of computer, electronic and optical products*
27	*Manufacture of electrical equipment*
28	*Manufacture of machinery and equipment n.e.c.*
29	*Manufacture of motor vehicles, trailers and semi-trailers*
30	*Manufacture of other transport equipment*
31	*Manufacture of furniture*
32	*Other manufacturing*
33	*Repair and installation of machinery and equipment*

Source: *Statistical Yearbook of Industry – Poland (2013).*

[3] Production and physical capital were deflated using price indices of sold production and *investment outlays* respectively.

The model was estimated using the Generalized Least Squares Method (GLS) with industry fixed effects to take into account possible group-wise heteroscedasticity between industries. Table 2 presents the results.

Table 2. *Estimates for the labour productivity model*

Variable	Coefficient
C	0.0031 [0.0047]
$\Delta \ln k_{i,t}$	0.4969*** [0.0609]
R-squared Adj. R-squared S.E. of regression	0.4114 0.2124 0.0930

*Notes: Industry controls are included but not reported. Robust standard errors in brackets. *** p <0.01, ** p < 0.05, * p < 0.1.*

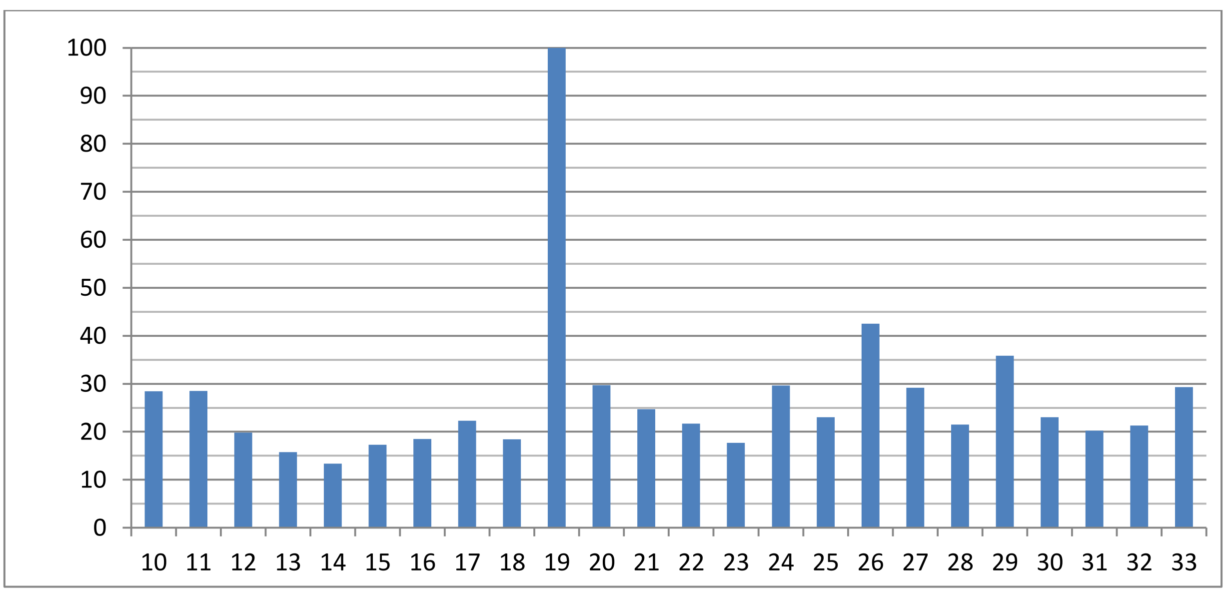
$k_{i,t}$ - capital to labour ratio in the i-th manufacturing division and year t.

Source: Author's calculations.

With the given value β, total factor productivity is computed using the formula:

$$TFP_{i,t} = \frac{y_{i,t}}{k_{i,t}^{0.4969}} \quad (6).$$

Figure 2. *Divisional differences in TFP in 2008-2012 (division 19 = 100)*



Note: Mean TFP for division 19 "Manufacture of coke and refined petroleum products" is assumed to be 100.

Source: *Author's calculations.*

Figure 2 presents mean values of TFP at the industry level. The leading industries on this basis are: 19 – Manufacture of coke and refined petroleum products, 26 – Manufacture of computer, electronic and optical products and 29 – Manufacture of motor vehicles, trailers and semi-trailer. The lagging are: 13 – Manufacture of textiles, 14 – Manufacture of wearing apparel, 15 – Manufacture of leather and related products, 16 – Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials, 18 – Printing and reproduction of recorded media, 23 – Manufacture of other non-metallic mineral products, 31 – Manufacture of furniture. These findings stay in line with the study of TFP values in Polish manufacturing sector in 1998-2007[4] (Dańska-Borsiak, 2011).

4. Innovation determinants of TFP – empirical study

The next step in the analysis was to estimate the impact of innovation expenditures on total factor productivity. An attempt was made to answer the question whether other types (apart from R&D expenditures) of innovation-related activities do matter in promoting productivity growth in case of Polish economy. Following Griffith et al. (2004) and Lopez-Rodriguez and Martinez (2014), R&D and non-R&D expenditures were differentiated. This theoretical framework augments traditional, R&D-determined productivity growth with micro approach by assuming positive impact of non-R&D activities on TFP level (Lopez-Rodriguez and Martinez, 2014).

The impact of innovation activities on TFP was estimated using dynamic TFP model, where TFP is autoregressive and depends on R&D and non-R&D innovation expenditures.

The estimated equation can be written as follows:

$$\ln(TFP_{i,t}) = \alpha_0 + \gamma \ln(TFP_{i,t-1}) + \beta_1 \ln(R\&D_{i,t-1}) + \beta_2 \ln(nonR\&D_{i,t}) + \varepsilon_{i,t} \quad (7),$$

where *i*, *t* indicate respectively industry and year; *TFP, R&D* and non *R&D* are straightforward, and ε is the error term. In order to avoid endogeneity bias, *R&D* variable is included with one year lag (Lopez-Rodriguez and Martinez, 2014). Table 3 reports summary statistics on the data employed in econometric model.

[4] See Sulimierska (2014) for results of TFP estimates for Polish manufacturing sector using different techniques and review of empirical studies about Polish productivity.

***Table 3**. Descriptive statistics*

Variable	Mean	Std. Dev.	Min	Max
$Y_{i,t}$	33420,8	30994,0	2725,8	153995,9
$K_{i,t}$	18600,1	15300,6	1319,3	72128,6
$L_{i,t}$	94,93	84,64	5,30	394,30
$y_{i,t}$	514,08	854,33	66,03	5933,66
$k_{i,t}$	301,46	392,84	23,53	2622,16
$TPF_{i,t}$	27,39	17,07	12,95	118,74
$R\&D_{i,t}$	114,88	178,36	0,60	1178,02
$nonR\&D_{i,t}$	576,57	762,13	11,70	5857,78
$R\&D_{i,t}/Y_{i,t}$	0,0037	0,0050	0,00004	0,0325
$nonR\&D_{i,t}/Y_{i,t}$	0,0159	0,0146	0,0013	0,1265

***Source:** Author's calculations based on data from Statistical Yearbook of Industry of the Polish Central Statistical Office (various years) and own's estimates.*

A positive coefficient for the lagged TFP is expected. The main interest is in β_1 and β_2, both of which are expected to be positive. Given the fact that on the one hand R&D expenditures play a minor role in innovation outlays in Polish economy as a whole and the importance of R&D activities in promoting productivity on the other, no a priori determination is made which of these variables' contribution to TFP is of relatively higher impact.

Equation (7) was estimated using both Least Squares Dummy Variable Corrected Estimator (LSDVC) and Blundell-Bond system GMM (SGMM) (1998), assuming endogeneity of R&D and non-R&D expenditures. Table 4 reports the results of the estimation.

Column (1) reports Least Squares Dummy Variable Corrected Estimator (LSDVC)[5] as the LSDVC estimator performs better than the GMM in case of low number of individuals related to the number of effects to identify and unbalanced panel (Bruno 2005a, 2005b). Robust standard errors are obtained through bootstrapping with 50 iterations.

Columns (2) and (3) report the one-step and two-step GMM-SYS assuming endogenity of R&D and non-R&D expenditures.

The high estimate (0.703) of the autoregressive parameter in columns (2) and (3) points to TFP stability in manufacturing divisions. This conclusion is consistent with the earlier study of TFP at the industry level in Polish manufacturing sector – Dańska-Borsiak (2011), using similar method, reports the coefficient level of 0.6725.

The impact of non-R&D expenditures is positive and significant at 10% level. Estimated elasticities of TFP with respect to non-R&D activities are relatively high compared to coefficients for R&D. A striking point is that the coefficients of R&D are not statistically significant across columns 1-3.

[5] LSDVC was initialized by GMM–SYS.

These results can be interpreted in terms of Polish specificity since in case of lagging economy, non-R&D activities are more profitable than investing in R&D. Insignificant impact of R&D expenditures may also suggest lack of sufficient critical mass of research activities to trigger technological progress. Being far from technological cutting edge, Polish manufacturing benefits from technology transfer from more developed economies (Kolasa and Żółkiewski, 2004). Non-R&D innovation investment data proxy technology transfer via purchase of machines, technical equipment and other assets required for introduction of innovations as well as acquisition of knowledge from external sources.

Table 4. *TFP regression – estimation results*

	LSDVC BB (1)	GMM-SYS one-step (2)	GMM-SYS two-step (3)
$\ln(TFP_{i,t})$	0.391***	0 .703***	0.703***
	[0.126]	[0.124]	[0.006]
$\ln(R\&D_{i,t-1})$	0.028	0.001	0.003
	[0.0244]	[0.012]	[0.003]
$\ln(nonR\&D_{i,t})$	0.073**	0 .044*	0.047***
	[0.035]	[0.027]	[0.006]
C		0.693***	0 .667***
		[0.349]	[0.006]
N instruments		25	25
AR(1)		-1.885	-2.066
p value		0.0606	0.038
AR(2)		-1.515	-1.528
p value		0.130	0.127
Sargan		32.096	21.393
p value		0.057	0.435

*Notes: Robust standard errors in brackets. *** p <0.01, ** p < 0.05, * p < 0.1.*

Source: *Author's calculations.*

The structure of Polish innovation expenditures is typical for countries with low income. The R&D expenditures are small compared to market size and capital expenditures on acquisition of machinery and technical equipment, tools and transport equipment, which dominate over other innovation expenditures (Geodecki et al., 2012). In this respect, the situation in Poland is similar to most of post-Soviet countries sharing common problems arising from the legacy of the previous era (i.a. largely outdated scientific research equipment, lack of institutional mechanisms relevant to the market economy generating commercially viable results) (Yegorov, 2009). As these constraints still persist in many less developed Central European economies, only a sound innovation policy can overcome it.

The structure of innovation expenditures results to a great extent from strategy of imitation based i.a. on technology transfer in the form of importing foreign machinery. The main drawback of this strategy is that the excessive imitation debilitates the ability of reducing the technological gap. Literature on technological catch-up stresses the fact that a latercomer has to accumulate a substantial amount of absorptive capacity to be able to acquire most modern technology and must go through imitation stage in order to achieve the innovation stage. However, lack of effective (appropriate) learning strategy will make the country remain imitator instead of becoming a significant "producer" of new knowledge (Sohn et al., 2009).

The situation in Poland is even more alarming taking under consideration the relative slowdown of productivity growth observed in Poland compared to the adjacent catching-up countries, accompanied by lower propensity to invest (Geodecki et al., 2012).

5. Conclusion

The study investigated total factor productivity (TFP) and its drivers using 2-digit NACE level data from Polish manufacturing between 2008 and 2012. In this paper new estimates for TFP were presented using the most recent data available.

Obtained results revealed considerable differences in TFP between the sectors as well as stability within particular industries. The econometric investigation highlighted also the contrast between the impact of R&D and non-R&D innovation activities.

It was shown that TFP of Polish industries is boosted rather by non-R&D expenditures. This was interpreted in terms of R&D underinvestment and technology transfer effect proxied mainly by expenditures on investments in acquisition of machinery and technical equipment which prevails over other innovation expenditures and (probably to a less extent) expenditures on acquisition of knowledge from external sources.

Result of the study lends some support for the view that TFP growth in case of lagging economy with relatively low share of R&D expenditures in GDP can be more effectively stimulated by increasing non-R&D expenditures (Lopez-Rodriguez and Martinez, 2014).

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