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The impact of research and development activity on the TFP level in manufacturing in Poland

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Keywords: total factor productivity; research and development activity; Cobb-Douglas function; manufacturing divisions; panel models

Abstract

Research background: The paper presents the issue of total factor productivity in the manufacturing industry in Poland. It has been assumed that total factor productivity (TFP) is a synthetic measure of efficiency of the production process and a measure of the impact of technical progress on the rate of economic growth.

Purpose of the article: The main aim of the paper is to assess the differentiation in the level of total factor productivity (TFP) occurring among the Section C manufacturing divisions in Poland. In particular, the paper raises the issue of measuring and analysing the relationship between expenditure on research and development and the level of TFP in manufacturing divisions in Poland.

Methods: In the presented research, the TFP level was determined by using the two-factor Cobb-Douglas production function, while econometric panel models were used to assess the studied relationship.

Findings & Value added: The presented considerations show that manufacturing divisions in Poland are diversified in terms of total factor productivity. Generally, manufacturing divisions with high R&D intensity, i.e. divisions classified as so-called high-tech ones, are characterised by

a high TFP level. The econometric analysis carried out allows us to conclude that expenditure on R&D incurred in manufacturing enterprises significantly affects the level of TFP.

Introduction

The results of the global crisis affected Poland to a much lesser extent than other countries of Central and Eastern Europe. And although, as in all of Europe, the economic growth rate in Poland decreased, the effects of the recession were less significant than in Hungary or the Baltic states. Emerging unscathed from the crisis was largely the result of not allowing a huge increase in credit at the expense of foreign debt. The maintenance of a stable economic situation in Poland expressed by an increase in the value of GDP in the entire 2008–2017 period was also reflected in changes in total factor productivity. Only a few years ago, the Baltic states were the leaders in TFP growth. Prior to the global crisis, they recorded very rapid economic growth, which was difficult to explain by changes in labour and physical capital, which is why it was attributed to TFP. Poland's position, though moderate, was not as good as that of the Baltic states. The results of the latest research covering the aforementioned time horizon indicate significant changes in the rankings of individual countries, and definitely show Poland's favourable position, with the relative deterioration of the situation of the Baltic states.

The recognition of total factor productivity (TFP) growth as one of the most important sources of economic growth has led to the situation in which a rise in TFP has become a nationwide goal. As a result, TFP has been growing in popularity as the subject of interest of economic theorists as well as economic practitioners, and has arisen increasing inquisitiveness of researchers (Griliches & Mairesse, 1984; Florczak & Welfe, 2001; Ascari & Di Cosmo, 2004; Meister & Verspagen, 2004; Nishimure, 2004; Crispolti & Marconi, 2005; Roszko-Wójtowicz *et al.*, 2018). The efficiency of production processes identified with the effects of broadly understood technical progress is reflected in the changes in total factor productivity (TFP). Therefore, an increase in TFP makes it possible to assess the efficiency of the production process resulting from technical progress.

The literature, comprising quite numerous publications regarding research on TFP, focuses most often on assessing this phenomenon on a macroeconomic scale, and it concerns less often sectors of the economy understood as divisions, groups or classes (in accordance with the Statistical Classification of Economic Activities in the EU — NACE). Even less attention is paid to identifying factors determining TFP growth and, above all, to quantifying this impact.

In the paper, an attempt is made to fill the gap concerning analysis of total factor productivity at the level of manufacturing divisions in Poland (list of manufacturing divisions covered by the analysis presents Table 1).

The main aim of the paper is to assess the differentiation in the level of total factor productivity (TFP) occurring among the Section C manufacturing divisions in Poland. In particular, the paper raises the issue of measuring and analysing the relationship between expenditure on research and development and the level of TFP in manufacturing divisions in Poland. Two research hypotheses were formulated for the purpose of implementing empirical proceedings.

H1: *Manufacturing divisions in Poland are diversified in terms of the level of total factor productivity (TFP).*

H2: *R&D expenditure is an important determinant of TFP in manufacturing divisions in Poland.*

The article is divided into introduction, five substantively related parts and conclusions. The first section is the Introduction, which sets out the main aim of the paper and its research hypotheses. The next section provides definitions of TFP (its essence is defined) and presents selected studies on TFP. It was decided that the implementation of the main aim, i.e. TFP assessment at the level of manufacturing divisions in Poland, should be preceded by the presentation of TFP changes at the macroeconomic level (economy/country level). The results for Poland concerning changes in total factor productivity in the years 2008–2017 are presented against the background of the EU–11 group, i.e. the countries that joined the EU at a similar time as Poland. The subsequent sections of the paper concern directly manufacturing divisions. First, manufacturing is characterised, then research methodology is described and empirical verification of TFP models is carried out at the level of manufacturing divisions in Poland. The conclusions drawn from the research complete the paper.

Literature review on total factor productivity

Productivity growth is seen in the modern world as one of the most important sources of economic growth, social progress and improving society's standard of living. The widest definition of productivity states that it is a measure of the efficiency of production expressing the number of product units per one unit of input (Krugman, 1990; Eatwell & Newman, 1991;

Yadav & Marwah, 2015). This measure is most often used for capital and labour (separately and jointly), and it shows how effectively these factors of production are transformed into the final product and where to look for potential determinants of an increase in this efficiency (Syverson, 2011). Numerous studies have made an attempt to answer the following questions: to what extent does economic growth result from changes occurring within measurable factors of production (capital, labour) and to what extent does it result from changes in the level of technology, measured by the rate of growth of total factor productivity (TFP)? The concept of total factor productivity was developed in the 1960s, originating from the research of the neoclassical economist Solow (1956, 1957), who claimed that part of productivity growth could not be explained by the capital and labour input. Using the macroeconomic function of production and differential calculus, he showed how to split the economic growth rate into a part resulting from increased input of production factors and the residual value, the so-called Solow residual. It shows what proportion of economic growth cannot be attributed to specific factors. Thus, this value includes various factors, including those not directly related to the accumulation of production factors (Barro & Sala-i-Martin, 2003). It is, therefore, a measure of technical progress, i.e. TFP growth. In practice, determining the residual value, i.e. the Solow residual, from the production function is the most commonly used TFP calculating method. However, because of its residual nature, total factor productivity remains difficult to assess, which makes it dependent on changes in non-observable inputs as the dimension of capital or labour.

In the following years, further publications in the field of TFP appeared, introducing new approaches and extensions of previous studies, containing new elements of empirical analysis (Artige & Nicolini, 2006; Caselli & Coleman, 2006; Świeczewska, 2007; Tokarski, 2008; Helpman, 2004; Dańska-Borsiak, 2011; Florczak, 2011; Syverson, 2011; Aghion *et al.*, 2015; Próchniak, 2018). Most of the existing analyses use panel data information, pooling together data on TFP levels and growth rates over several years and countries. There are also papers that use information at the sectoral/industry level, with the datasets (Nicoletti & Scarpetta, 2003, 3005; Griffith *et al.*, 2004; Conway *et al.*, 2006).

The literature indicates various factors that are crucial for the growth of TFP.

1. Knowledge and technology discussed, among others, in Solow (1957); Romer (1990); Prescott (1998).
2. R&D activities (Guelllec & van Pottelsberghe de la Potterie, 2001; Ulku, 2004, Bronzini & Piselli, 2009) including:

- a. patents e.g. Chen and Dahlman (2004)
- b. knowledge creation e.g. Abdih and Joutz (2005).
3. The production and use of information and communication technologies (Jorgenson & Stiroh, 2000).
4. FDI together with transfer of technology described, among others, by (Keller & Yeaple, 2003; Griffith *et al.*, 2003).
5. Human capital quality (Romer, 1990; Barrett & O’Connell, 1999; Fleisher *et al.*, 2010).
6. The physical infrastructure (Bronzini & Piselli, 2009; Fleisher *et al.*, 2010).
7. Effective innovation system Chen and Dahlman (2004).

Results of numerous studies show that a long-term rise in total factor productivity is based on innovations, and innovations, in turn, depend, among others, on investments in research and development (R&D) (Aghion *et al.*, 2015). They enhance companies’ innovative capacity and their ability to gain and sustain a competitive advantage, thus contributing directly to the rate of TFP growth. Moreover, R&D improves absorptive capacity¹ of companies and industries as well as facilitates the adoption of existing technologies, spurring TFP convergence. Total factor productivity is therefore a useful measure of the impact of technical progress on the rate of economic growth. In the opinion of many economists, total factor productivity has become a proper measure of differences in efficiency, as it can explain why lower-TFP producers will obtain smaller outputs with the same set of observable inputs than higher-TFP ones (Syverson, 2011).

TFP in Poland and selected CEE countries

Empirical research related to economic growth issues, e.g. Klenow and Rodriguez-Clare (1997), Easterly and Levine (2001), Helpman (2010), Hulten and Isaksson (2007) indicates that most of the observed differentiation in countries’ GDP per capita is due to the difference in TFP which reflects changes in the efficiency of production processes taking place under the influence of broadly understood technical progress.

The results of cyclical research carried out for several years by Próchniak (2018) are an important source of information about changes in TFP in Poland in comparison with selected EU countries. In the latest edition, the author analyses 11 countries of Central and Eastern Europe, i.e. the EU–11

¹ Cohen and Levinthal (1990, p. 28) define absorptive capacity as “*the ability of the firm to recognize the new value of new, external information, assimilate it, and apply it to commercial ends.*”

group (Poland, Bulgaria, Croatia, the Czech Republic, Estonia, Lithuania, Latvia, Romania, Slovakia, Slovenia and Hungary), in the period 2008–2017. It turns out that in the period under review the highest TFP growth rate was recorded by Poland, Romania, Slovakia, Bulgaria, and Lithuania. Total factor productivity increased in the years 2008–2017 at an average rate of 1.1% per year in Poland, 0.4% in Romania and Slovakia, and 0.2% in Bulgaria and Lithuania. In other EU–11 countries, total factor productivity growth was negative (mainly due to negative productivity growth rates during the global crisis). Próchniak (2018) has documented that over the entire 10-year period, Slovenia recorded an average decline in TFP of 0.1%, the Czech Republic — 0.4%, Hungary and Latvia — 0.6%, Croatia — 1.0%, and Estonia — 1.1% per year (Figure 1)

Analysing the above-presented information, it can be noted that in 2017 there was a further acceleration of TFP growth observed in the EU–11 group. The Baltic states and Poland were at the forefront. Poland achieved a TFP growth rate of 1.7% (the same as Hungary) and ranked 5th (*ex aequo* with Hungary). Higher total factor productivity growth rates comparable to Poland's rate were achieved by the Baltic states and Romania.

In their study based on a comprehensive data set, Baier *et al.* (2006) indicate that TFP growth contributes modestly to the average performance of output growth across all 145 countries they studied. The study shows that weighted-average TFP growth is only about 0.22% per year, which is about 14% of growth of output per worker. Similar conclusions are provided in the analysis carried out by Próchniak (2018). Based on statistical data covering the period 2008–2017, a direct assessment of TFP contribution to economic growth in CEE countries may be ambiguous. This is due to, among others, the fact that the positive TFP dynamics during the recession period means a negative TFP contribution to economic growth, whereas during a strong economic slowdown when the GDP growth rate is close to 0%, changes of total factor productivity of several percent translate into several thousand of TFP contributions to economic growth. It is worth noting that, according to the conclusions of the theory of endogenous growth, sustainable economic growth should be expected in the long run under the influence of TFP. However, other factors also determine macroeconomic management efficiency, which means that long-term growth is not a foregone conclusion. Positive effects associated with TFP can be weakened or even eliminated by deteriorating indicators of social, demographic or institutional development. Therefore, non-economic determinants should be included in the analysis of economic growth determinants in an equal measure to strictly economic factors, which also results from theoretical models of endogenous growth, e.g. (Aghion & Howitt, 1998).

Nevertheless, it can be said that in the years 2008–2017 TFP contributions to economic growth were in most CEE countries (excluding the Czech Republic and Bulgaria) at the level of 28–85% (Próchniak, 2018). This confirms the important role of TFP in the economic growth of the analysed countries in the years of their membership in the European Union. In Poland, the TFP contribution to GDP growth averaged 28% in the years 2008–2017.

Reflections on the general economic situation of CEE countries are summarised in Table 2 presenting the dynamics of GDP, gross value added, gross (fixed) capital formation, and total employment changes. The presented data show that GDP increased in all 11 countries in the years 2008–2017. The largest average annual changes were recorded in Estonia (4.1%) and Bulgaria (3.7%), Hungary, the Czech Republic, Poland and Slovakia. i.e. the members of the Visegrad Group, are of particular note, as only in these countries stable average annual GDP and gross value added growth translates into an increase in total employment.

It is worth mentioning here that Polish researchers have made a significant contribution to the development of empirical analysis dedicated to the research on decomposition of economic growth and TFP estimates (Florczak & Welfe, 2000; Welfe, 2001; 2002; Florczak, 2011). In studies on identifying the factors that determine changes in total factor productivity at the level of the Polish economy (Welfe, 2009), national knowledge resources represented by the amount of R&D expenditure as well as knowledge capital resources from abroad are of significant importance (Świczewska, 2013). For example, Florczak and Welfe (2000) and Welfe (2001) calculated TFP in Poland in the years 1982–2000 on the basis of the standard growth accounts, taking into consideration two factors of production: labour and physical capital (machinery and equipment or total fixed assets). In their study, the elasticity of production relative to fixed assets. i.e. the share of return on tangible equity, is calibrated at 0.5 or estimated on the basis of the production function. In the study by Welfe (2002), TFP for Poland in the years 1986–2000 was estimated using various alternative values of the share of return on tangible equity (from 0.25 to 0.7). In turn, Florczak (2011) estimated the TFP values devoid of short-term demand fluctuations for Poland in the years 1970–2008, using the Wharton method. and then examined determinants of total factor productivity (Próchniak, 2018).

Manufacturing in Poland

An in-depth analysis of data from the last few years confirms that manufacturing in Poland is an important element of the national economy, which is reflected in newly created jobs and increasing gross value of fixed assets. In 2017, compared to 2010, the number of people working in industry increased by almost 5.5%, and the value of fixed assets by 39%. The role and importance of manufacturing in the Polish economy (2017) is demonstrated, among others, by its share: in the creation of gross domestic product (22.8% compared to 23.5% in 2016), in investment expenditure (36.9% in relation to 38.4% in 2016), and in the gross value of fixed assets (32.6% compared to 32.5% in 2016). Employment in manufacturing in Poland remains stable. In both 2016 and 2017, the percentage of employed persons in industry was 20.8% of the total number of employed in the country (GUS 2017, pp. 30-37; GUS 2018, pp. 30-31). Further on, innovation activity of the manufacturing divisions in Poland strongly depends on the scale of operations of enterprises (Świadek, 2018). Due to this, the dynamics in sold production are also presented here and the positive upward trend is confirmed in all the manufacturing divisions (Table 3).

The latest CSO data published show that industrial output in Poland after 2010 increased at a double-digit rate only in four months — most recently in July 2018, when production growth was 10.3% (year on year), and the increase in sold production was recorded in most manufacturing divisions (Table 1). Manufacture of machinery and equipment recorded the best performance — 25% growth (year on year) as well as Manufacture of other transport equipment (e.g.: shipyards) — 20.6% year on year. This is confirmed by favourable assessments of the general economic climate registered in all manufacturing divisions. The indicator of the general economic climate in March 2018 was at the level of + 18.7, and the improvement in the economic situation was signalled by 26.0% of enterprises, and its deterioration by only 7.3% (GUS, 2018). The most optimistic opinions on the economic situation were formulated in March 2018 by manufacturers of rubber and plastic products, pharmaceutical products, other non-metallic mineral products, chemicals and chemical products, as well as those conducting activities in the field of printing and reproduction of recorded media.

In the long-term perspective, in the years 2010–2017, the largest increases were recorded in Manufacture of paper and paper products (Division 17). In this division, in 2017, compared to 2010, more than 10 times higher expenditure on innovative activity in the area of product and process innovations in industry (in PLN million) as well as 25 times higher ex-

penditure (internal and external) on research and development activity (in PLN million) was recorded. For Manufacture of products of wood and cork, excluding furniture; manufacture of articles of straw and plaiting materials, expenditure on research and development increased by over 800% (in PLN million). Decreases in the values of the discussed diagnostic variables in individual manufacturing divisions were rare (Table 3, Table 4).

Research methodology and data

Data sources

The paper uses data published by the Central Statistical Office. For the needs of conducted analyses, data were obtained in particular from the Statistical Yearbooks of Industry for the years 2010–2018 and from the Local Data Bank. Changes in time in the level of indicators selected for analysis covered the years 2009–2017. The database prepared for the needs of the empirical study the results of which are presented in the paper includes seven diagnostic variables (see Table 5). Six of these variables are presented in terms of value, in constant prices from 2009, with the investment expenditure price index, the GDP price index and the price index of sold production of individual manufacturing divisions used as a deflator.

According to the Polish Classification of Economic Activity, the initial database was prepared at a two-digit level of aggregation, i.e. for all 24 divisions of Section C — Manufacture. Due to the lack of data, resulting, among others, from statistical confidentiality, finally 5 divisions were excluded from the analyses presented in the subsequent sections of the paper, i.e. 11 — Manufacture of beverages, 12 — Manufacture of tobacco products, 14 — Manufacture of wearing apparel, 15 — Manufacture of leather and related products, as well as 19 — Manufacture and processing of coke and refined petroleum products.

TFP measurement methodology

It is widely accepted that total factor productivity (TFP) is a synthetic measure of the efficiency of the production process in the country resulting from technical progress (Fernández-Arias, 2017), which can be estimated using one of two alternative approaches.

First of all, a starting point in such analyses is usually the macroeconomic function of production (CES) or the Cobb-Douglas production function, taking into account two or three measurable factors of production,

namely: labour, physical capital and possibly human capital. In this case, the function (model) parameters are estimated or calibrated based on available statistical data (Welfe, 2001; 2009). In addition, if the function is in the form of a two-factor Cobb-Douglas function (the square root version) with neutral technological progress in the sense of Hicks, then TFP corresponds to the factor describing the production technology, and its calculation requires estimation of production elasticity coefficients relative to selected factors, i.e. labour and capital (Ascari & Cosmo, 2004; Tokarski, 2008; Dańska-Borsiak, 2011). Secondly, there are index methods that allow us to build synthetic statistical indices of total factor productivity, such as are the Laspayres, Paasche and Fisher indices, or the recently commonly used Tornquist or Malmquist indices (Kuusmanen & Sipiläinen, 2004; Świeczewska, 2007).

In the presented studies, the TFP level was determined by using the two-factor Cobb-Douglas production function (Tokarski, 2010; Dańska-Borsiak & Laskowska, 2012):

$$Y_{it} = A_0 e^{gt} K_{it}^\alpha L_{it}^{1-\alpha} \quad (1)$$

where:

Y – gross value added in million PLN in the i -th division in year t ,

L – labour input (expressed in thous. employees),

K – capital input (measured by the value of gross fixed assets in PLN million).

$A_0 e^{gt} > 0$ – total factor productivity (TFP),

g – the technical progress rate in the sense of Hicks²,

α – elasticity of the Y variable relative to the K variable.

Parameters α and $(1 - \alpha)$ are the elasticity of the production function in relation to (respectively) capital and labour inputs.

By dividing equation (1) on both sides by the number of employed $L_{it} > 0$, we obtain:

$$y_{it} = A_0 e^{gt} k_{it}^\alpha \quad (2)$$

where:

$y_{it} = Y_{it}/L_{it}$ – labour productivity,

$k_{it} = K_{it}/L_{it}$ – the technical infrastructure of labour.

² That is, technical progress which does not change the marginal rate of substitution between labour and capital inputs (Tokarski, 2010).

In addition, by logarithmising the side of equation (2). we obtain:

$$\ln(y_{it}) = \ln(A_0) + gt + \alpha \ln(k_{it}) \quad (3)$$

The expression $\ln(A_0) + gt$ is the logarithm of total factor productivity (TFP).

It follows that the estimation of the parameters of equation (3) will allow for estimating the value of the parameter α , by means of which the value of total factor productivity can be determined as:

$$TFP_{it} = \frac{y_{it}}{k_{it}^\alpha} \quad (4)$$

Due to the panel structure in which the basic period is the calendar year, and the objects are manufacturing divisions, models suitable for panel data were used in the study. The most general model based on cross-sectional and time series data can be written in the following form:

$$y_{it} = \alpha_i + \mathbf{X}'_{it} \beta + \varepsilon_{it}, \quad (5)$$

where: index $i=1\dots N$ denotes the object, $t=1\dots T$ – the period, while \mathbf{X}'_{it} is the vector of observations of explanatory variables. In the fixed effects model, α_i is a specific effect for the object, with the same distribution in groups and over time. In the random effects model, α_i are treated as random variables (Maddala, 2006).

Results

Labour productivity model

The presented research used two most popular approaches to take into account the heterogeneity of studied objects: the fixed effects model (FEM) and the random effects model (REM). The results are presented in Table 6.

The results obtained, presented in Table 6, seem satisfactory. All variables are statistically significant and a very good fit of the model, measured with the coefficient of determination, allows us to recognise that the TFP values that will be determined on the basis of formula (4) will be reliable. The results of Hausman test indicate that the random effects model (REM) has a higher statistical value. The rate of technical progress in the sense of Hicks estimated on the REM basis is about 2.7%, and the elasticity of la-

bour productivity relative to technical labour infrastructure is equal to ≈ 0.2986 .

Based on the results of the REM estimation, the TFP values were then estimated in the i -th division in the year t according to the formula:

$$TFP_{it} = \frac{y_{it}}{k_{it}^{0.298656}} \quad (6)$$

Figure 2 presents the average TFP value in the years 2009–2017 in the analysed manufacturing divisions.

As the presented data indicate, total factor productivity varied among the divisions. A particularly high TFP value in this period was observed in Manufacture of basic pharmaceutical substances and medicines and other pharmaceutical products. According to the classification of manufacturing activity and services, based on the intensity of R&D (PKD 2007) (*Sectoral approach: Classification of manufacturing and services sector according to R&D intensity (NACE Rev. 2)*) (GUS, 2019), this division is one of high-tech divisions. The following divisions are also characterised by a high TFP level: Manufacture of chemicals and chemical products (medium-high technology) and Manufacture of other transport equipment (medium-high technology). Interestingly, Repair, maintenance and installation of machinery and equipment, classified as one of medium-low technology divisions, is also characterised by a high TFP level. In the case of this division, the high level of TFP results from the relatively low technical labour infrastructure measured by the value of gross fixed assets per employee in the considered period.

The lowest TFP level is characteristic for low or medium-low technology divisions: Manufacture of textiles (low technology); Manufacture of products of wood and cork except furniture; Manufacture of articles of straw and plaiting materials (low technology); Manufacture of metals (medium-low technology).

The presented figure indicates that divisions with higher intensity of R&D expenditure have a higher TFP level. In the further part of the presented research, an attempt was made to construct and estimate an econometric model describing the impact of expenditure on R&D on total factor productivity by division.

Total factor productivity model

The importance of expenditure on R&D for the TFP level in manufacturing in Poland in the years 2009–2017 in the light of empirical research is discussed in this section.

According to the literature review presented earlier, in the light of research conducted worldwide, it can be said that knowledge capital resources related to expenditure on R&D are the potential determinant of the level of total factor productivity in a given economy. An important role is attributed to the absorption of scientific and technical knowledge from abroad and to human capital resources (Świczewska, 2007; Brzozowski, 2018). The last two variables are not available for manufacturing divisions. At this level of analysis, it is also not possible to use a number of other variables that may determine the level of TFP (see Section 1).

Considering the aim of the research and the availability of relevant statistical material, in the presented analysis, total factor productivity in individual manufacturing divisions was associated with expenditure on R&D (current and lagged by one period). Investment outlays are also considered among the factors determining total factor productivity (Dańska-Borsiak & Laskowska, 2013). This variable was also included in the model presented below.

Finally, the model explaining the TFP level in the i -th division in the year t has the following form in the analysed manufacturing divisions:

$$\ln(TFP)_{it} = \alpha_i + \beta_0 + \beta_1 \ln\left(\frac{R\&D}{EMPL}\right)_{it} + \beta_2 \ln\left(\frac{R\&D}{EMPL}\right)_{i,t-1} + \beta_3 \ln\left(\frac{INVT}{EMPL}\right)_{it} + \varepsilon_{it} \quad (7)$$

where:

$\ln\left(\frac{R\&D}{EMPL}\right)_{it}$ – natural logarithm of expenditures on R&D at 2005 constant prices in PLN million (the CSO price index of GDP was used to adjust the data) per employee;

$\ln\left(\frac{R\&D}{EMPL}\right)_{i,t-1}$ – natural logarithm of expenditure on R&D per employee in the period $t-1$;

$\ln\left(\frac{INVT}{EMPL}\right)_{it}$ – natural logarithm of investment outlays at 2005 constant prices in PLN million (the CSO price index of investment outlays was used to adjust the data) per employee.

The FEM and REM results of total factor productivity are shown in Table 7.

The research conducted on the relationship between R&D expenditure and total factor productivity confirms the importance of internal expenditure on research and development in manufacturing enterprises for increasing TFP, regardless of the panel model. The Hausman test indicates that the REM has a higher statistical value. The results obtained for this model allow us to state that 1% growth of current R&D expenditure may result in TFP growth of 0.039%. Expenditure on R&D incurred in the previous period also plays an important role. Its 1% increase results in an average TFP increase of 0.043%. It should be emphasised that this impact is higher than the impact of the current expenditure on R&D, which suggests that their positive effect in the form of an increase in TFP appears with some lag.

According to the conducted research, expenditures related to research and development activities (current and lagged) determine changes in total factor productivity to a much lower degree than investment expenditure incurred in individual manufacturing divisions. 1% increase in the latter translates into an increase of 0.17% in TFP.

Discussion

Every society strives to improve its quality of life, and economic growth is a prerequisite for achieving this goal. In the light of endogenous growth theory, the propensity of individual economies to invest in sectors related to research and development activity and education is of key importance in the process of generating technical progress. It is assumed that technical progress is primarily the result of innovations arising from domestic and foreign research and development activity (Romer, 1990; Aghion-Howitt, 1998; Świczewska, 2007).

An attempt to determine factors influencing an increase in productivity and a quantitative assessment of the relationship between productivity and research and development activity are important aspects of the research on productivity of factors of production, including TFP, carried out by the authors. In the past, mainly productivity of individual factors of production (labour and capital) was analysed on a macroeconomic scale. Griffith *et al.* (2004) in a study on TFP determinants conducted on a time series from 1970 and 1992 across 13 manufacturing sectors in a panel of OECD countries indicate that R&D has a direct impact on TFP growth and plays a role in facilitating the cross-country convergence of TFP levels. This article focuses on measuring total factor productivity (TFP) and analysing the relationship between expenditure on research and development activity and the level of TFP in manufacturing divisions. It was assumed that in Poland,

due to the great importance of industry in the national economy, the TFP level would be primarily a derivative of the TFP level in manufacturing enterprises. The study of TFP (in Poland) at this level of aggregation should be considered as innovative. The conclusions resulting from the analysis of the results of the research conducted at the level of manufacturing divisions seem to clearly confirm the existence of a positive relationship between the amount of expenditure on R&D and the TFP level. The results of the presented research for manufacturing divisions are consistent with the results of research conducted globally at various levels of aggregation (Griliches, 1981; Cameron *et al.*, 2005; Dańska-Borsiak, 2011). According to these studies, changes in total factor productivity (TFP) are the result of investment in the R&D sphere, increasing the existing knowledge capital resources in the economy, represented by R&D expenditure (e.g. Guellec & van Pottelsberghe de la Potterie, 2001; Bronzini & Piselli, 2009).

An important value of this study is the observation that the use of panel models makes it possible to draw a conclusion about the existence of heterogeneity of manufacturing divisions, which should be an indication for the future policy aimed at supporting manufacturing divisions. It seems that it is necessary to support primarily those industries that have development potential and may become our national specialty.

Understanding the causes of TFP diversity in manufacturing divisions requires further research which will take into account other important variables describing determinants of and barriers to TFP growth. The level of TFP in manufacturing divisions depends not only on the research and development activity of a given division, but also on the activity of related enterprises and divisions. The process of transferring R&D effects between enterprises or industry sectors is referred to in the literature as an R&D spillover. However, measuring technology transfer is a complicated task, among others, due to a lack of data describing this process.

Conclusions

In the presented study, the assessment of the TFP level in manufacturing divisions was preceded by an analysis of changes in this index at the macroeconomic level. The results of the conducted analysis of the TFP level and dynamics in Poland in the years 2008–2017 provide grounds for optimism. Poland's relatively good results in terms of changes in total factor productivity compared to the EU–11 group are a sign of success. The research quoted in the paper shows that TFP increases have played a significant role in the economic growth of Poland as well as other Central and

Eastern European countries, which in turn means improving their competitiveness in the global market. This allows for drawing a positive conclusion that in the years 2008–2017 the competitive position of the Polish economy, measured by TFP growth, increased to the greatest extent among the new EU Member States.

An important element of the Polish national economy is manufacturing, as evidenced, among others, by its share in the creation of gross domestic product. For this reason, research related to estimating the TFP level and identifying its determinants in the manufacturing industry seems important. The vast majority of research conducted for Poland concerns a macroeconomic (Welfe, 2009) or regional (Tokarski, 2010; Dańska-Borsiak & Laszkowska, 2012) scale. Research on economic sectors is conducted much less frequently. The analyses of total factor productivity at the level of manufacturing divisions presented in this paper are an attempt to fill the gap in this respect. Panel data econometric models were used as the analysis tool, allowing for the inclusion of information on individual divisions in many periods, which is an extension in relation to the analyses carried out so far for manufacturing divisions using time series covering the period 1992–2008 (Świczewska, 2013).

The empirical studies carried out confirm the validity of the research hypotheses. TFP estimates positively verify the first hypothesis, which states that manufacturing divisions in Poland are diversified in terms of the level of total factor productivity. One of the reasons for the differences existing between the divisions in terms of total factor productivity can be expenditure on research and development.

The validity of the latter hypothesis is confirmed by econometric analysis. Model estimation has shown the existence of a statistically significant relationship between R&D expenditure incurred in manufacturing enterprises and the TFP level. However, the strength of the impact of examined expenditure on R&D, expressed in the estimation of the model parameter, is definitely lower than the impact of another analysed variable — investment outlays incurred in individual manufacturing divisions.

The aim of the study has been achieved, but there are many limitations to the TFP estimation. The spectrum of factors affecting total factor productivity is much broader than assumed in this study. In addition to knowledge capital, TFP is also affected by social, demographic and institutional determinants, which should constitute the area of further research. However, taking into account methodological aspects, an interesting solution seems to be the application of an error correction model (ECM), which allows for separating short-term effects from long-term ones.

The TFP theory, despite considerable scientific achievements to date, still provides a valuable research perspective, creating many recommendations for regulating processes occurring in the economy.

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Annex

Table 1. List of manufacturing divisions covered by the analysis

No. of division	Name of division
Div. 10	Manufacture of food products
Div. 13	Manufacture of textiles
Div. 16	Manufacture of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Div. 17	Manufacture of paper and paper products
Div. 18	Printing and reproduction of recorded media
Div. 20	Manufacture of chemicals and chemical products
Div. 21	Manufacture of basic pharmaceutical substances and medicines and other pharmaceutical products
Div. 22	Manufacture of rubber and plastic products
Div. 23	Manufacture of other non-metallic mineral products
Div. 24	Manufacture of metals
Div. 25	Manufacture of fabricated metal products, except machinery and equipment
Div. 26	Manufacture of computer, electronic and optical products
Div. 27	Manufacture of electrical equipment
Div. 28	Manufacture of machinery and equipment not elsewhere classified
Div. 29	Manufacture of motor vehicles, trailers and semi-trailers excluding motorcycles
Div. 30	Manufacture of other transport equipment
Div. 31	Manufacture of furniture
Div. 32	Other manufacturing
Div. 33	Repair, maintenance and installation of machinery and equipment

Table 2. Selected measures of economic development in the countries of Central and Eastern Europe – dynamics of change

Country	Gross domestic product at market prices		Gross value added		Gross capital formation		Gross fixed capital formation		Total employment domestic concept	
	i _{G2008-2017}	i _{E01/7/2008}	i _{G2008-2017}	i _{E01/7/2008}	i _{G2008-2017}	i _{E01/7/2008}	i _{G2008-2017}	i _{E01/7/2008}	i _{G2008-2017}	i _{E01/7/2008}
Bulgaria	3.7%	38.9%	4.1%	43.2%	-3.1%	-24.6%	-2.7%	-22.1%	-0.87%	-7.58%
Croatia	0.2%	1.8%	-0.1%	-0.6%	-4.2%	-32.3%	-3.5%	-27.4%	-0.94%	-8.17%
Czechia	1.9%	18.9%	1.8%	17.6%	-0.1%	-1.0%	0.2%	1.7%	0.30%	2.73%
Estonia	4.1%	43.0%	3.7%	39.1%	2.2%	21.3%	1.3%	12.0%	-0.01%	-0.09%
Hungary	1.5%	14.7%	1.4%	13.3%	0.6%	5.5%	1.1%	10.2%	1.09%	10.24%
Latvia	1.2%	11.0%	0.8%	7.8%	-3.8%	-29.7%	-3.5%	-27.6%	-1.92%	-16.03%
Lithuania	2.9%	29.0%	2.9%	29.2%	-2.1%	-17.4%	-0.6%	-4.9%	-0.57%	-5.05%
Poland	2.7%	27.6%	2.8%	28.3%	0.3%	2.6%	-0.4%	-3.1%	0.41%	3.71%
Romania	2.8%	27.9%	2.9%	29.1%	-1.1%	-9.6%	-2.9%	-23.1%	-0.87%	-7.60%
Slovakia	2.8%	28.6%	2.8%	27.7%	0.1%	1.1%	0.8%	7.7%	0.60%	5.57%
Slovenia	1.4%	13.3%	1.3%	12.5%	-4.0%	-30.9%	-3.8%	-29.5%	-0.12%	-1.12%

Source: own elaboration based on Eurostat data. *GDP and main components (output, expenditure and income)* [nama_10_gdp]. *Population and employment* [nama_10_pe]; accessed: 02.09.2019.

Table 3. Dynamics of changes in the levels of individual variables in the years 2010–2017

	I _{2017/2010}							I _{2017/2016}						
	X1	X2	X3	X4	X5	X6	X7	X1	X2	X3	X4	X5	X6	X7
Div. 10	137.1%	102.7%	101.4%	134.7%	139.9%	168.0%	173.0%	72.4%	186.8%	101.3%	109.8%	106.9%	102.7%	106.9%
Div. 13	508.7%	376.2%	101.6%	133.4%	173.7%	314.8%	129.7%	192.2%	412.1%	99.4%	95.2%	105.4%	113.2%	108.1%
Div. 16	264.5%	929.9%	101.3%	139.3%	147.1%	267.2%	158.6%	150.0%	134.4%	101.7%	108.3%	106.1%	138.0%	105.3%
Div. 17	1041.0%	2450.3%	117.8%	164.8%	172.0%	168.2%	186.8%	229.1%	129.0%	103.9%	99.5%	106.3%	109.6%	106.7%
Div. 18	70.8%	148.2%	126.1%	137.9%	162.6%	113.1%	148.1%	74.9%	148.5%	104.2%	102.1%	103.9%	118.1%	102.9%
Div. 20	150.7%	285.6%	109.8%	165.7%	140.2%	148.0%	161.5%	128.5%	120.9%	100.6%	96.8%	101.9%	99.9%	106.4%
Div. 21	139.8%	153.1%	90.7%	116.4%	105.1%	136.3%	127.7%	113.7%	97.2%	97.0%	91.8%	102.7%	129.7%	102.5%
Div. 22	106.1%	278.9%	132.5%	166.0%	180.0%	201.2%	187.6%	119.5%	86.2%	105.3%	102.3%	108.7%	107.3%	108.9%
Div. 23	99.2%	170.5%	101.8%	121.4%	157.1%	130.3%	142.4%	76.9%	97.6%	103.2%	102.5%	107.9%	108.6%	104.9%
Div. 24	146.5%	576.1%	109.5%	166.9%	152.5%	92.0%	161.4%	95.9%	245.0%	102.2%	96.2%	112.0%	97.7%	105.3%
Div. 25	165.2%	445.6%	125.7%	169.7%	200.2%	164.6%	195.3%	103.7%	77.8%	104.2%	102.5%	110.0%	115.2%	106.5%
Div. 26	281.9%	682.8%	102.6%	73.9%	156.7%	126.8%	136.2%	333.9%	332.2%	105.5%	100.9%	105.2%	126.0%	100.7%
Div. 27	193.2%	260.4%	117.5%	124.7%	179.4%	213.3%	175.6%	97.2%	100.9%	106.0%	92.7%	103.1%	118.5%	107.6%
Div. 28	156.1%	197.1%	87.7%	102.9%	125.6%	143.7%	116.9%	135.3%	126.6%	102.6%	106.5%	112.1%	112.9%	104.3%
Div. 29	184.7%	210.4%	140.3%	173.1%	174.8%	216.9%	183.7%	112.8%	96.3%	107.5%	102.7%	107.1%	86.0%	107.4%
Div. 30	171.9%	320.8%	89.1%	141.1%	151.7%	159.9%	148.4%	93.8%	116.5%	100.7%	103.9%	107.1%	102.6%	108.6%
Div. 31	131.8%	340.7%	114.4%	129.1%	164.6%	146.6%	171.9%	94.0%	193.9%	105.6%	102.9%	107.0%	103.8%	105.2%
Div. 32	158.0%	176.3%	118.3%	152.0%	173.9%	201.6%	200.5%	130.0%	135.2%	104.4%	100.0%	109.4%	135.7%	110.2%
Div. 33	133.5%	290.6%	117.1%	247.5%	177.8%	167.1%	167.3%	60.7%	119.5%	100.8%	106.6%	107.2%	116.0%	103.3%

Source: own elaboration based on Statistics Poland.

Table 4. Values of selected measures of descriptive statistics for diagnostic variables in individual manufacturing divisions

	X1	X2	X3	X4	X5	X6	X7	X1	X2	X3	X4	X5	X6	X7	
Div. 10	average	1710.9	129	386.7	36509.8	159204.5	79310.4	average	1209.7	292.8	267.2	28294.6	82621	3785.7	38757.4
	V _{sk}	30.50%	78.70%	1.50%	11.40%	10.70%	18.30%	V _{sk}	20.30%	62.20%	7.80%	19.60%	21.40%	21.00%	21.80%
Div. 13	average	89.8	23.5	47.7	3510.5	10564.7	5896.6	average	501.7	180.4	56.5	6434.8	39079.7	847.3	10488.6
	V _{sk}	58.10%	61.40%	6.50%	15.90%	21.20%	11.00%	V _{sk}	52.50%	87.20%	5.50%	16.00%	12.20%	18.00%	12.10%
Div. 16	average	371.4	28.5	107	9562	28896.9	1704.3	average	879.7	277.2	95.2	10707.1	49657.5	1927.1	20948.1
	V _{sk}	84.70%	96.20%	3.90%	13.40%	13.10%	15.80%	V _{sk}	25.20%	29.40%	5.40%	13.00%	18.90%	22.60%	18.60%
Div. 17	average	666.3	12.2	53.6	8252.8	27830.3	2402	average	866.3	278.5	124.8	12990.9	39420.1	1797	22010
	V _{sk}	65.50%	109.60%	5.00%	19.40%	16.40%	25.60%	V _{sk}	17.40%	20.10%	6.30%	8.00%	9.10%	15.50%	8.20%
Div. 18	average	164.1	18.1	39.2	4954.9	12538.7	670.6	average	2953	1046.5	162.5	21225.5	113754.8	5722.5	54716.1
	V _{sk}	26.60%	15.10%	7.60%	12.80%	17.00%	11.30%	V _{sk}	19.70%	30.10%	11.10%	20.60%	17.20%	37.50%	21.00%
Div. 20	average	1040.7	197.9	74.2	12997.6	47336.5	2991.4	average	574.8	230.6	43.2	5392.6	15809.2	872.3	8062.6
	V _{sk}	16.80%	57.60%	3.10%	17.30%	9.90%	16.20%	V _{sk}	35.60%	38.50%	5.10%	20.10%	16.00%	25.80%	16.00%
Div. 21	average	562.6	262.4	22.6	4748.9	10628.6	508.4	average	367.6	45.1	150.8	10920.8	33968.9	1394.6	14971.4
	V _{sk}	26.80%	32.20%	5.10%	12.30%	5.60%	10.00%	V _{sk}	25.50%	38.10%	7.90%	15.80%	20.70%	22.90%	20.30%
Div. 22	average	961.5	126.2	173.5	19146.8	62513.2	44469.9	average	121	37.6	40.2	4171.5	9508.8	461.4	4756.3
	V _{sk}	17.60%	33.90%	9.40%	18.80%	17.90%	21.50%	V _{sk}	29.10%	37.70%	6.60%	17.90%	19.60%	22.70%	23.40%
Div. 23	average	769	54.3	123	15146.2	48061.2	3139.3	average	205.9	63.3	91.8	12654.9	26421.1	712.2	7645.9
	V _{sk}	25.90%	23.20%	2.60%	11.10%	13.50%	12.20%	V _{sk}	24.90%	47.30%	6.40%	29.50%	21.30%	16.90%	18.50%
Div. 24	average	656.4	70.2	61.8	7224.5	35607	1621.6	average	205.9	63.3	91.8	12654.9	26421.1	712.2	7645.9
	V _{sk}	22.40%	74.80%	3.90%	21.70%	11.00%	14.60%	V _{sk}	24.90%	47.30%	6.40%	29.50%	21.30%	16.90%	18.50%

Table 5. List of diagnostic variables with assigned deflators

Symbol	Name of variable	Name of deflator
X1	Expenditure on innovative activity in the area of product and process innovations in industry (in PLN million)	Investment expenditure price index
X2	Expenditure (internal and external) on research and development activity (in PLN million)	Investment expenditure price index
X3	Average employment (in thousand people)	n/a
X4	Gross value added (in PLN million)	GDP price index
X5	Sold production (in PLN million)	Price index of sold production of manufacturing divisions
X6	Investment expenditure (in PLN million)	Investment expenditure price index
X7	Gross value of fixed assets (in PLN million)	Investment expenditure price index

Table 6. Results of labour productivity model estimation

Explanatory variables and selected statistics	Dependent variable $\ln(y_{it})$			
	FEM		REM	
	Parameter estimates	t-statistics and p-value	Parameter estimates	t-statistics and p-value
$\ln(k_{it})$	0.28667	2.115 (0.036)	0.2986	4.024 (0.000)
t	0.02712	3.927 (0.000)	0.0265	6.102 (0.000)
$\ln(A_0)$	1.86455	7.800 (0.000)	1.8434	13.220 (0.000)
R-squared	0.918			
Within R- squared	0.626			
Estimation of the significance of individual effects (value of test statistics)	F = 0.626 (p = 0.000)		LM = 473.775 (p = 0.000)	
Hausman test			Chi-square(3) = 0.0113 (p = 0.914)	

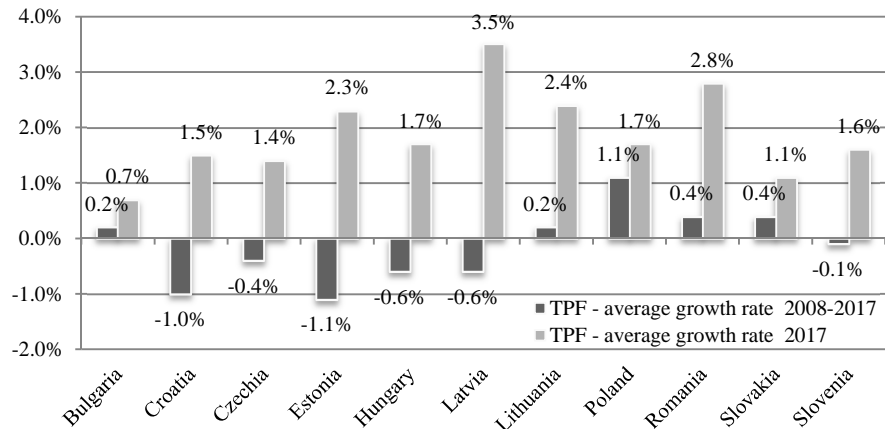
Note: N = 150

Table 7. Estimation results of FEM and REM of total factor productivity (TFP)

Explanatory variables and selected statistics	Dependent variable $\ln(TFP_{it})$			
	FEM		REM	
	Parameter estimates	t-statistics and p-value	Parameter estimates	t-statistics and p-value
$\ln\left(\frac{R\&D}{EMPL}\right)_{it}$	0.0376	2.647 (0.009)	0.0396	2.876 (0.004)
$\ln\left(\frac{R\&D}{EMPL}\right)_{i,t-1}$	0.0410	2.701 (0.007)	0.0437	3.011 (0.002)
$\ln\left(\frac{INVT}{EMPL}\right)_{it}$	0.1963	5.125 (0.000)	0.1711	4.834 (0.000)
Constant	2.2700	20.260 (0.000)	2.1964	19.430 (0.000)
R-squared	0.9021			
Within R-squared	0.451			
Estimation of the significance of individual effects (value of test statistics)	F = 48.1389 (p = 0.000)		LM = 350.028 (p = 0.000)	
Hausman test	Chi-square(3) = 4.728 (p = 0.192)			

Note: N = 150

Figure 1. TFP growth rates in CEE countries



Source: own elaboration based on Próchniak (2018, p. 179).

Figure 2. TFP level in the analysed manufacturing divisions (average value for the period 2009–2017)

