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Total Factor Productivity and its Determinants in Poland - Evidence from Manufacturing Industries. The Role of ICT

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Summary

The aim of the paper is total factor productivity (TFP) analysis in Poland and identification of its determinants. In the first part, TFP growth in Poland is calculated. Following the growth literature, TFP is frequently interpreted as the level of technology and effectiveness of its use. In the remaining sections, the authors try to identify the factors determining TFP growth in Poland. The analysis is carried out on a panel of manufacturing industries over the period of 1994-2001. The determinants of TFP can be divided into four groups. First of all, TFP in Poland grows as a result of convergence, which can be explained by the transfer of technology from more technologically developed countries. Another factor accelerating TFP growth is the innovativeness of domestic enterprises, which can be approximated by expenditures on R&D. Transition reforms had also a positive impact on TFP growth in Poland in the analysed period, by increasing the effectiveness of the production factors use. Finally, ICT investment is found to contribute positively to TFP growth as well.

1. Introduction

The aim of the paper is total factor productivity (TFP) analysis in Poland and identification of its determinants.[1] The role of TFP for macroeconomic policy is significant for at least two reasons. First of all, TFP growth, interpreted as technological and organizational progress, determines the long run pace of economic development. Secondly, describing the supply side of the economy, TFP is a key element of potential output estimates relying on the production function approach. Thus, in this framework, TFP growth increases the maximum level of output which can be achieved without triggering-off inflationary pressure.

The empirical part of the paper follows recent international studies on factors determining TFP growth (see Griffith et al (2001), Scarpetta and Tressel (2002)) but concentrates on the case of Poland. It can be argued that in transition economies such as Poland, especially in the early phase of transition, institutional reforms contribute relatively much to TFP growth (for instance, important sources of factor productivity growth are better utilisation of existing capacities, achieved through privatisation and development of market competition mechanism, and through bankruptcies of inefficient firms), whereas in the long-run innovation (including ICT) and technology transfers become the more important factors influencing technological progress and the role of reforms gradually disappears.

The paper is divided into five sections. In section 2, TFP growth in Poland is calculated using a conventionally applied theoretical framework based on a neoclassical production function. Section 3 introduces the theoretical framework of identification of TFP determinants in Poland, underlying the empirical analysis presented in section 4. Section 5 summarizes the main findings.

2. TFP and Output Growth in Poland

Total factor productivity (TFP) is broadly understood as the efficiency of combining production factors. The standard interpretation of TFP in most growth models is that it reflects the level of knowledge (including technology, management skills etc.), which can be applied to the production process, and the efficiency of the use of knowledge. The concept of

[1] The previous version of this paper was presented at the conference “Potential Output and Barriers to Growth” organized by NBP in Zalesie Górne on 27-28 November 2003. This version is different from the former one in that it uses updated data, contains an additional endogeneity check and considers the impact of ICT on TFP

TFP began to receive increasing attention after the development of endogenous-growth models (see e.g. Lucas (1988)), in which the technological progress was no longer treated strictly exogenously. This gave rise to more careful studies on sources of technological progress and to the incorporation of models explaining R&D into the growth theory.

In most recent works, TFP is named as one of the factors accounting for income differences between countries. For instance, according to Parente and Prescott (2000), improvements in TFP, in particular resulting from the removal of rigidities in the factor allocation mechanism, can explain past or recent growth miracles (e.g. in Japan, Taiwan, South Korea) and determine the pace of catching-up with the world leader.

Being one of the determinants of the production capacity of the economy, TFP growth increases the level of output, which can be produced without triggering-off inflationary pressure. The role of TFP as one of determinants of the potential output can explicitly be seen, when one takes a look at methods of its estimation using production function approach.

The standard departure point for deriving TFP growth is neoclassical production function:

$$Y = F(TFP, L, K), \quad (1)$$

where Y is the volume of output, K is the capital stock and L is the labour input.

Differentiating equation (1) with respect to time, dividing by Y and rearranging terms yields:

$$\frac{dY}{Y} = \frac{F_{TFP}TFP}{Y}\frac{dTFP}{TFP} + \frac{F_L L}{Y}\frac{dL}{L} + \frac{F_K K}{Y}\frac{dK}{K},$$

where F_{TFP}, F_L, F_K are marginal products of production factors. Further assuming that TFP change can be represented by a disembodied progress (Hicks neutral), we arrive at the following formula:

$$\frac{dY}{Y} = \frac{dTFP}{TFP} + \frac{F_L L}{Y}\frac{dL}{L} + \frac{F_K K}{Y}\frac{dK}{K}. \quad (2)$$

An additional assumption frequently made in empirical analyses is that the production function exhibits constant returns to scale. As shown by Gradzewicz and Kolasa (2004), this assumption fits Polish data, thus formula (2) in discrete time finally becomes:

$$\frac{\Delta TFP}{TFP} = \frac{\Delta Y}{Y} - e^L\frac{\Delta L}{L} - (1-e^L)\frac{\Delta K}{K}, \quad (3)$$

where e^L is the elasticity of output with respect to labour input.

Empirical TFP growth calculated with formula (3) depends on the estimates of output elasticities with respect to production factors. Estimating a Cobb-Douglas production function

growth. On the other hand, the previous version includes regressions based on the translog production function, estimated as a robustness check, which were omitted in this paper.

for Poland using quarterly data over the period of 1995-2002 in a VECM system, Gradzewicz and Kolasa (2004) obtained an output elasticity with respect to labour input of 0.55. According to estimates done by Czyżewski (2002) on yearly data over the period of 1993-2001, the elasticity equals 0.66.

Due to well-known problems with short time series, output elasticities are often approximated by the shares of factor payment in total product, rather than estimated using econometric techniques. This alternative approach can only be justified on the additional assumption that production factors prices are equal to their marginal product. According to Polish national accounts for the analysed period, the average compensation of employees accounted for 52% of gross value added, which is close to estimates made by Gradzewicz and Kolasa (2004). However, as pointed out by Czyżewski (2002), this proportion may underestimate the true labour income share in total GDP due to the income generated by the small ifrms classified within the households sector, which is treated in the national accounts as the part of gross operating surplus. Hence, the labour income should be rather assessed at 70% of Poland's GDP, which is closer to the share used frequently in the growth literature (66%).

As can be seen from Table 1, the estimated average annual TFP growth varies from 3.1% to 3.6%, depending on the assumed elasticity.

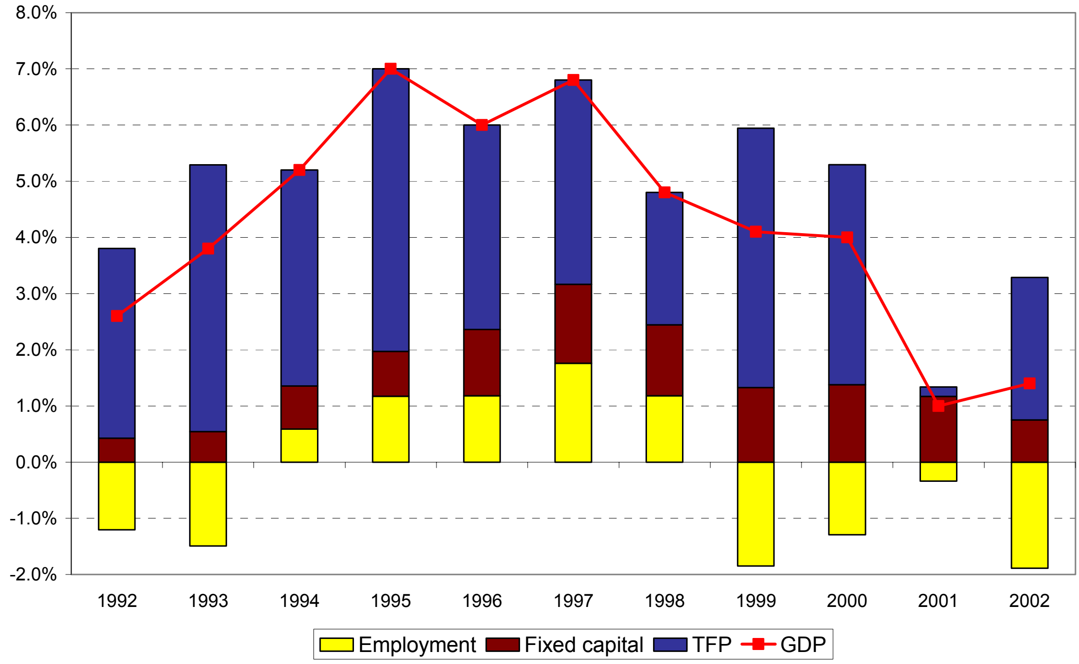
Table 1: Average GDP and factor growth in Poland 1992-2002

	Average annual growth
GDP	4.2%
Employment	-0.3%
Fixed capital	2.9%
TFP (α = 0.55)	3.1%
TFP (α = 0.66)	3.4%
TFP (α = 0.70)	3.6%

The empirical TFP growth rate from Table 1 is lower than that calculated by Rapacki (2002), who estimated it at above 4% over the period of 1992-2000 using α = 0.65 and a slightly different data set. Still, the implied contribution of TFP to GDP growth in 1992-2002 is 73%-84%, which is relatively high compared to developed countries, where it accounts for about half of GDP growth. As can be seen from Graph 1, the contribution was positive throughout the whole period. The same can be said about the capital deepening, accounting for 20%-31% of GDP growth. Changes in employment contributed positively to GDP growth only from 1994 to 1998, being negative since then.

As pointed out by many authors, the empirical TFP growth derived using the method described above cannot be attributed to technological and organizational progress only. Especially during the initial recovery period in 1992-1993, TFP growth reflected also an increase in capacity utilization rates (see De Broeck, Koen (2000)). Excluding these two years from the sample yields the average TFP growth 3%-3.4% and its share in GDP growth 66%-77%. The opposite could be argued for 2001, when the demand subsided, leaving the economy with excess capacities.

Graph 1: Contribution of production factors to GDP growth (α = 0.66)



Estimating capacity utilization is a rather complicated task and requires additional assumptions or assessments, since it is unobservable. According to Gradzewicz and Kolasa (2004), TFP contributed to about 2/3 of potential output growth over the period of 1995-2002. Żółkiewski (2003) estimated the average TFP growth rate during 1991-2001 at 2.6%, which means a 60% contribution to GDP growth. Findings presented by Welfe (2003) suggest an even less significant role of TFP in explaining the economic growth in Poland. According to his estimates, from 1992 to 1998 the pure level of technological progress in Poland may have been growing by less than 1% annually, accounting for less than a quarter of potential GDP growth.

However, in the remaining part of the paper we expect that a significant part of TFP growth in Poland can be attributed to technological or organizational progress and an increased level of efficiency (eg, by reduction of abundant capital or labour). Due to a shorter sample starting from 1994, at least the initial recovery effect should not affect the results.

Theoretical Framework for Econometric Analysis

Following Griliches and Lichtenberg (1984), we assume that TFP level is a function of the stock of knowledge (*E*) and other factors (*V*), which can be written as

$$TFP = f\left(E,V\right).(4)$$

Under the assumption of separability between knowledge and other factors of production (here capital and labour) the rate of TFP growth can be derived from equation (4) by logarithmic differentiation with respect to time, i.e.

$$\frac{dTFP}{TFP} = e^{E}\frac{dE}{E} + e^{V}\frac{dV}{V}, \quad (5)$$

where $e^{E} \equiv \frac{dY}{dE}\frac{E}{Y}$ and $e^{V} \equiv \frac{dY}{dV}\frac{V}{Y}$ are elasticities of output with respect to knowledge stock and other factors respectively. Further assuming zero or very small depreciation of the stock of knowledge, equation (5) can be rewritten as

$$\frac{dTFP}{TFP} = \rho\frac{R}{Y} + e^{V}\frac{dV}{V}, \quad (6)$$

where *R* is real expenditure on knowledge and $\rho \equiv \frac{dY}{dE}$ is the marginal product of knowledge. Approximating marginal percentage change with increments of logarithms and moving to discrete time finally yields

$$\Delta \ln TFP_{t} = \rho\frac{R_{t-1}}{Y_{t-1}} + e^{V}\Delta \ln V_{t}. \ (7)$$

This specification implies a direct effect of investment in knowledge, which is consistent with standard theoretical models of endogenous growth. The natural extension of equation (7) is to substitute the abstract term $e^{V}\Delta \ln V_{t}$ for variables representing factors other than innovation that might have an impact on TFP growth.

Following Griffith et al (2001), we first allow for the transfer of technology from the technology leader or the frontier country to a country behind the technological frontier. The transfer might be instantaneous, meaning that TFP growth in the frontier country induces faster TFP growth in the catching-up country in the current period. Secondly, taking into account convergence effects, the rate of TFP growth should depend on the gap between the frontier and non-frontier country. Thus, equation (7) becomes

$$\Delta \ln TFP_{t} = \rho\frac{R_{t-1}}{Y_{t-1}} + \alpha_{1}\Delta \ln TFP_{t}^{F} + \alpha_{2}\ln\left(\frac{TFP_{t-1}}{TFP_{t-1}^{F}}\right), \ (8)$$

where superscript F corresponds to the frontier country.

Furthermore, TFP growth may depend on a set of institutional factors (e.g. product and labour market regulations – see Scarpetta, Tressel (2002)), market structure (e.g. ownership, monopolization), market openness (measured for instance as import penetration) or international competitiveness (usually approximated by export share). This yields

$$\Delta \ln TFP_t = \rho \frac{R_{t-1}}{Y_{t-1}} + \alpha_1 \Delta \ln TFP_t^F + \alpha_2 \ln\left(\frac{TFP_{t-1}}{TFP_{t-1}^F}\right) + \sum_k \beta_k X_{kt-1} , \quad (9)$$

where X_k is the set of variables representing the above mentioned factors.

The next step is to expand the dimension by disaggregating the variables and allowing for industry specific effects. If technology can be transferred only between the same types of industries in the frontier and non-frontier country and if all other variables in equation (9) have an industry dimension, the final specification becomes

$$\Delta \ln TFP_{it} = \rho \frac{R_{it-1}}{Y_{it-1}} + \alpha_1 \Delta \ln TFP_{it}^F + \alpha_2 \ln\left(\frac{TFP_{t-1}}{TFP_{t-1}^F}\right) + \sum_k \beta_k X_{kit-1} + s_i , \quad (10)$$

where subscript i stands for a given industry and s_i denotes its specific characteristics (constant over time).

There are at least two ways in which the impact of information and communication technologies can be introduced into this theoretical framework. One is to treat ICT as one of the general factors increasing efficiency or competitiveness, which means that ICT would be included in the vector X_k. However, ICT expenditures can be also viewed as investment in ICT knowledge, which would mean that it augments the total stock of knowledge (E). Assuming that ICT and non-ICT knowledge are separable and the elasticities of output with respect to these knowledge stocks might be not equal, and further proceeding similarly as while deriving (7), equation (10) can be written as:

$$\Delta \ln TFP_{it} = \rho \frac{R_{it-1}}{Y_{it-1}} + \sigma \frac{I_{it-1}}{Y_{it-1}} + \alpha_1 \Delta \ln TFP_{it}^F + \alpha_2 \ln\left(\frac{TFP_{t-1}}{TFP_{t-1}^F}\right) + \sum_k \beta_k X_{kit-1} + s_i , \quad (11)$$

where σ is the marginal product of ICT knowledge.

Similarly to Griffith et al (2001), if we assume that equation (11) holds true for the frontier country as well (the only difference is that there is no technology transfer to the frontier country, i.e. $\alpha_1 = 0$ and $\alpha_2 = 0$), long-run determinants of the level of TFP can be derived by considering a steady-state equilibrium. In a steady-state equilibrium independent variables are constant over time and TFP in an industry i grows at the same constant rate both in the frontier and non-frontier country. Combining equation (11) for the frontier and non-frontier country and solving for the level of TFP in the non-frontier country yields

$$\ln TFP_i = \ln TFP_i^F - \frac{1}{\alpha_2}\left(\rho\frac{R_i}{Y_i} + \sigma\frac{I_i}{Y_i} + \sum_k \beta_k X_{ki} + s_i - (1-\alpha_1)\left(\rho\frac{R_i^F}{Y_i^F} + \sigma\frac{I_i^F}{Y_i^F} + \sum_k \beta_k X_{ki}^F + s_i^F\right)\right). \quad (12)$$

Catching-up implies $\alpha_2 < 0$, so the level of TFP in the follower country depends positively on its own investment in innovations (including ICT) and the speed of technology transfer. Since the level of TFP is also dependent on the TFP level in the frontier country, it depends indirectly on investment in ICT and non-ICT knowledge undertaken by the technology leader.

3. Empirical Analysis

4.1 Variables and Data Description

The variables in equation (11) can be grouped into five blocks of explanatory factors so that the general model explaining changes in TFP can be formulated as

$\Delta TFP = f$(*Technology transfer, Innovation, Reforms, ICT, Individual characteristics*).

In the empirical analysis below we consider several specifications, in which the blocks are represented by various sets of variables. The block corresponding to technology transfer consists of the third and fourth term on the right hand side of equation (11). If we leave out the remaining terms it becomes an ADL(1,1) process with a restriction on long-run homogeneity. Thus equation (11) can be viewed as an error correction process augmented by exogenous variables, with long-run equilibrium defined as the state in which TFP levels in the frontier and non-frontier country are equal.

In analyses with a large set of countries (see for example Scarpetta, Tressel (2002)) the frontier is usually defined as a hypothetical economy consisting of industries with the highest TFP level among analysed countries. Since in this paper we concentrate only on factors determining TFP growth in Poland, it was assumed that the technology frontier is Germany, although this country is not a world technology leader in all industries. However, this choice seems to be justified, given the relative size of the German economy, its multinational connections and a higher level of development compared to Poland. Moreover, Germany is Poland’s major trade partner and FDI exporter, meaning that its share in total technology transfer to Poland should be substantial.

As regards the innovation block, several variables were taken into consideration. The two most natural candidates are the share of R&D and innovation expenditures in gross value added (*RDY* and *INY* respectively). In this block we also tried to include a variable approximating the level of human capital (*WCO*, defined as the share of white-collar workers in total employment as a proxy for employees' innovativeness and absorption of new capabilities). Finally, the share of foreign capital in total assets (*FCA*) was used, capturing both domestic investment in knowledge made by foreign companies and the transfer of technologies or management from the frontier[2].

As pointed out earlier, a large set of variables in the block reforms could be considered. In this paper we concentrated on two variables having an industry dimension. In order to extract the impact of the privatization process on TFP growth, the share of the private sector in an industry's total sold production (*PSP*) was used as a candidate variable. As a measure of product market reforms, including the level of competitiveness, we used the Herfindahl-Hirschmann index of market concentration calculated on sales revenues (*HHR*).

In order to measure the impact of ICT investment on TFP growth we used a variable *ICT* defined as the share of ICT expenditures in gross value added. Due to lack of appropriate data, ICT investment is approximated by intermediate consumption of goods originating from two industries: manufacture of office machinery and computers and computer services. This means that we account only for a part of ICT input defined by OECD, and perhaps what we measure could rather be called IT input. Adding inputs from other ICT producing industries would require data on a more disaggregate level. However, we believe that the variable we use can serve as a good proxy for an indirect impact of new technologies on TFP growth.

Finally, individual characteristics of each industry were considered by including in each regression industry-specific fixed effects.

The complete panel for Poland consists of 21 manufacturing industries over the period 1994-2001, according to the classification of Poland's Central Statistical Office (consistent with ISIC two- or three-digit industries). The main data sources for Polish data were official publications of the CSO, except for the HH index, which was calculated using the database of quarterly reports F-01. Data for Germany, covering the period 1994-2001, was taken from the OECD Structural Analysis Database (STAN). All currency conversions were made with Purchasing Power Parities published by OECD.

[2] The proposed classification of variables is conventional only, in particular *FCA* can as well be a member of the reforms block or the technology transfer block.

4.2 TFP Measurement

TFP growth measurement was based on the standard neoclassical production function, as shown in section 2. We allowed the elasticities of output with respect to production factors (approximated by the shares of factor payments in total value added) to vary over time for panel regressions and to be fixed for aggregate data (calculated as arithmetic averages of factor income shares).

As shown by Shaikh (1974), the latter case leads directly to a Cobb-Douglas production function, so TFP levels can be calculated easily. For panel data analysis we applied shifting elasticities to a Cobb-Douglas production function, i.e. TFP levels, and consequently TFP growth rates, were derived from the following formula:

$$\ln TFP_{it} = \ln Y_{it} - e_{it}^{L} \ln L_{it} - \left(1 - e_{it}^{L}\right)\ln K_{it}. \quad (13)$$

A typical problem encountered while applying factor income shares as approximation for output elasticities at a disaggregate level is their relatively high volatility. Assuming that this is due to measurement errors, applying a smoothing procedure may be justified. We follow Harrigan (1997) and substitute e_{it}^{L} for fitted values of regression

$$e_{it}^{L} = \xi_i + \beta\left(\ln K_{it} - \ln L_{it}\right), \quad (14)$$

which was estimated with a fixed effects technique for panel data estimation with cross-section weights to eliminate heteroskedasticity. The output of the regression is reported in Table 2.

Table 2. Smoothing factor income shares

Regressors	*Coefficients (*t-values*)*
$\ln K_{it} - \ln L_{it}$	0.12 (*8.8*)
Fixed effects	
R^2	0.98
DW	1.87
Sample (adjusted)	94-01
Method of estimation	WLS

As can be seen, the fit is very good and there is no first order serial correlation, so the fitted values of (14) can be used as smoothed values of factor income shares, approximating output elasticities.

4.3 Estimation Results

All regressions for pooled data were estimated with Weighted Least Squares (WLS) with a full set of fixed effects, i.e. we eliminated cross-section heteroskedasticity and allowed for industry-specific effects affecting the TFP growth rate. Due to data availability, the number of observations used in the regressions depends on the variables used. In particular, R&D outlays and HH-indexes are not available for 1994. The regression results are reported in Table 3.

As pointed out earlier, the estimated equations can be viewed as ADL models, which means that the estimated coefficients may be biased, even though the time dimension of the panel used is not very short for a standard panel data set. As shown for example by Greene (2000), the finite sample bias is of order $1/T$ and its consistency relies upon T being sufficiently large.

A typical alternative approach relies on instrumental variables (IV) estimators, although they neglect quite a lot of information and are therefore inefficient. This approach will not be followed in this paper for other reasons as well. First of all, the aim of the paper is to identify factors influencing TFP growth and not provide precise estimates of elasticities, which could be used for policy decisions (the interpretation of the values of the coefficients should not be direct due to short time series and structural changes in Poland's economy, in particular an expected diminishing role of factors representing reforms). Since statistical significance of the estimates is relatively high, it can be argued that the inference based on them should not be undermined by the possible bias, i.e. the identified factors explain TFP growth in Poland and the direction of their influence is assessed correctly.

The second problem is the possible endogeneity of some of the regressors. As pointed out by Griffith et al (2001), the weak exogeneity assumption might not hold if companies could predict future shocks or if there are common shocks in an industry that are not controlled for by other variables used in the estimated regressions. This would result in a serial correlation of residuals, therefore special attention was paid to the autocorrelation test. As an additional check, the robustness of the results with respect to the possible endogeneity of the gap term (i.e. $\ln\left(\frac{TFP_{t-1}}{TFP_{t-1}^{F}}\right)$) and the immediate technology transfer term (i.e. $\Delta \ln TFP_t^F$) was examined.

Table 3. Regression results – panel data estimation (Cobb-Douglas production function)

Regressors		Coefficients (*t-values*) 1	2	3	4	5	6	7	8	9	10
Techno-logy transfer	$\ln\left(\frac{TFP_{it-1}}{TFP_{it-1}^{F}}\right)$	-0.22 (*-4.8*)	-0.21 (*-3.6*)	-0.20 (*-5.2*)	-0.18 (*-3.7*)	-0.24 (*-5.4*)	-0.37 (*-5.9*)	-0.40 (*-6.2*)	-0.21 (*-4.5*)	-0.24 (*-5.5*)	-0.24 (*-5.8*)
	$\Delta \ln TFP_{t}^{F}$			0.47 (*4.5*)	0.42 (*1.9*)	0.31 (*2.7*)	0.41 (*3.5*)	0.41 (3.*6*)	0.46 (*3.8*)	0.23 (*2.0*)	0.17 (*1.5*)
Innovation	$RDY_{t\text{-}1}$					4.71 (*3.5*)	4.59 (*3.5*)	4.69 (3.*6*)		4.87 (*3.8*)	5.01 (*4.0*)
	$INY_{t\text{-}1}$										
	$WCO_{t\text{-}1}$										
	$FCA_{t\text{-}1}$						0.94 (*2.7*)	1.15 (*3.2*)			
Reforms	$PSP_{t\text{-}1}$										
	$HHR_{t\text{-}1}$							-1.37 (-1.*9*)			-2.06 (*-3.3*)
	$ICT_{t\text{-}1}$								1.14 (*2.2*)	1.34 (*2.6*)	1.85 (*4.7*)
Fixed effects		√	√	√	√	√	√	√	√	√	√
(F-values)		(*2.2*)		(*2.2*)		(*4.2*)	(*5.3*)	(*3.8*)	(*1.8*)	(*3.6*)	(*2.7*)
R^2		0.37	-	0.50	-	0.63	0.65	0.65	0.58	0.67	0.57
DW		2.08	-	2.21	-	2.33	2.31	2.34	2.49	2.38	2.46
Sample (adjusted)		95-01	96-01	95-01	96-01	95-01	95-01	95-01	96-01	96-01	96-01
Method of estimation		WLS	IV	WLS	IV	WLS	WLS	WLS	WLS	WLS	WLS

First, we estimated the basic regression with the WLS method (regression 1 in Table 3) and then reestimated it instrumenting the gap term with $\ln\left(\frac{TFP_{t-2}}{TFP_{t-2}^{F}}\right)$ (regression 2). Similarly, we followed the same procedure by estimating a restricted ADL(1,1) model in form of an error-correction process using the WLS method (regression 3) and then reestimating it using as an additional instrument (for the immediate technology transfer term) past investment in knowledge at the frontier (regression 4). As can be clearly seen, treating the gap variable or the TFP growth at the frontier term as endogenous has hardly any effect on the estimation results, which suggests that the possible bias can be neglected. Thus, all remaining regressions were run with the WLS method, ensuring that no first-order autocorrelation of residuals is present.

The results reported in Table 3 show the impact of various factors on TFP growth in Poland over the period of 1994-2001. In order to avoid redundancy and collinearity problems, blocks innovation and reforms are represented by only one variable each (except for regression 7, where *FCA* was treated as a separate block). Regressions 8, 9 and 10 show the impact of IT investment on TFP growth.

According to the results, technology transfer played an important role in the TFP growth process over the analysed period. The technology gap term enters negatively and is statistically significant in all specifications, implying that the larger is the distance to the technology frontier, the higher is the rate of productivity growth. The speed of convergence, close to 0.24 on average, is about twice as high compared to international studies among developed countries (see Griffith et al (2001)), meaning that the technological catching-up process in Poland was quite rapid. The immediate technology transfer was also relatively high, although in regression 10 not statistically significant. It shows that TFP growth in Germany by 1% translates immediately into 0.17%-0.47% TFP growth in Poland.

The innovativeness, measured by innovation outlays, contribute positively to TFP growth. As derived in equation (6), the coefficients corresponding to variable *RDY* can be interpreted as the marginal product of R&D and innovation outlays respectively. However, if we take into account their low intensity and low stability in Poland[3], such inference would be too far-reaching.

Moreover, there are more general theoretical and empirical reasons why the interpretation of ρ from equation (6) should not be direct. First of all it is not clear that knowledge is

[3] In 2000, R&D intensity in the Polish manufacturing sector was about 1%, compared to 7.8% in Germany.

separable from other production factors. Secondly, labour and capital components of knowledge expenditures are already accounted for in the production function, which means that ρ should be looked at as an excess marginal product of knowledge rather than the total rate of return to knowledge (see Cameron (1998), Guellec and van Pottelsberge (2001) for more detailed comments and references).

Therefore, given the present innovation activity in Poland and the above mentioned problems, it is safe to say only that the impact of variables *RDY* and *INY* on TFP growth is positive and statistically significant. For more accurate estimates a larger data set, higher innovation intensity and more extensive robustness checks would be necessary.

The higher the share of foreign capital in the economy's total assets, the higher is the TFP growth rate. This could mean relatively higher innovativeness of companies with foreign capital. On the other hand, a large share of foreign companies are former state-owned enterprises, so the positive contribution of variable *FCA* can also be interpreted as a positive impact of privatisation.

According to estimation results, structural changes in Polish manufacturing, resulting in lower market concentration helped TFP to grow. This suggests that higher competition facilitates technological progress, forcing companies either to invest in innovations or to import technologically advanced machinery and equipment, patents etc.

IT investment intensity (variable *ICT*) enters positively regressions 8-10, indicating that by using new technologies as input companies can improve their productivity. Due to reasons mentioned in the case of R&D outlays, a straightforward interpretation of the coefficients corresponding to variable *ICT* as a marginal product of IT outlays may be not appropriate.

The significance of individual characteristics was examined by comparing the models presented in Table 3 with their simplified counterparts (simple panel regressions, in which the intercept did not have an industry dimension). According to the Wald test, fixed effects are statistically significant in all specifications from Table 3, indicating that the impact of industry specific characteristics on TFP growth in Polish manufacturing should not be neglected.

Due to the small sample size and problems with data quality and availability, an analysis at a more disaggregate level is not possible in the framework presented above. Since there may be a possibility that the results are strongly dependent on the time period used for estimation, we ran a simple regression for the total manufacturing over the period of 1991-2001. The estimated equation including only the technology gap term among the regressors (other variables were omitted to spare degrees of freedom) is presented in Table 4.

Table 4. Regression results – total manufacturing

Regressors	*Coefficients* (*t-values*)
$\ln\left(\frac{TFP_{it-1}}{TFP_{it-1}^{F}}\right)$	-0.22 (*-3.5*)
Constant	√
R^2	0.72
DW	2.84
Sample (adjusted)	91-02
Method of estimation	OLS

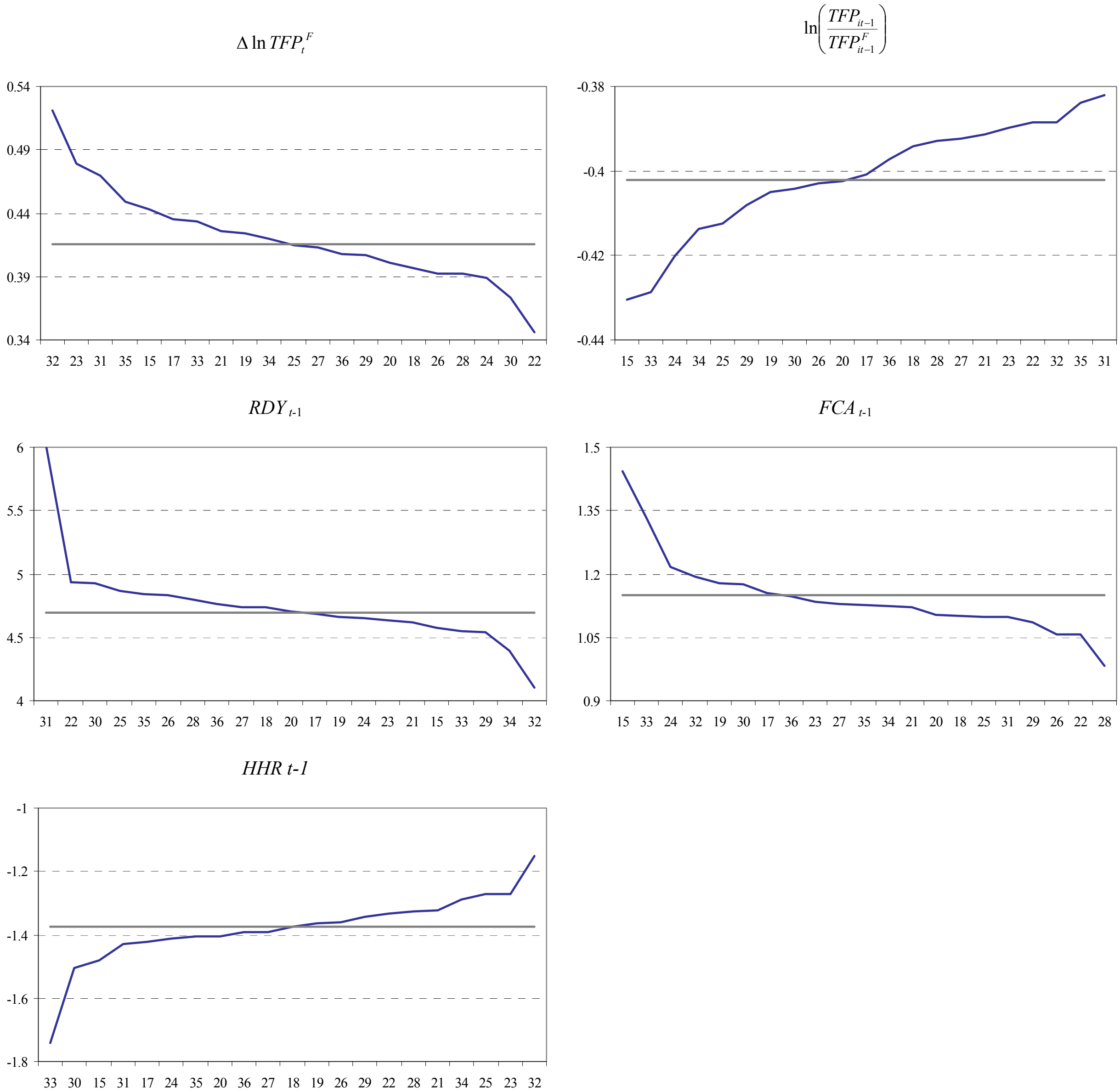
The results are very similar to those obtained for panel data estimation (see corresponding regressions 1 and 2 in Table 3), indicating that at least the impact of technology transfer was assessed correctly in our baseline analysis. Moreover, it could suggest that the finite sample bias in the panel regressions is negligible. However, it has to be noted that due to a small sample size and possible problems signalled by DW statistics, the results for total manufacturing should be treated only as a very rough robustness check.

4.4 Impact of Cross-section Diversity on Estimated Coefficients

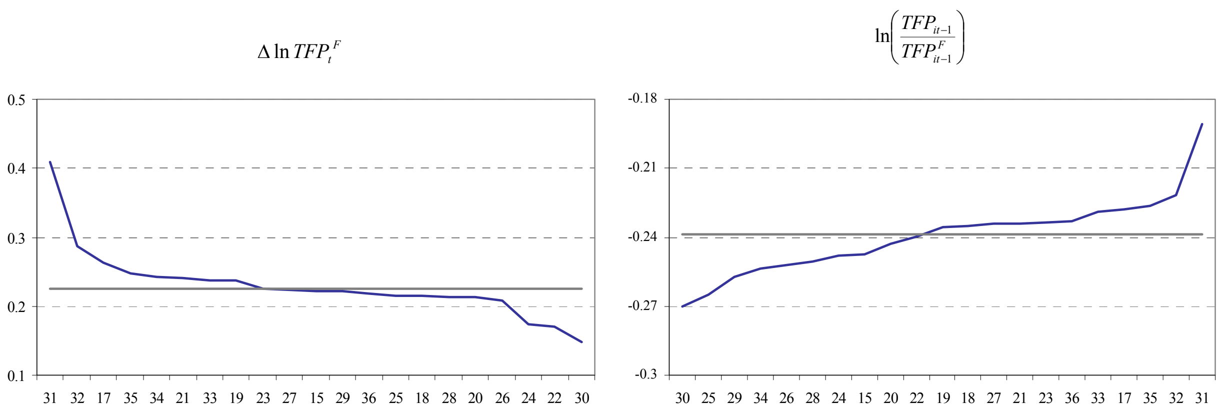
In the analysis presented so far, cross-section diversity has been accounted for by including fixed effects into the estimated equations, assuming that other estimated coefficients do not have an industry dimension. In reality, at least some elasticities may differ across sections, which can be attributed for instance to institutional regulations facilitating or inhibiting either technology transfer or expenditures on knowledge.

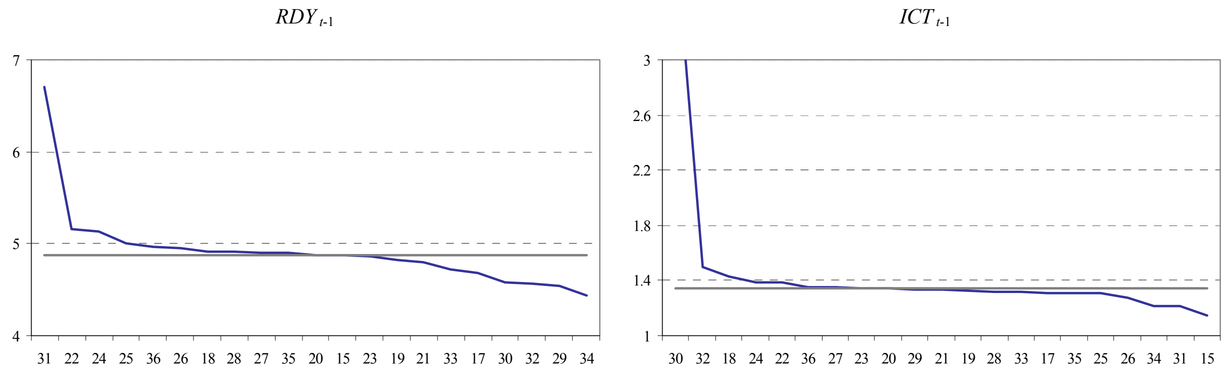
Due to the relatively short time dimension of the panel, running 21 separate regressions to extract these differences would not yield plausible results. However, the impact of a particular industry on the value of estimated coefficients may be assessed by excluding it from the regression. If a coefficient estimated for such a reduced panel is lower in the absolute value compared to the baseline regression, it could be concluded that the impact of the corresponding variable on TFP growth for the industry excluded is stronger than that implied by the analysis for the complete data set. Otherwise, the industry-specific elasticity is either lower, statistically insignificant or might even have the opposite sign.

Graph 2. Cross-section diversity – regression 7

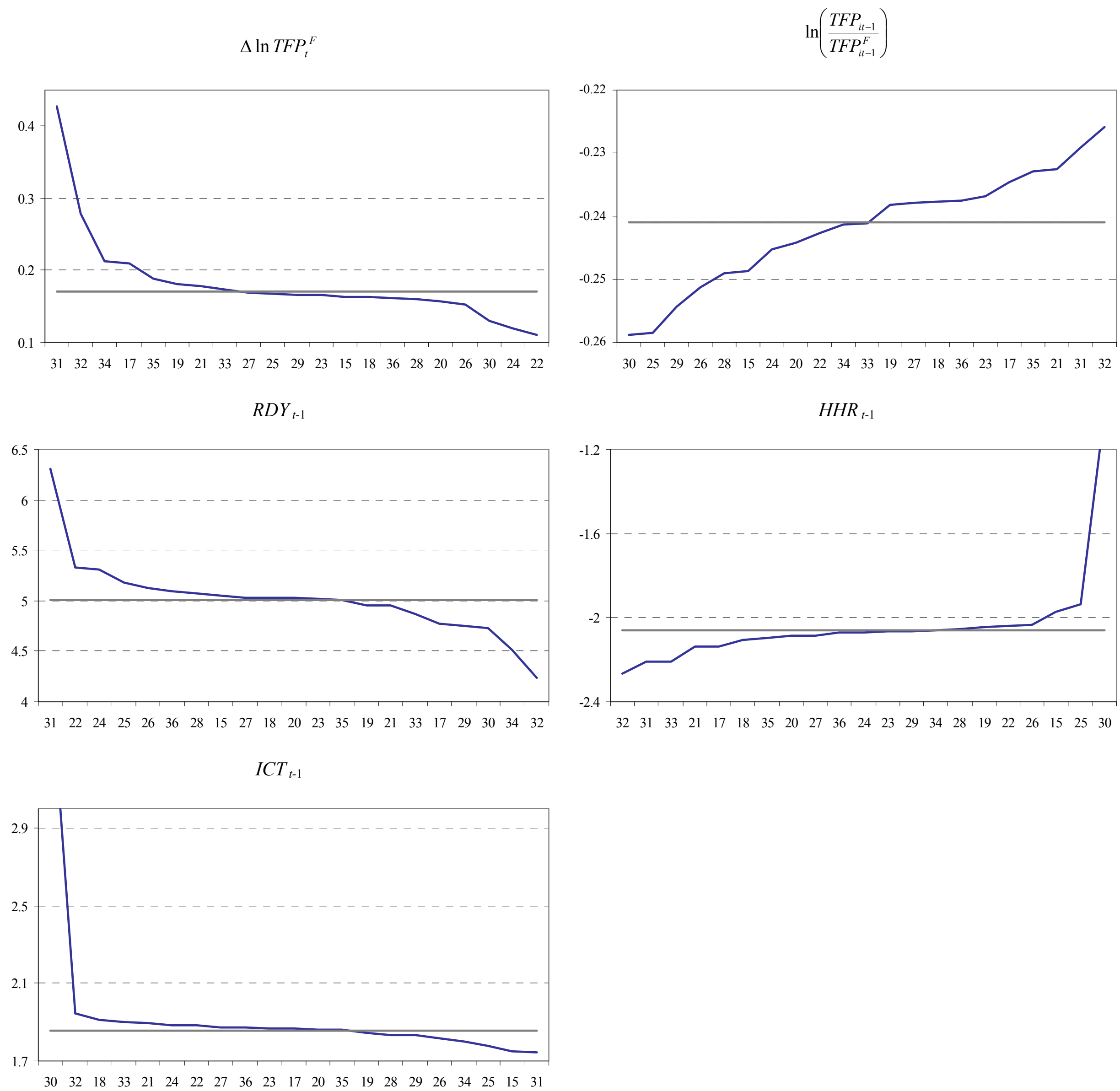


Graph 3. Cross-section diversity – regression 9





Graph 4. Cross-section diversity – regression 10



We apply the procedure described above, i.e. for every preferred specification (regressions 7, 9 and 10 from Table 3) we run 21 regressions, each time excluding one industry from the data set. The results are reported in graphs 2, 3 and 4, continuous horizontal lines corresponding to the coefficients estimated from the regressions run on the complete panel.

Without taking a closer look at the industry-specific characteristics, including initial conditions, institutional factors, Poland's structural policy etc., sensible interpretation of these results is hardly possible. However, at least several general remarks could be made[4].

Relatively fast technology transfer seems to be characteristic to a few high or medium tech industries (chemicals, office machinery and computers, radio, television and communication equipment, electrical machinery and apparatus, but in the last two cases only by the technology gap) or industries with productivity highly dependent on computer data processing capacity (publishing, printing and reproduction). The same could be argued for innovativeness, although the set of industries benefiting particularly strongly from increased R&D expenditures is different (motor vehicles, office machinery and computers, radio and television equipment, machinery and equipment n.e.c.) and there are several exceptions to the proposed rule. Growing competition and structural reforms were beneficial to low tech industries (publishing, printing and reproduction, rubber and plastic, leather, mineral products, metal products) rather than to several high-tech sections (medical, precision and optical instruments, electrical machinery and apparatus, other transport equipment). Finally, among the industries highly benefiting from investment in IT technologies one could name a few high or medium tech ones, e.g. electrical machinery and apparatus, rubber and plastic products, motor vehicles, but also food products and beverages.

4.5 Guidelines on Future Research

In the empirical analysis presented so far several simplifying assumptions have been made, which, if violated, might have the impact on the obtained results. One point has already been mentioned and is connected with capacity utilization, which cannot be assumed constant over the time period used for the estimation procedure. At the aggregate level it is usually taken into account by analysing potential output changes rather than actual GDP growth. For Polish manufacturing, capacity utilization indexes assessed by CSO business tendency survey could theoretically be used. Unfortunately, their quality at an industry level is dubious.

[4] For the following suppositions, variable *FCA* is treated as a member of the reforms block.

Another problem is measurement of the labour input, approximated in this paper by the number of employed persons. A much better indicator would be the number of hours worked, but it is not available at an industry level for the whole period of 1994-2001.

An interesting and desirable future extension of the analysis is connected with the variables used in the block reforms. It can be expected that with the transformation process coming to an end their impact on TFP growth will be diminishing. Moreover, the variable measuring the market concentration might become ambiguous. As long as a decreasing HH-index can be explained as a result of breaking-down ineffective state-owned enterprises and the springing-up of small private companies, its sign in the regression should be negative. On the other hand, in 2001 the market concentration started to grow again, in many cases reflecting the process of mergers and acquisitions, which can in the medium run lead to higher efficiency. Therefore it might be interesting to examine the impact on TFP growth of another set of variables approximating changes in competitiveness and the efficiency of factor use. A natural candidate could be any indicator measuring openness of the economy, such as exports, imports or total trade to GDP ratios. However, as shown by Miller and Upadhyay (2002), openness to foreign trade can have a negative impact on TFP growth in countries with a low human capital stock. This may be the case particularly for countries with high imports penetration, crowding out the economic activity of domestic companies. As regards exports, the causality may be from productivity to exporting, i.e. high productivity helps to compete with other countries rather than the presence on the world markets increases productivity (see Bernard and Jensen (1999)).

Finally, following Nicoletti and Scarpetta (2003), it might be interesting to examine the effect of regulations and institutions (e.g. unionisation of industries) on TFP growth in Poland, however data availability on an industry level might be a problem hard to overcome.

4. Concluding Remarks

Putting aside all well-known problems with TFP measurement, it seems that its contribution to GDP growth in Poland has been substantial, significantly improving the capacities of the economy and thus increasing the rate of potential output growth. Although it could be argued that at least a part of empirical TFP growth could be attributed to increasing capacity utilization following the initial decline at the beginning of the transition process, the results obtained in this paper indicate that it was also driven by technological progress and improving efficiency.

Being a country far behind the technological frontier in most industries, Poland benefits highly from the technology transfer from more developed economies via foreign direct investment and knowledge spillovers. Market reforms aimed at privatization, breaking-down state-owned giants and facilitating the springing-up of small private companies contributed significantly to the improvement of efficiency of factor use. Finally, TFP growth was also driven by domestic investment in innovations and ICT technologies, although the intensity of such activities in Poland is several times lower than in most European countries (see Czyżewski, Kolasa (2003)).

For the future, several suppositions could be ventured. It is quite clear that sooner or later the potential for rapid TFP growth by the technology transfer only will be exhausted, or at least its impact will be diminishing (although nearing EU accession may speed up knowledge spillovers). The same could be argued about the impact of reforms, however there will be still room for improving efficiency by increasing the competitiveness of domestic enterprises. The sole set of factors contributing to TFP growth, regardless of Poland's progress in introducing market reforms and catching-up process, is investment in knowledge. Therefore intensification of R&D, ICT expenditures and investment in human capital are highly desired for strong and sustainable economic growth. The latter might also help to increase the technology transfer by attracting foreign direct investment in modern technologies demanding highly skilled labour force and strong scientific centres.

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