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The Total Factor Productivity and the Potential Product in Poland 1992-2002

The aim of the paper is total factor productivity (TFP) analysis in Poland over the period of 1992-2002 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. However, conventionally used measurement methods lead to empirical estimates of TFP containing other elements, e.g. capacity utilization, which makes the interpretation more difficult and ambiguous. 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 three groups. First of all, TFP in Poland grows as a result of the convergence effect, which can be explained by technology transfer from more technologically developed countries. Another factor accelerating TFP growth is innovativeness of domestic enterprises, which can be approximated with expenditures on R&D and human capital. Transition reforms had also a positive impact on TFP growth in Poland in the analysed period, by increasing effectiveness of the production factors use.

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1. Introduction

The aim of the article is total factor productivity (TFP) analysis in Poland over the period of 1992-2002 and identification of its determinants. 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 and thus 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 reforms contribute relatively much to TFP growth, whereas in the long-run innovation and technology transfers become the more important factors influencing technological progress and the role of reforms is gradually disappearing.

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

2. TFP and Potential Output 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 its use. The concept of TFP began to receive increasing attention after 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 the incorporation of R&D theories into the growth theory and more careful studies on sources of technological advance.

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, understood as removal of constraints on the choice of production units, 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.

Determining the production capacity of the economy, TFP growth increases the level of output, which can be produced without triggering-off inflationary pressures. 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:

$$Y = F(TFP, L, K)\,, \tag{1}$$

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, division by Y and rearrangement of 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 is disembodied progress, i.e. it is Hicks neutral, we arrive at the following formula:

$$\frac{dY}{Y} = \frac{dTFP}{TFP} + \frac{F_L L}{Y}\frac{dL}{L} + \frac{F_K K}{Y}\frac{dK}{K}\,. \tag{2}$$

An additional assumption frequently made in empirical analyses is that the production function exhibits constant returns to scale. As shown by Gradzewicz and Kolasa (2003), this assumption fits Polish data, thus forumla (2) in discrete time finally becomes:

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

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 for Poland using quarterly data over the period of 1995-2002 in a VECM system, Gradzewicz and Kolasa (2003) obtained 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 done by Gradzewicz and Kolasa (2003). 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 households, which is classified 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.

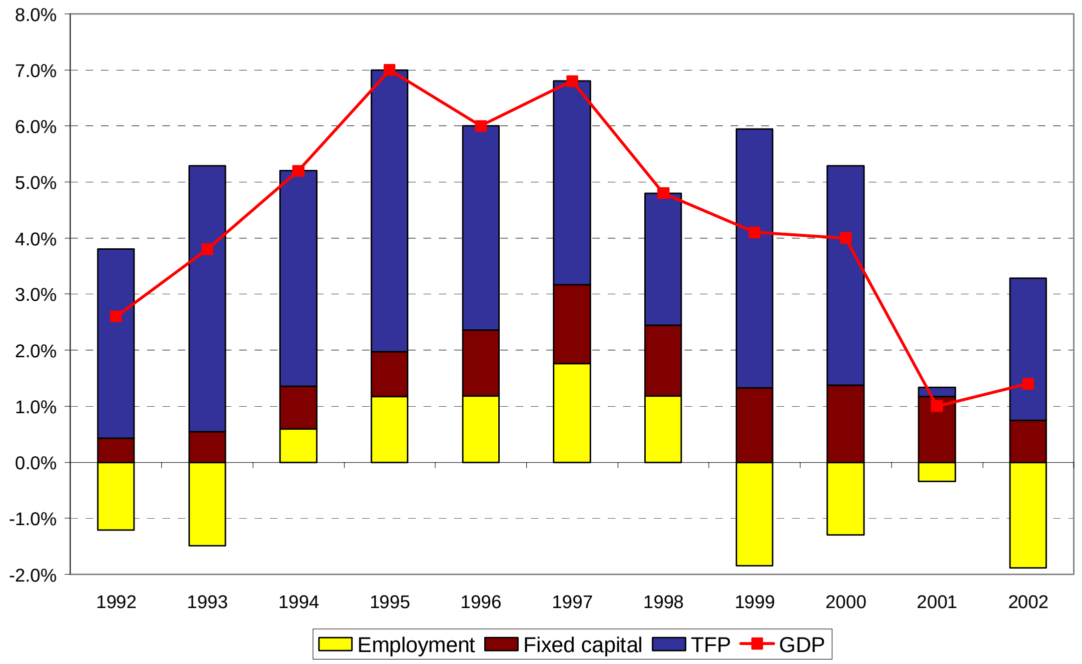
Table 1. Average GDP and factor growth in Poland 1992-2002

	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 calculated by Rapacki (2002), who estimated it at above 4% over the period of 1992-2000 using $\alpha = 0.65$ and slightly different data set. Still, the implied contribution of TFP to GDP growth in 1992-2002 is 73%-84%, which is relatively high comparing 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%-21% 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 of 3%-3,4% and its contribution to GDP growth of 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



Taking into account capacity utilization is due to its unobserved character a rather complicated task and requires additional assumptions or assessments. According to Gradzewicz and Kolasa (2003), TFP contributed to about 2/3 of potential output growth over the period of 1995-2002. Findings presented by Welfe (2003) suggest 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 grown by less than 1%, accounting for less than a quarter of potential GDP growth.

However, in the remaining part of the article we expect that a significant part of TFP growth in Poland can be attributed to technological or organizational progress and increased level of efficiency. Due to shorter sample starting from 1994, at least the initial recovery effect should not affect the results.

3. 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

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

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

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

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 residual influences respectively. Further assuming zero or very small depreciation of the stock of knowledge, equation (5) can be rewritten as

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

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

$$\Delta \ln TFP_t = \rho \frac{R_{t-1}}{Y_{t-1}} + e^V \Delta \ln V_t. \tag{7}$$

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 the 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

$$\Delta \ln TFP_t = \rho \frac{R_{t-1}}{Y_{t-1}} + \alpha_1 \Delta \ln TFP_t^F + \alpha_2 \ln\left(\frac{TFP_{t-1}}{TFP_{t-1}^F}\right), \tag{8}$$

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

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

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

The last 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 the industry dimension, the final specification becomes

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

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

Similarly to Griffith et al. (2001), if we assume that equation (10) holds 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 (10) for the frontier and non-frontier country and solving for the level of TFP in the non-frontier country yields

$$\ln TFP_i = \ln TFP_i^F - \frac{1}{\alpha_2}\left(\rho \frac{R_i}{Y_i} + \sum_k \beta_k X_{ki} + s_i - (1-\alpha_1)\left(\rho \frac{R_i^F}{Y_i^F} + \sum_k \beta_k X_{ki}^F + s_i^F\right)\right). \qquad (11)$$

Catching-up implies $\alpha_2 < 0$, so the level of TFP in the follower country depends positively on its own investment in innovations 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 knowledge undertaken by the technology leader.

4. Empirical analysis

4.1. Variables and data description

The variables in equation (10) can be grouped into four blocks of explanatory factors so that the general model explaining changes in TFP can be formulated as

ΔTFP = f(Technology transfer, Innovation, Reforms, 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 second and third term on the left hand side of equation (10). If we leave out the remaining terms it becomes an ADL(1,1) process with the restriction on long-run homogeneity. Thus equation (10) 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.

Table 2. TFP in Poland relative to Germany and TFP growth in Poland

PKD symbol	Industries	Relative TFP 1994	Relative TFP 2000	Average rate of TFP growth in Poland 1994-2001
D	**Manufacturing**	**22,6%**	**28,4%**	**6,9%**
15	Food products and beverages	50,2%	76,5%	8,1%
17	Textiles	40,7%	55,8%	6,4%
18	Wearing apparel and furriery	41,1%	57,5%	5,8%
19	Leather and leather products	63,3%	58,8%	-1,5%
20	Wood and wood, straw and wicker products	41,3%	46,2%	2,2%
21	Pulp and paper	20,4%	28,8%	10,2%
22	Publishing, printing and reproduction of recorded media	76,8%	92,3%	3,1%
23	Coke and refined petroleum products	38,8%	5,0%	-6,4%
24	Chemicals and chemical products	18,5%	22,8%	8,2%
25	Rubber and plastic products	19,1%	35,1%	11,2%
26	Other non-metallic mineral products	29,2%	61,9%	10,9%
27	Basic metals	25,1%	34,4%	5,8%
28	Metal products	26,1%	42,4%	9,3%
29	Machinery and equipment n.e.c.	20,5%	31,3%	12,0%
30	Office machinery and computers	6,8%	36,3%	22,8%
31	Electrical machinery and apparatus n.e.c.	17,6%	30,7%	11,2%
32	Radio, television and communication equipment and apparatus	7,1%	13,8%	22,6%
33	Medical, precision and optical instruments, watches and clocks	22,5%	37,4%	13,5%
34	Motor vehicles, trailers and semi-trailers	11,4%	27,4%	18,6%
35	Other transport equipment	22,2%	24,1%	10,8%
36	Furniture; manufacturing n.e.c.	34,3%	39,7%	4,8%

As can be seen from Table 2, in 1994 TFP level in Poland was significantly lower than in Germany for all analysed industries, which confirms the huge potential for technology transfer between these two countries. In 2000 the gap was still relatively large, but convergence could be recorded in all but one industries. The correlation coefficient between TFP level in Poland relative to Germany in 1994 and average TFP growth in Poland over the period of 1994-2001 equals –0.74, meaning that the larger the technology gap, the higher the rate of catching-up.

As regards the innovation block, several variables were taken into consideration. Two most natural candidates are the share of R&D and innovation expenditures in gross value added (*RDY* and *INY* respectively). As alternative measures of knowledge outlays two other variables were accounted for. The first one is the share of white-collar workers in total employment (*WCO*) as a proxy for research and innovation activities of employees, the second is the share of foreign capital in total assets (*FCA*) corresponding to the assumption that most investment in knowledge is made by foreign companies[1].

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 private sector in industry's total sold production (*PSP*) was used. As a measure of product market reforms, including the level of competitiveness, we used Herfindahl-Hirschmann index of market concentration calculated on sales revenues (*HHR*). Other possible variables were excluded due to lack of appropriate data.

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 publications of the CSO, except for the HH index, which was calculated using the database of quarterly reports F-01. Data for Germany were taken from OECD Structural Analysis Database (STAN). All currency conversions were made with Purchasing Power Parities published by OECD.

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

$$\ln TFP_{it} = \ln Y_{it} - e_{it}^{L} \ln L_{it} - \left(1 - e_{it}^{L}\right) \ln K_{it} . \tag{12}$$

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

$$e_{it}^{L} = \xi_i + \beta\left(\ln K_{it} - \ln L_{it}\right), \tag{13}$$

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 3.

Table 3. Smoothing elasticities

Regressors	Coefficients (*t-values*)
$\ln K_{it} - \ln L_{it}$	0.094 (*4.15*)
Fixed effects	
R^2	0.97
DW	1.77
No. of observations	168
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 (13) can be used as smoothed values of the 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

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

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 4.

As was 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 8 years 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. This would result in serial correlation of residuals, therefore special attention was paid to the Durbin-Watson autocorrelation test. As an additional check, robustness of the results with respect to the possible endogeneity of the gap term (i.e. $\ln\left(\frac{TFP_{t-1}}{TFP^{F}_{t-1}}\right)$) was examined.

Table 4. 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	$\ln\left(\frac{TFP_{it-1}}{TFP^F_{it-1}}\right)$	-0.23 (*-5.3*)	-0.23 (*-4.1*)	-0.27 (*-5.7*)	-0.20 (*-3.5*)	-0.28 (*-6.5*)	-0.33 (*-5.4*)	-0.21 (*-2.8*)	-0.27 (*-4.0*)	-0.26 (*-2.9*)	-0.23 (*-3.1*)
	$\Delta \ln TFP^F_t$				0.25 (*1.6*)		0.27 (*2.1*)	0.26 (*1.4*)	0.28 (*1.5*)	0.20 (*1.1*)	0.25 (*1.5*)
Innovation	RDY_{t-1}					5.50 (*5.1*)			5.53 (*3.5*)		4.50 (*2.6*)
	INY_{t-1}			0.44 (*1.9*)							
	WCO_{t-1}				0.87 (*2.2*)						
	FCA_{t-1}						1.9 (*5.4*)	1.09 (*3.1*)			0.76 (*2.3*)
Reforms	PSP_{t-1}									0.14 (*1.7*)	
	HHR_{t-1}							-1.98 (*-2.9*)	-1.75 (*-3.1*)		-1.88 (*-2.9*)
Fixed effects		√	√	√	√	√	√	√	√	√	√
(F-values)		(*2.6*)		(*2.3*)	(*3.6*)	(*3.9*)	(3.*9*)	(*3.1*)	(*3.1*)	(*3.6*)	(*2.7*)
R^2		0.40	-	0.43	0.48	0.65	0.74	0.58	0.61	0.59	0.57
DW		2.05	-	2.08	2.04	2.33	2.13	2.29	2.30	2.36	2.26
No. of observations		147	126	147	147	126	126	126	126	126	126
Method of estimation		WLS	IV	WLS	WLS	WLS	WLS	WLS	WLS	WLS	WLS

First we estimated the basic regression with WLS method (regression 1 in Table 4) and then reestimated it instrumenting the gap term with $\ln\left(\frac{TFP_{t-2}}{TFP^F_{t-2}}\right)$ (regression 2).[2] As can be clearly seen, treating the gap variable as endogenous has no effect on the estimation results, which suggests that the possible bias can be neglected. Thus, all remaining regressions were run with WLS method, ensuring that no first-order autocorrelation of residuals is present.

The results reported in Table 4 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 10, where *FCA* was treated as a separate block). The most complete, and therefore preferred, are regressions 7, 8 and 10. The estimation results for other specifications were reported to show the impact of variables not included in the preferred regressions.

According to the results, the technology transfer played an important role in the TFP growth process over the analysed period. The 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, ranging between 0.20 and 0.33, 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 some specifications not statistically significant. It shows that TFP growth in Germany by 1% translates immediately into 0.2%-0.28% TFP growth in Poland.

The innovativeness, measured either by innovation outlays or human capital, contribute positively to TFP growth. As derived in equation (6), the coefficients corresponding to variables *RDY* and *INY* can be interpreted as marginal product of R&D and innovation outlays respectively. However, if we take into account their low intensity and low stability in Poland, 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 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

[2] Since the estimation was made in a system of equations, R^2 and DW statistics are available only for individual equations.

than 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 foreign capital share in 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 the Polish manufacturing, resulting in lower market concentration and progress in privatization 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.

The significance of individual characteristics was examined by comparing the models presented in Table 4 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 4, indicating that the impact of industry specific characteristics on the TFP growth in Polish manufacturing should not be neglected.

Table 5. Regression results – total manufacturing

Regressors	**Coefficients (*t-values*)**
$\ln\left(\frac{TFP_{it-1}}{TFP^F_{it-1}}\right)$	-0.22 (*-4.2*)
Constant	√
R^2	0.68
DW	2.62
No. of observations	11
Method of estimation	OLS

Due to small sample size and problems with data quality and availability, the analysis at a more aggregate 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 gap term among the regressors (other variables were omitted to spare degrees of freedom) is presented in Table 5.

The results are very similar to those obtained for panel data estimation (see corresponding regressions 1 and 2 in Table 4), 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.

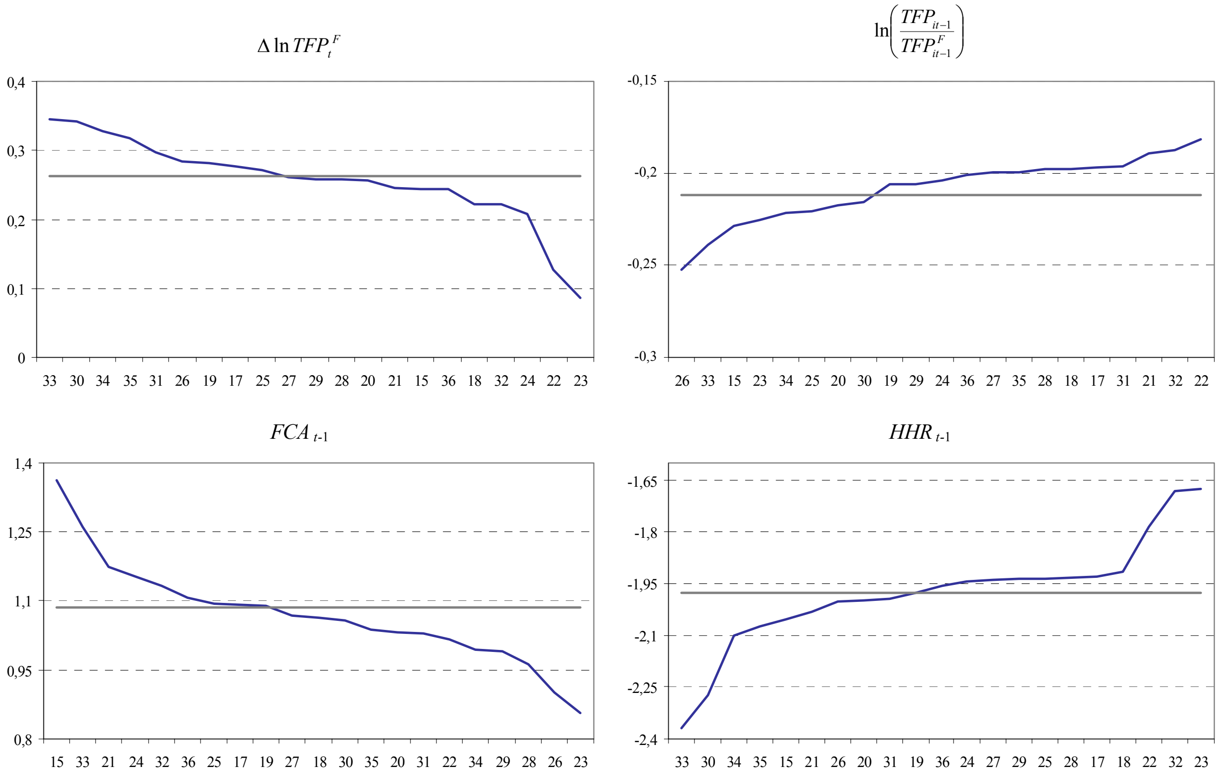
4.4. Impact of cross-section diversity on estimated coefficients

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.

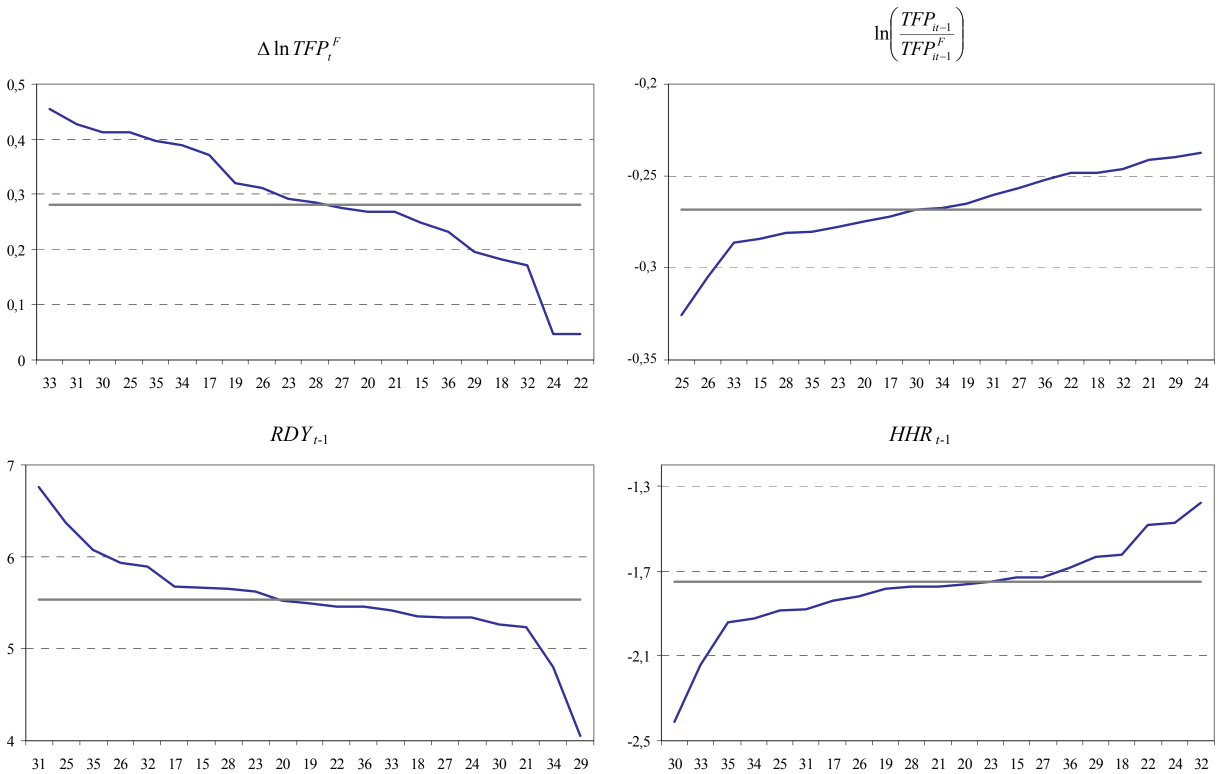
Due to relatively short time dimension of the panel, running 21 separate regressions to extract these differences would not yield plausible results. However, the impact of a particular industry on the value of estimated coefficients may be assessed by excluding it from the regression. If a coefficient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

We apply the procedure described above, i.e. for every preferred specification (regressions 7, 8 and 10 from Table 4) 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.

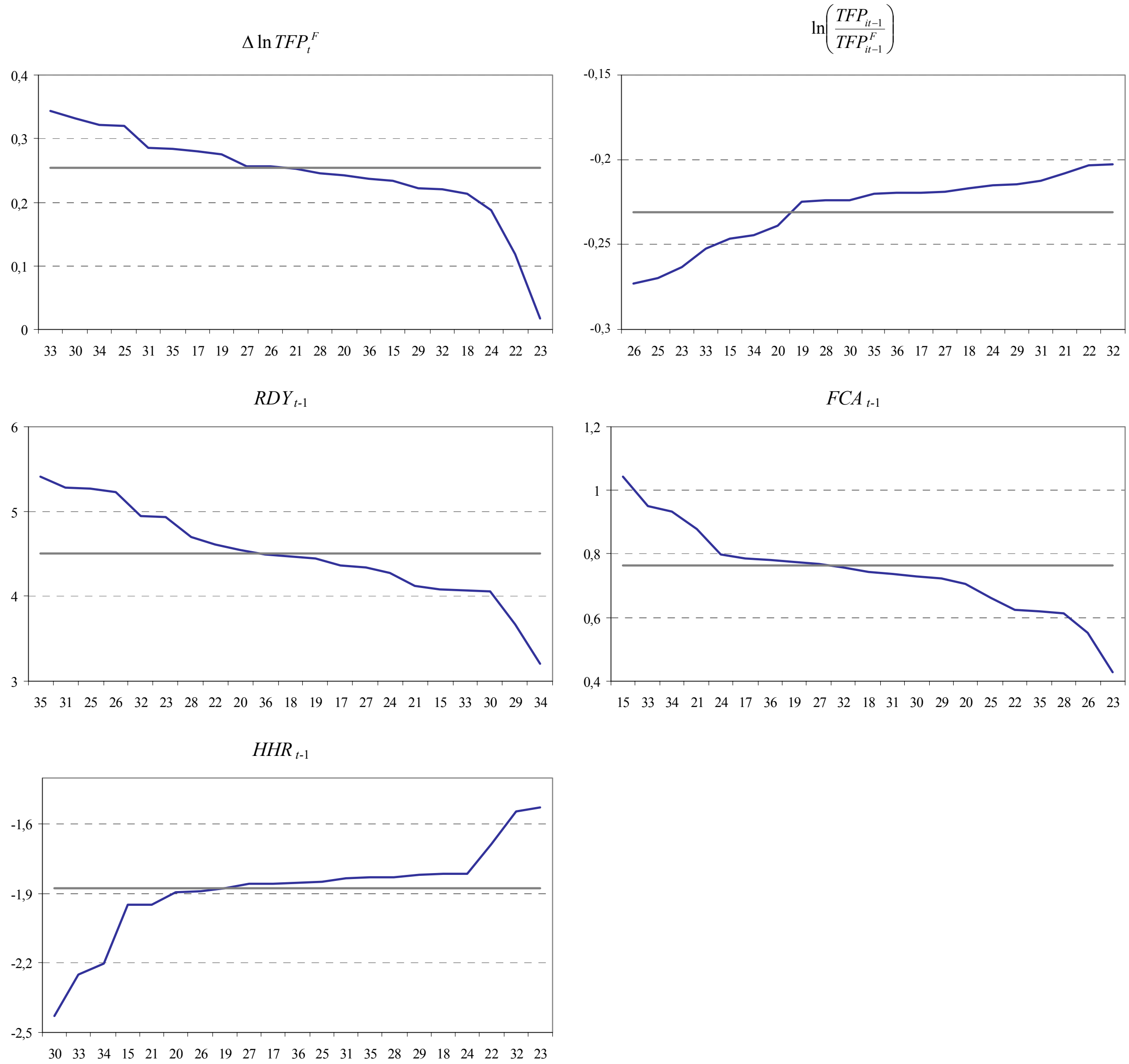
Graph 2. Coefficients stability – regression 7



Graph 3. Coefficients stability – regression 8



Graph 4. Coefficients stability – regression 10



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

Relatively fast technology transfer seems to be characteristic to a few high or medium tech industries (chemicals, electrical machinery, radio, television and communication equipment, electrical machinery and apparatus, but in the latter case only by the technology gap) or industries with productivity highly dependent on computer data processing capacity (publishing, printing and reproduction). Similar 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, chemicals, machinery and equipment n.e.c.) and there are several exceptions to the proposed rule. Finally, growing competition and structural reforms were beneficial to low tech industries (coke and refined petroleum products, publishing, printing and reproduction, wearing apparel and furriery, mineral products, metal products) rather than to several high-tech sections (medical, precision and optical instruments, office machinery and computers, motor vehicles).

4.5. Translog production function

Since a standard Cobb-Douglas model is often called into question, a more flexible functional form is also applied as a robustness check. For this purpose we use the translog production function described in Greene (2000). TFP growth and TFP level relative to the frontier country is calculated using the approach developed in Caves et. al. (1982).[3] Thus TFP growth is given by

$$\Delta \ln TFP_t = \Delta \ln Y_t - \frac{e_t^L + e_{t-1}^L}{2} \Delta \ln L_t - \left(1 - \frac{e_t^L + e_{t-1}^L}{2}\right) \Delta \ln K_t \,, \tag{14}$$

and the level of TFP relative to the frontier country can be assessed as

$$\ln\left(\frac{TFP}{TFP^F}\right) = \ln\left(\frac{Y}{Y^F}\right) - \frac{\left(\sqrt{e^L} + \sqrt{e^{LF}}\right)^2}{4} \ln\left(\frac{L}{L^F}\right) - \left(1 - \frac{\left(\sqrt{e^L} + \sqrt{e^{LF}}\right)^2}{4}\right) \ln\left(\frac{K}{K^F}\right). \tag{15}$$

For econometrical analysis smoothed elasticities were applied using procedure from section 4. The results are reported in Table 6.

The major problem with applying translog production function for Polish data is that it generates higher TFP levels in Poland than in Germany for four manufacturing industries (symbols 19, 22, 23 and 30 from Table 2), which particularly in the latter case (production of office machinery and computers) seems to be surprising. Therefore additional caution should be paid to the reliability of the estimation results. Since the theoretical framework described in section 3 could not be applied for these four industries, they had to be omitted in the following estimation procedure. Hence, one should also bear in mind that the results from Table 4 and Table 6 are not completely comparable.

[3] For recent international TFP studies based on the translog function see Griffith et. al. (2001) and Scarpetta, Tressel (2002).

Table 6. Regression results – panel data estimation (translog production function)

Regressors		Coefficients (*t-values*)									
		1	2	3	4	5	6	7	8	9	10
Techno-logy transfer	$\ln\left(\frac{TFP_{it-1}}{TFP^F_{it-1}}\right)$	-0.32 (*-6.4*)	-0.32 (*-7.0*)	-0.36 (*-6.7*)	-0.36 (*-5.6*)	-0.39 (*-7.6*)	-0.54 (*-3.7*)	-0.61 (*-6.5*)	-0.62 (*-5.9*)	-0.48 (*-5.0*)	-0.57 (*-6.3*)
	$\Delta \ln TFP^F_t$				0.36 (*2.3*)		0.43 (*3.6*)	0.22 (*1.4*)	0.18 (*1.0*)	0.20 (*1.1*)	0.16 (*1.0*)
Innovation	RDY_{t-1}					5.22 (*5.5*)			4.83 (*3.6*)		3.45 (*2.5*)
	INY_{t-1}			0.43 (*2.0*)							
	WCO_{t-1}				0.58 (*1.2*)						
	FCA_{t-1}						2.37 (*7.1*)	1.60 (*4.2*)			1.24 (*2.3*)
Reforms	PSP_{t-1}							0.11 (*1.6*)	0.14 (*2.2*)	0.21 (*3.1*)	
	HHR_{t-1}										
Fixed effects (F-values)		√ (*2.3*)	√	√ (*2.5*)	√ (*3.8*)	√ (*7.2*)	√ (*4.3*)	√ (*8.3*)	√ (*6.0*)	√ (*2.8*)	√ (*5.1*)
R^2		0.43	-	0.45	0.48	0.67	0.76	0.81	0.76	0.65	0.76
DW		2.13	-	2.19	1.95	2.38	2.18	2.46	2.41	2.39	2.43
No. of observations		119	102	119	119	102	102	102	102	102	102
Method of estimation		WLS	IV	WLS	WLS	WLS	WLS	WLS	WLS	WLS	WLS

Regressions from Table 6 have generally worse statistical properties and yield elasticities different from those in Table 4. In particular they imply faster convergence, which is not surprising taking into account that TFP growth in the omitted industries (except for office machinery and computers) was relatively small and in the case of coke and refined petroleum product even negative.

In spite of the discrepancies in the estimates it can still be argued that each block (technology transfer, innovation, reforms and individual characteristics) played a statistically significant role in TFP growth in Poland over the analysed period. The main difference in the choice of variables concerns the block reforms, which is better represented by the progress of privatisation rather than by decreasing market concentration.

4.6. 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 process. 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.

Another problem is measurement of the labour input, in this article approximated 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 decreasing HH-index can be explained as a result of breaking-down ineffective state-owned enterprises and 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 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.

5. 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 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 article 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 better developed economies via foreign direct investment and knowledge spillovers. Market reforms aimed at privatization, breaking-down state-owned giants and facilitating springing-up of small private companies contributed significantly to improvement of efficiency of factor use. Finally, TFP growth was also driven by domestic investment in innovations and human capital, 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 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 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 high-skilled labour force and strong scientific centres.

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