# The role of innovation in the Polish economy's efficiency growth: a sectoral view

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# Structure of the presentation

- Total factor productivity (TFP) as a measure of efficiency. Estimates of growth rates of TFP for the Polish economy's industries
- Impact of innovations on the efficiency of the economy: methodological aspects
- Diffusion of innovations and its measure at the sectoral level
- Impact of innovations on the efficiency of the economy: empirical results
- Conclusions

# Total factor productivity

$$tfp\_gr_t = Y\_gr_t - \sum_{i=1}^{n} w_{it}(X_i\_gr_t)$$

$tfp\_gr_t$ - rate of growth of TFP in period *t;*

$Y\_gr_t$ - rate of growth of output in period *t*;

$X_i\_gr_t$ - rate of growth of the i-th factor of production in period *t*;

$w_{it}$ - weight of the i-th factor in output.

# Total factor productivity

- The weights ( $w_{it}$ ) are either the shares of respective factors of production in output or the elasticities of output with respect to the i-th production factor.
- Assuming weights to be the shares of production factors in output, index method (usually the Törnquist index) can be used to assess rates of growth of TFP (Griliches, Jorgenson, 1967; Gullickson, 1995).
- The second approach requires the use of production function (usually of the neoclassical, Cobb-Douglas form, with constant returns to scale, Coe, Helpman, 1995, Welfe, 2001).
- In this paper the estimation of TFP was based on index methods (the Törnquist index). Gross output was assumed as a measure of production of each industry, thus including intermediate inputs of raw materials into the list of production factors.

**Table 1a. TFP growth rates in industries**

| | 1993-2005 | 1993-96 | 1997-99 | 2000-02 | 2003-05 |
|---|---|---|---|---|---|
| | % | | | | |
| **Industry** | **2.0** | **3.0** | **2.1** | **1.2** | **1.3** |
| Mining and quarrying | 1.5 | 3.1 | 1.7 | -0.3 | -0.1 |
| **Manufacturing** | **2.1** | **3.1** | **2.5** | **1.2** | **1.3** |
| manufacture of food products | 1.3 | 1.9 | 2.0 | 0.6 | 1.2 |
| manufacture of tobacco products | -1.2 | -0.8 | -4.4 | 1.3 | 1.4 |
| manufacture of textiles | 2.2 | 3.8 | 3.6 | 1.6 | 1.1 |
| manufacture of wearing and fur products | 1.7 | 4.8 | 1.2 | -1.4 | -1.5 |
| manufacture of leather and leather products | 0.3 | 4.9 | 0.3 | -1.3 | -2.6 |
| manufacture of wood and wood products | 0.6 | 0.1 | 0.0 | 0.3 | 0.7 |
| manufacture of paper and paper products | 1.8 | 0.8 | 4.7 | 0.9 | 0.8 |
| publishing and printing | 0.8 | 5.9 | 0.9 | -3.1 | -2.5 |
| manufacture of coke and refined petroleum products | -0.1 | 3.2 | -3.7 | -3.0 | -3.8 |
| manufacture of chemicals and chemical products | 1.5 | 1.3 | 2.0 | 0.7 | 1.3 |
| manufacture of rubber and plastic products | 2.9 | 3.0 | 5.4 | 1.0 | 2.0 |
| manufacture of other non-metallic and other mineral products | 4.5 | 3.7 | 3.8 | 8.5 | 2.8 |
| manufacture of basic metals | 0.9 | 1.8 | 1.2 | 1.3 | 0.5 |
| manufacture of fabricated metals | 3.6 | 3.6 | 3.3 | 3.9 | 3.5 |
| manufacture of machinery and equipment | 4.2 | 5.8 | 3.2 | 2.4 | 4.3 |
| manufacture of office machinery and computers | 10.1 | 17.3 | 15.0 | 2.7 | 9.4 |
| manufacture of electrical equipment | 2.9 | 3.2 | 3.9 | 3.2 | 3.9 |
| manufacture of radio, television and communication equipment | 5.1 | 12.7 | 3.6 | -0.6 | 1.8 |
| manufacture of medical, precision and optical instruments, watches and clocks | 3.5 | 8.7 | 7.8 | -2.6 | 2.3 |
| manufacture of motor vehicles | 2.4 | 2.4 | 0.7 | 2.7 | 2.8 |
| manufacture of other transport equipment | 0.6 | -0.7 | 6.6 | -2.8 | -0.6 |
| manufacture of furniture | 1.7 | 3.3 | 1.1 | 1.5 | 2.2 |
| recycling | -0.1 | -2.1 | 5.0 | -1.4 | 4.4 |
| Electricity, gas distribution, water supply | 0.6 | 0.6 | -0.8 | 0.7 | 1.2 |

**Table 1b. TFP growth rates in the Polish economy at the level of NACE sections**

| | 1993-2005 | 1993-96 | 1997-99 | 2000-02 | 2003-05 |
|---|---|---|---|---|---|
| | % | | | | |
| **TOTAL** | **1.4** | **1.5** | **1.3** | **1.8** | **2.2** |
| Agriculture, hunting and forestry | 1.4 | 0.1 | 0.9 | 0.5 | 4.4 |
| Fishing | 0.9 | -3.6 | 2.7 | 6.2 | 2.3 |
| Industry | 2.0 | 3.0 | 2.1 | 1.2 | 1.3 |
| Mining and quarrying | 1.5 | 3.1 | 1.7 | -0.3 | -0.1 |
| Manufacturing | 2.1 | 3.1 | 2.5 | 1.2 | 1.3 |
| Electricity, gas distribution, water supply | 0.6 | 0.6 | -0.8 | 0.7 | 1.2 |
| Construction | 0.0 | 1.9 | 0.8 | -1.7 | 0.1 |
| Trade and repair | -1.6 | -1.5 | -3.1 | -0.6 | -0.1 |
| Hotels and restaurants | 0.5 | 1.2 | 1.9 | -1.6 | 0.0 |
| Transport, storage and communication | 1.7 | 0.5 | 2.6 | 1.9 | 1.3 |
| Financial intermediation | 7.3 | 14.5 | 4.5 | 2.0 | 3.0 |
| Operation of real estate and services delivered to firms | -0.2 | 0.4 | -2.0 | 0.3 | 0.5 |
| Public administration and defence | -2.4 | -1.4 | 1.0 | -8.4 | 1.6 |
| Education | 0.9 | 0.6 | 2.4 | 1.0 | 1.5 |
| Health care and social security | 0.9 | 1.1 | -2.6 | 3.6 | 1.8 |
| Other services, public utilities, social and individual services | -2.9 | -5.3 | -3.8 | -1.0 | 0.1 |

Source: Own calculations based on Central Statistical Office (CSO) data on gross output, intermediate use, fixed assets and employment, included in CSO Statistical Yearbooks 1995-2006 and Statistical Yearbooks of Industry 1996-2006.

# Empirical results: TFP growth in the Polish economy – some conclusions

- Average annual rates of TFP growth for the whole economy in the years 1993–2005 were around the level of 1.4%, with the highest being 2.2% in the last period (2003–2005).
- The rate of growth of TFP in the industry sector (including mining and quarrying, manufacturing and energy supply) in the whole sample time-span was at the level of approximately 2% annually, the highest rates being observed in the nineties.
- This is mainly the result of TFP growth in manufacturing, whose share in industry exceeds 80%.
- Among the manufacturing industries, the highest TFP growth rates were found for high- and mid- technology industries (manufacture of office machinery and computers, manufacture of radio, television and communication equipment, manufacture of machinery and equipment, manufacture of 'other non-metallic' products, etc.).
- Rates of TFP growth in other manufacturing industries never reached 4%, the lowest, or even negative, appearing in material- and labour-intensive branches.
- Rates of TFP growth in the service sectors were considerably lower than in the industrial branches. The highest rate was reported for financial intermediation and for transport, storage and communication services.

# Impact of innovation on the efficiency of the economy: methodological aspects

$$Y_t = TFP_t \cdot F\left(RDC_t, K_t, L_t\right),$$

where:

$Y_t$ - volume of output in period *t*;

$TFP_t$ - total factor productivity in period *t*;

$RDC_t$ - volume of cumulative R&D outlays in period *t*;

$K_t$ - capital stock;

$L_t$ - labour force.

Differentiating the above relationship with respect to time and dividing both sides by $Y_t$ leads to determining the rate of growth of TFP as function of cumulative R&D expenditures growth rate:

$$TFP\_gr_t = \lambda + \gamma \cdot RDC\_gr_t$$

or alternativly as function of R&D outlays intensity:

$$TFP\_gr_t = \lambda + \mu \frac{RD_t}{Y_t}$$

# Diffusion of innovations and its measure at the sectoral level

$$RDspill_j = \sum_{i \neq j} v_{ij} RD_i$$

where:

$BRspill_j$ - potential R&D outlays in industry *j*, stemming from diffusion of innovation from source *i* (industry *i*);

$BR_i$ - R&D expenditures in the sources (industries), from which innovation transfer ensues;

$v_{ij}$ - proportionality coefficients (weights).

In this paper, benefits from the diffusion process for a given industry are assumed proportional to R&D outlays intensity (the ratio of R&D outlays to gross output) of those branches from which the transfer of innovation ensues, i.e.:

$$\overline{RDspill_j} = \sum_{i \neq j} v_{ij} \frac{RD_i}{Y_i}$$

where $Y_i$ - gross output of industry *i*.

# Inter-sectoral and inter-country innovation carriers

- Inter-sectoral innovation carriers :

  1.investment good flows between suppliers and purchasers (Terleckyj, 1974; Sveikauskas, 1981; Sterlacchini, 1989);

  2. raw materials flows (Brown, Conrad, 1967; Wolff, Nadiri, 1993; Dietzenbacher, 2000);

- Inter-country innovation carriers:

  3. imports, especially the investment imports (Coe, Helpman, 1995);

  4. foreign direct investment (Lichtenberg, van Pottelsberghe de la Potterie, 1996);

  5. foreign patent flows (Jaffe, Trajtenberg, 1999).

# Impact of innovations on the efficiency of the economy : the model

$$TFP\_gr_{jt} = \lambda + \mu_1 \frac{RD_{jt}}{Y_{jt}} + \mu_2 \overline{RDspill}_{jt}^{(domestic)} + \mu_3 \overline{RDspill}_{jt}^{(foreign)} + \varepsilon_{jt}$$

where:

$TFP\_gr_{jt}$ - rate of growth of TFP in industry $j$ in period $t$;

$\frac{RD_{jt}}{Y_j}$ - intensity of R&D expenditures made by industry $j$ in period $t$;

$\overline{RDspill}_{jt}^{(domestic)}$ - benefits for industry $j$ in period $t$ from intersectoral diffusion of innovations;

$\overline{RDspill}_{jt}^{(foreign)}$ - benefits for industry $j$ in period $t$ from diffusion of innovations coming from abroad;

$\varepsilon_{jt}$ - error term.

# Impact of innovations on the efficiency of the economy : empirical results

| Variables | Estimates (t-value in brackets) | | | |
|---|---|---|---|---|
| | I | II | III | IV |
| Constant | -0.07<br>(-1.32) | 0.02<br>(0.64) | 0.05<br>(0.92) | 0.03<br>(0.91) |
| $\frac{RDexpend_{jt}}{Y_j}$ | **0.14**<br>**(1.92)*** | **0.14**<br>**(1.92)*** | **0.17**<br>**(1.81)*** | **0.17**<br>**(2.45)**** |
| $\overline{RDspill}_{jt}^{(domestic)}$ | | 0.39<br>(1.33) | 0.40<br>(1.40) | |
| $\overline{RDspill}_{jt}^{(foreign)}$ | **0.18**<br>**(3.20)***** | **0.17**<br>**(3.06)***** | **0.29**<br>**(3.71)***** | **0.30**<br>**(3.88)***** |
| Dummy for industries | yes | yes | yes | yes |
| Dummy for periods | yes | yes | yes | yes |
| $R^2$ adjusted | 0.47 | 0.48 | 0.51 | 0.49 |
| No. of observations | 128 | | | |

Source: own calculations; * - statistically significant at the level of 0.1; ** - statistically significant at the level of 0.05; *** - statistically significant at the level of 0.01.

Channels of innovations diffusion in different variants of the model: (I) – diffusion of innovations from abroad *via* imports and FDI, (II) – domestic diffusions of innovations through raw material flows, diffusion of innovations from abroad *via* imports and FDI, (III) – domestic diffusion of innovations through raw material flows, diffusion of innovations from abroad *via* investment imports and FDI, (IV) - diffusion of innovations from abroad *via* imports and FDI.

# Conclusions

- In all tested variants the parameters of industry R&D intensity have proven to be positive and statistically significant. The 1 pp. growth of domestic R&D expenditure intensity in a given industry resulted in 0.14–0.17 pp. increase of TFP growth rate, on average.

- In all variants of the model the effects of innovation diffusion from abroad were positive and statistically significant, both for diffusion *via* imports (total as well as investment imports) and *via* FDI. In the light of these results it can be concluded that innovation diffusion from abroad invokes TFP growth rate increase by, on average, 0.17–0.30 pp., the impact obviously being stronger with investment imports (machinery and equipment) as the diffusion channel.

- The effects of domestic innovations spreading through inter-industry raw material flows turned out to be positive, though not significant.