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New labor productivity equations for IMPEC

The concept and first results

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1 Introduction

The IMPEC model is undergoing a deep restructuring now. The previous version of the model was based on the 1990 I-O matrix built on a 43 branch system used to the year 1992. The new model version uses the 1995 matrix with the 57 branch NACE system. The conducted research aims to construct equations explaining the productivity of labor in Polish economy according to the new setup of branches.

With a given demand for production, the productivity of labor is used to calculate the demand for labor. In the theory of economy the productivity of labor is examined in terms of the production function whose parameters are to describe elasticities of production with respect to particular factors, with a clear distinction of the impact of non-material factors of production growth called total factor productivity (TFP).

The discussion below, even though it refers to research on TFP, concentrates exclusively on questions such as the productivity of labor, identification of the basic factors that explain it, which is expected to result in the formulation of the model equations.

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2 Data

In IMPEC, labor productivity has been defined as value added in constant prices per working hour. When the information about working hours is missing, we used employment in full time equivalent. This definition differs from the INFORUM approach, where productivity is measured in terms of output (Meade 1997, Iommi 2000). In our new calculations we have considered both value added and output.

Data, from which the sectoral time series were calculated, were taken from:

- Statistical Yearbooks of the Polish Central Statistical Office (CSO),
- The Input-Output Tables for the 1995,
- publications of Polish Agency for Foreign Investment (PAFI), available at www.paiz.gov.pl.

Data on output, value added, employment, capital stock and foreign direct investment were collected in 27 branches according to NACE. As NACE was introduced in 1992, our series cover only the period 1992-99. The base of our databank was the input output table for 1995. Data for other years were calculated using indices and deflators taken from the Statistical Yearbooks, and they are expressed in 1995 prices.

The only exception was the value of the FDI, taken from PAFI, available only in current prices (USD). This data cover only investments of at least 1 million USD. PAFI estimates, that investments under 1 million USD account for about 10% of the total FDI in Poland. Value of the FDI for the years 1997-99 were taken directly from PAFI. For previous years we had to calculate the data accumulating individual investments, also published by PAFI.

3 Analyses of the data

Despite of differences in growth rates (see Table 1), changes of branch structure of output are generally modest. Manufacturing and services dominate the output structure, and the domination deepens during the period 1992-99.

The output grew in all branches of manufacturing and services, especially in transport equipment and rubber and plastic products industries (average growth rate exceeded 17,5%), pulp and paper industry together with printing and publishing (about 16%), hotels and restaurants, furniture and other industries (14,5%). The highest growth rates were observed between 1992 and 97. In last two years the growth rates were reduced and, in some branches, became negative.

Tab. 1 Average annual percentage rates of growth of output, value added, employment and fixed capital, 1992-1999

L.P.	Number of sector in I-O table	Sectors	Output Q	Value Added V	Employed Persons L	Capital K
1	1-2	Agriculture, hunting and forestry	1,13	1,12	1,08	0,04
2	3	Fishing	-9,07	-12,38	-6,01	-1,10
3	4-7	Mining and quarrying	-3,25	-2,08	-7,83	-6,89
4	8-9	Manufacture of food products, beverages and tobacco products	7,82	9,95	1,39	6,52
5	10-12	Manufacture of textiles, wearing apparel and furriery	4,31	4,08	-3,75	-2,59
6	13	Manufacture of wood and wooden products	10,42	6,04	1,63	9,84
7	14-15	Manufacture of pulp and paper with publishing and printing	15,98	17,19	3,27	11,45
8	16	Manufacture of coke, refined petroleum products and derivatives	2,34	-2,61	2,13	13,65
9	17	Manufacture of chemical and chemical products	6,55	6,09	-2,39	4,72
10	18	Manufacture of rubber and plastic products	17,58	18,90	5,27	8,92
11	19	Manufacture of other non-metallic mineral products	10,48	10,52	-0,17	4,65
12	20-21	Manufacture of basic metals and metals products	8,14	8,48	-0,81	1,10
13	22-26	Manufacture of machinery and equipment, electrical machinery, precision and optical instruments	12,19	13,26	-2,87	-1,17
14	27-28	Manufacture of transport equipment	17,53	7,26	-2,60	4,18
15	29	Manufacture of furniture and other manufacturing	14,48	12,22	2,91	7,71
16	30	Recycling	4,78	5,85	5,47	3,95
17	31-32	Electricity, gas and water supply	-0,19	3,18	-0,42	4,26
18	33	Construction	6,71	5,46	-1,46	5,22
19	34-36	Trade and repair	8,17	4,53	1,62	12,98
20	37	Hotels and restaurants	14,53	9,57	4,00	11,29
21	38-42	Transport, storage and communication	5,36	2,25	-1,21	1,81
22	43-45	Financial intermediation	12,62	26,03	10,91	33,17
23	46-50	Real estate and business activities	5,85	2,45	5,23	2,90
24	51	Public administration	3,52	5,03	5,99	6,82
25	52	Education	2,74	3,12	1,62	5,62
26	53	Health and social work	0,58	-0,54	-0,61	7,20
27	54-57	Other community, social and personal service activities	1,11	-1,34	-0,33	10,46

Source: Authors' calculation

For the whole period, we can see two branches with negative growth rates: fishing (-9,1%), and mining and quarrying. The output practically hasn't change in electricity, gas and water supply as well as health and social work.

There is not much difference between the structure of output and structure of value added. Growth rates are also quite similar. The fastest growth we can see in financial intermediation (over 26%), on the contrary, for transport equipment industry the growth rate of value added is modest comparing to output. For coke and petroleum industry we find a negative number.

Looking at growth rates of employment, we can see less variance and more negative numbers than in two columns on the left. Generally, the structure of employment changed in favor of services.

Assuming that the productivity of labor is measured by output per worker, then in actually all analyzed branches and sectors of economy (excluding fishery and fish farming, public administration and national defense) we can observe an increase in the productivity of labor (detailed data can be found in Table 2), the highest in the transport equipment industry (annual average exceeding 20%) and in the aggregated electroengineering industry (over 15% a year). Over 10% productivity growth can be found also in the pulp and paper industry (together with printing activities), in rubber and plastic products industry, the mineral industry, the furniture industry and in other manufacturing activities. In the service sector an increase exceeding 10% was only found for hotels and restaurants. The decline in the productivity of labor in fishery is due to the simultaneous decrease in output and the size of employment, but the rate of output decline much exceeds that of the number of employees. In the public administration sector the employment rate of growth almost doubled the rate of production growth.

When the productivity of labor is measured by value added per worker, rates of growth slightly vary from their output equivalents. With this methodology of arriving at productivity negative rates of growth were obtained also for the coke and petroleum products, and in the service sectors in real estate and business activities and other community, social and personal services.

Productivity of fixed capital measured by the value of output per unit of capital (expressed by the gross value of capital assets in fixed prices) evolved differently. Positive rates of growth can be found for all branches of the industry, agriculture and selected service sectors. The decline in fixed capital productivity characterized fishing (over 8% a year), financial intermediation (over 15% a year), as well as trade and repairs, the public administration sector, education, healthcare and other community, social and personal services.

Tab. 2 Average annual percentage rate of growth of productivity of basic production factors and rate of growth of capital to labor ratio, 1992-99

L.P.	Number of sector in I-O table	Sectors	Q/L	V/L	Q/K	K/L
1	1-2	Agriculture, hunting and forestry	0,05	0,04	1,09	-1,03
2	3	Fishing	-3,25	-6,78	-8,6	5,22
3	4-7	Mining and quarrying	4,96	6,24	3,91	1,02
4	8-9	Manufacture of food products, beverages and tobacco products	6,34	8,44	1,22	5,06
5	10-12	Manufacture of textiles, wearing apparel and furriery	8,37	8,13	7,08	1,20
6	13	Manufacture of wood and wooden products	8,64	4,33	0,53	8,07
7	14-15	Manufacture of pulp and paper with publishing and printing	12,31	13,48	4,07	7,92
8	16	Manufacture of coke, refined petroleum products and derivatives	0,21	-4,64	-9,94	11,28
9	17	Manufacture of chemical and chemical products	9,15	8,68	1,75	7,28
10	18	Manufacture of rubber and plastic products	11,69	12,95	7,95	3,47
11	19	Manufacture of other non-metallic mineral products	11,27	11,31	5,56	5,40
12	20-21	Manufacture of basic metals and metals products	9,03	9,37	6,96	1,93
13	22-26	Manufacture of machinery and equipment, electrical machinery, precision and optical instruments	15,51	16,61	13,52	1,75
14	27-28	Manufacture of transport equipment	20,66	10,12	12,81	6,96
15	29	Manufacture of furniture and other manufacturing	11,24	9,04	6,29	4,66
16	30	Recycling	-0,65	0,37	0,80	-1,44
17	31-32	Electricity, gas and water supply	0,23	3,62	-4,27	4,70
18	33	Construction	8,28	7,03	1,41	6,78
19	34-36	Trade and repair	6,44	2,87	-4,26	11,18
20	37	Hotels and restaurants	10,13	5,36	2,91	7,01
21	38-42	Transport, storage and communication	6,65	3,50	3,49	3,06
22	43-45	Financial intermediation	1,54	13,64	-15,43	20,07
23	46-50	Real estate and business activities	0,59	-2,65	2,87	-2,22
24	51	Public administration	-2,34	-0,91	-3,09	0,77
25	52	Education	1,10	1,48	-2,73	3,94
26	53	Health and social work	1,20	0,07	-6,17	7,86
27	54-57	Other community, social and personal service activities	1,44	-1,02	-8,46	10,82

Source: Authors' calculations

Sources of this huge variation in the productivity of the basic factors of production should be sought for instance in the different levels of entrepreneurship in branches, their ability to absorb new technologies and the feasibility of fast reconstruction of particular branches. Especially in manufacturing the main reasons for such a considerable increase in the productivity of labor were different rates of reducing the hidden unemployment in particular branches (see Zienkowski 2001). Another important fact can be the considerable influx of foreign direct investments that apart from their production asset multiplying function are the vehicles of broadly meant technological progress.

Looking at tab. 1 and 2 we can find some exceptional sectors. One of them is agriculture, where, surprisingly, we noticed growth in employment, which leads to decrease of K/L ratio. This is quite opposite to the aims of long term restructurization plans. On the other hand, restructurization of mining and quarrying seems successful, as the reduction in employment allowed for growth in labor productivity. The opposite is for fishing, where reduction in output and value added is stronger than in employment.

4 Major factors explaining the productivity of labor

In the theory of economy the productivity of labor – that is value added or output per unit of labor input – is viewed in terms of the production function. Value added (output) is assumed to depend on the amount of two primary input factors – labor and capital, with the factors being treated as substitutive and complementary at the same time.

The substitutability of these factors causes that their inputs are somewhat predetermined by their relative prices. A decline in labor price with respect to capital may therefore result in a growth of employment at the cost of investment outlays. In this case we can observe a decline in the productivity of labor with a steady level of production. Therefore a change in relations between the amounts of the involved factors of production (substitution) makes productivity vary. On the other hand the relation of capital to labor inputs is decided by their relative cost (price related to productivity).

In addition, the productivity of labor is often defined as output per worker. Then the third factor of productivity is taken into consideration – material inputs. This approach is typically used in sectoral analyses, especially when the diffusion of the technological progress is examined (the difference between the two approaches was described by van Meijl 1997).

The major factor explaining the productivity of labor is the value of capital assets per worker known as capital to labor ratio. This results immediately from the transformation of the production function. In addition to the physical enlargement of fixed capital assets it is also improved, which stimulates additional productivity of labor. Finally, a third group of factors exists, such as organizational progress, training of personnel and, generally speaking, all other changes in the manufacturing conditions.

Value of the capital stock is calculated as:

$$K_t = (1-d)K_{t-1} + V_t \qquad (1)$$

where:

K_t – capital stock at the end of period t,

V_t - investment

d - physical depreciation rate, which is not equivalent to economic depreciation.

This formula ignores the changes in capital efficiency. Technological progress causes, that every year the new equipment allows higher labor productivity than the old one. Thus, in equations explaining output and labor productivity one can find variety of values of capital stock recalculated to reflect its efficiency. Most popular methods are distributed lags of investment, and qualifying the capital stock to different generations. For example, Solow (1962) uses the term „equivalent stock of capital". Review of methods used at INFORUM can (average installation date, vintage models) can be found in Meade (1997).

Similar methodology was applied by Iommi (2000), who measures the capital stock in efficiency units:

$$K_t^{'} = e_t V_t + (1-d)e_{t-1}V_{t-1} + ... + (1-d)^t e_0 V_0 \qquad (2)$$

where:

e_t - index of best-practice level of technology in year t.

Together with expansion of the growth theory the problem of including the impact of broadly meant technical progress on output growth started to emerge more and more often. This progress contributes to a production growth that is not related to increments in the basic factors of production such as labor and fixed capital. Initially, the technical progress was treated as exogenous and included in the production function as the time function. In the recent years it was attempted to make it endogenous as it was assumed that a higher efficiency of the production process is mainly dependent on the innovativeness of this process, the introduction of new technological solutions and outlays on R&D.

5 Total factor productivity

The answer to the question which part of the production growth does not result from the increase in the basic factors of production can be given by the TFP analysis. The total productivity growth is measured using the difference between the output rate of growth and the rate of growth of combined basic factors of production: labor and capital.

Writing the general form of production function with the formula:

$$X_t = A_t f(K_t, L_t), \qquad (3)$$

where:

X_t - output (or GDP or gross value added in constant prices),

K_t - capital stock (in constant prices),

L_t - employment,

A_t - total factor productivity,

we can define the TFP growth rate as:

$$\frac{\dot{A}_t}{A_t} = \frac{\dot{X}_t}{X_t} - \left(e_{Kt} \frac{\dot{K}_t}{K_t} + e_{Lt} \frac{\dot{L}_t}{L_t} \right) \quad , \qquad (4)$$

where the dot means differential by time, for example $\dot{X}_t = \frac{dX}{dt}$, and e_{Kt} , e_{Lt} stand for elasticities with respect to capital and labor inputs.

Most commonly used form of production function is the Cobb-Douglas function, which can be written as:

$$X_t = A_t K_t^{a} L_t^{1-a} \qquad (5)$$

Total factor productivity can be measured using economical calculus of growth or by estimating parameters of function (5).

The first method consists in calibrating of elasticity with respect to capital (a - usually from 0.3 to 0.4, and close to the ratio of operational surplus to value added), and then, estimating the growth rate of TFP changes:

$$\frac{A_t}{A_{t-1}} = \frac{X_t}{X_{t-1}} - \left(\frac{K_t}{K_{t-1}}\right)^a \left(\frac{L_t}{L_{t-1}}\right)^{1-a} \qquad (6)$$

The second way means direct estimation of production function assuming, that A_t is a function of time (usually exponential). Both methods assume that potential production is equal to real one.

In terms of input-output, Wolff (1997), quoting Leontief (1953), defines rate of TFP growth for sector j in period T as follows:

$$TFPGRT_{jt} = -\left(\sum_i \overline{p}_{iT} \Delta a_{ijT} + \overline{w}_T \Delta l_{jT} + \bar{i}_T \Delta k_{jT}\right) / \, p_{jt_0} \qquad (7)$$

where: *i,j* mean sectors, T observed period, lines over the letters mean the averages over the period T,

$\overline{p}$ - average price,

a - input-output coefficient,

$\overline{w}$ - average wage,

l - labor coefficient (employment per unit of output),

$\bar{i}$ - average rate of profit,

k - capital stock coefficient (capital per unit of output),

p_{t_0} - price at the beginning of the period (t_0).

The first significant attempts to estimate TFP for Poland were undertaken in the second half of the 1990s. Results of the TFP examination for Poland presented by Florczak and Welfe (2000) based on the production functions whose parameters were calibrated or estimated using the fixed capital productivity function. The research was conducted for economy as a whole and covered years 1971-90 (besides, the research took into account selected countries of western Europe, USA and Japan). Results obtained for Poland are dramatically different from results for the other countries. In the first half of the 1970s the average annual rate of growth reached 3.71% and was the highest in the examined group of countries. This may have been related to the huge investment outlays particularly in industry, and the period of moderate economic upswing. Between 1976 and the beginning of the 1990s we can observe a rapid decline in TFP (negative rates throughout the period). In the period in question TFP started to grow only in the decade of the 1990s (approx. 0.5% a year). In addition, the authors stress that TFP dynamics reflects changes in the actual total productivity of labor and capital, i.e. also these that result from demand and supply shocks (periods when the shocks occurred were characterized by negative TFP rates of growth), which is particularly justified in the case of Poland.

First estimates of TFP made for particular branches of industry (however according to the KGN system and aggregated to nine branches) were provided by Juszczak-Szumacher (1996). The estimates were derived from formula (4), following an estimation of production elasticity with respect to fixed capital and labor inputs. The research covered years 1971-89. The results obtained then did not significantly vary from those presented above. As before positive rates of TFP growth can only be found in the 1970s. In the next period productivity declined in all analyzed branches (the largest drop affected the fuel-power, the steel and chemical industries).

Recently a work by Zienkowski was published (2001), whose author attempts to estimate TFP for both economy as a whole and the market branches of economy (minus agriculture) and industry. TFP was assumed as the ratio between GDP dynamics (but also gross value added, particularly when economy is considered as a whole) and the sum of indexes of labor and capital dynamics weighted by their share in value added (the weights 0.6 for labor inputs and 0.4 for fixed capital, respectively), and the obtained results are close to those quoted above.

6 Making technical progress endogenous

There are two main sources of technical progress: domestic R&D expenditures, and transfer of technology from abroad.

Instead of R&D expenditures, number of patents is often used (see for example Fagerberg 1987). This allows for skipping the discussion about the effectiveness R&D expenditures.

Decomposition of sources of technical progress in macro scale was presented by Coe and Helpman (1995). They proposed the following equation:

$$\log F_i = a_i^0 + a_i^d \log S_i^d + a_i^f m_i \log S_i^f , \qquad (8)$$

where:

i is a country index,

F - total factor productivity,

S^d - domestic R&D capital stock,

m - fraction of imports in GDP,

S^f - foreign capital stock defined as the import-share-weighted average of the domestic R&D capital stocks of trade partners.

In sectoral analyses another important factor should be considered: technological spillovers. Thus, the stock of productive knowledge, PK_{tj}, is a function of the industry's own R&D, R_{tj}, and of technological spillovers, both from other domestic industries, S_{tj}, and from industries abroad, F_{tij}:

$$PK_{tj} = R_{tj} + s_{tj} \sum_i S_{tij} + f_{tj} \sum_i F_{tij} \ , \qquad (9)$$

where j is the industry using spillovers, i the industry generating them, and s_{ij} and f_{tj} are empirically determined parameters identifying the effective contribution of interindustry and international spillovers respectively (Hanel 2000). Investigations of technological spillovers base on input-output tables (Wolff 1997).

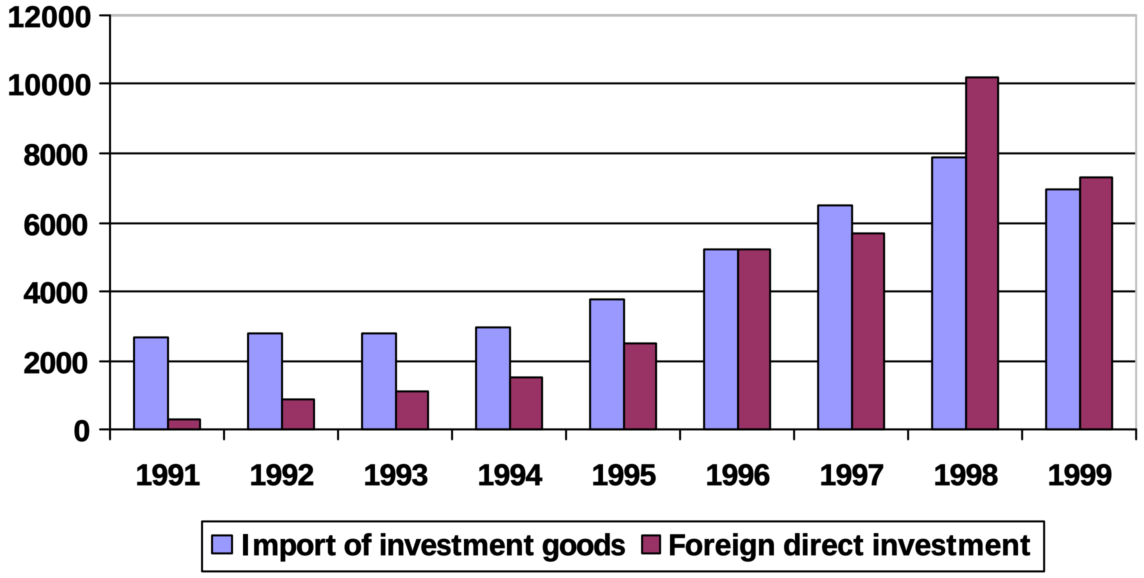
For Poland, Florczak et al. (2001) did research similar to Coe and Helpman's (1995, see equation 8). Additionally, they attempted to explain domestic R&D expenditures. They used GDP as the main explanatory variable, estimating the coefficient as about 0,65. As an alternative, they distinguished between two sources of financing the expenditures – state budget and other.

In case of Poland, the import of technical progress can be studied only in macro scale. Data on import of investment goods are given altogether, so we don't know how much is imported by each branch. However, sectoral data are available for the FDI probably the most efficient way of technology transfer.

Fig. 1 shows that foreign investors could be one of the main importers of investment goods.

The first foreign direct investment came to Poland in 1977, but the phenomenon started to be significant in nineties. According to PAFI, most of the investment is located in industry. In the period 1992 to 99 it was about 50-65% of total FDI, with slightly declining tendency of this share.

Fig. 1 Import of investment goods and FDI (in million USD)



Source: Imports: Yearbooks of Foreign Trade Statistics, Central Statistical Office, Warsaw, 1991-92 estimates,
FDI: Polish Agency for Foreign Investment www.paiz.gov.pl, 1991-1995 estimates

The investments are located in transport equipment industry, food processing, chemical and mineral industries. Services improve their position in the structure of FDI inflow. Most attractive sectors for the investors were financial intermediation and trade.

7 FDI and their impact on the productivity of labor

The role of foreign direct investments in the restructuring process of Polish economy is hard to overestimate. Generally, in the literature of the subject many authors agree that for a foreign company to be able to effectively compete with local producers it has to have considerable competitive advantages (see Bedi, Cie lik 1999). Such advantages result mainly in increased productivity of the basic factors of production, primarily through the application of more effective manufacturing management tools and more modern manufacturing technologies, that is factors that can be termed as the capital of knowledge (Markusen 1995).

A short review of research on FDI in Central European countries was presented by Brandmeier (2000). Attempts have already been taken to build causal models explaining the FDI value in these countries (Barell and Holland 2000).

Attempting to quantify the impact of foreign investments on Polish economy produces many problems whose major source is the unavailability of complete or up-to-date statistics and the comparatively short period when the foreign capital has operated in the Polish market. The work edited by Bak and Kulawczuk (1996) deserves a special attention, as it presents a comprehensive analysis of the FDI impacts on Polish economy. Results of many research activities headed by the two authors suggest a positive impact of foreign capital on a restructuring economy. Also Karpinski (1998) attempted to evaluate how FDI contributes to changes in the structure of Polish industry. His analysis is based not on the branch structure of industry but on a system employing the division of industry into four areas according to the final use of products.

The phenomenon of FDI was already used in the IMPEC model as an explanatory variable in the export and import equations (Przybylinski 2000).

Privatization is a particularly important factor in Poland in the 1990s, hence the attempts to explain the productivity of labor using the degree and pace of privatization. Estimates (Sztaudynger 2000) confirm the significance of this factor, it seems though that its usefulness for forecasting is much smaller, as the major wave of privatization is already behind us.

8 Equations of labor and fixed capital productivity in the previous versions of the IMPEC model

The first versions of the IMPEC model included equations of the productivity of labor based on the capital to labor ratio and trend functions.

An interesting modification of this solution was the version IMPEC-CIM, where various impact scenarios of the Computer Integrated Manufacturing expansion on the economic development of Poland were tested. The major modification introduced in the IMPEC-CIM model was distinguishing this part of fixed capital that corresponded with the CIM definition and revaluation (increasing the value) of this capital, so as to reflect a faster growth in the productivity of labor caused by CIM (Balcerak 1993).

In the last version of the model using the old 43 branch classification, the classic solution was taken as the specification of productivity of labor function, where category depends on changes in the capital to labor ratio. In selected branches of industry the FDI value was included as an additional explanatory variable. The productivity of labor function took one form for branches of industry and another for divisions, which was due to the range of statistical data used (Tomaszewicz 2001).

Information on industry that distinguished its 21 branches allowed to define productivity as gross value added generated by particular branches per working time, which is quite important as at the end of the 1990s the variability rates of working time and the size of employment were different. When defining the capital to labor ratio in branches of industry the total working time was consistently taken as the measure of labor inputs. An additional modification was introduction of the shift coefficient, as a reflection of the utilization degree of fixed assets. For the productivity functions in sections of economy productivity is defined as gross value added per worker, and when calculating the capital to labor ratio inputs are meant as the number of workers in a given division.

Estimation of the productivity of labor equations provided the following conclusions:

1) The value of fixed capital does not show its growing efficiency, as a result high estimates of elasticity of productivity with respect tot he capital to labor ratio were obtained.
2) The productivity growth in the last several years of the sample is connected in some branches of industry with the contribution of foreign capital.
3) In some branches, especially the fuels-power industry where demand dropped and employment was artificially retained, the relationship between the productivity of labor and the capital to labor ratio turned out to be negative. The explanation of the function occurred clearly weaker in the case of non-industrial sections, particularly in forestry and agriculture where production is characterized by a substantial irregularity.

The productivity of labor function was not specified for sections of the public sphere, based on the assumption that in this case it is not a category connected with the capital to labor ratio.

The calculated productivity of labor, combined with the rate of man-hours worked per worker, provided an estimation of the demand for labor which demand, after taking into account some inertia in economy, translates into the size of employment in particular branches.

Another concept that appeared at the last stage of work on the previous model version was revaluation of fixed capital taking into account the value of FDI. For the decade of the 1990s a hypothesis was posed that foreign direct investments contribute to a change in the structure of types of investment outlays, are directly mainly to modernize the machinery. The short investment cycle for machinery and equipment and increased share of this part of investment results in the observable faster enlargement of fixed capital than it might result from the constant pattern of the taken distribution weights of investment outlays' lags.

9 The concept of new equations for IMPEC

According to theory of TFP to our experiences, both mentioned above we decided to concentrate on three main factors explaining the labor productivity:

$$\frac{X_t}{L_t} = f\left(\frac{K_t}{L_t}, RDC_{t-k}, \frac{FDI_{t-s}}{L_{t-s}}\right) \tag{10}$$

where:

k,s – time lags,

RDC – domestic R&D capital stock,

FDI – FDI stock.

We started from the most popular form of production function (5), which, after dividing by L may be written as:

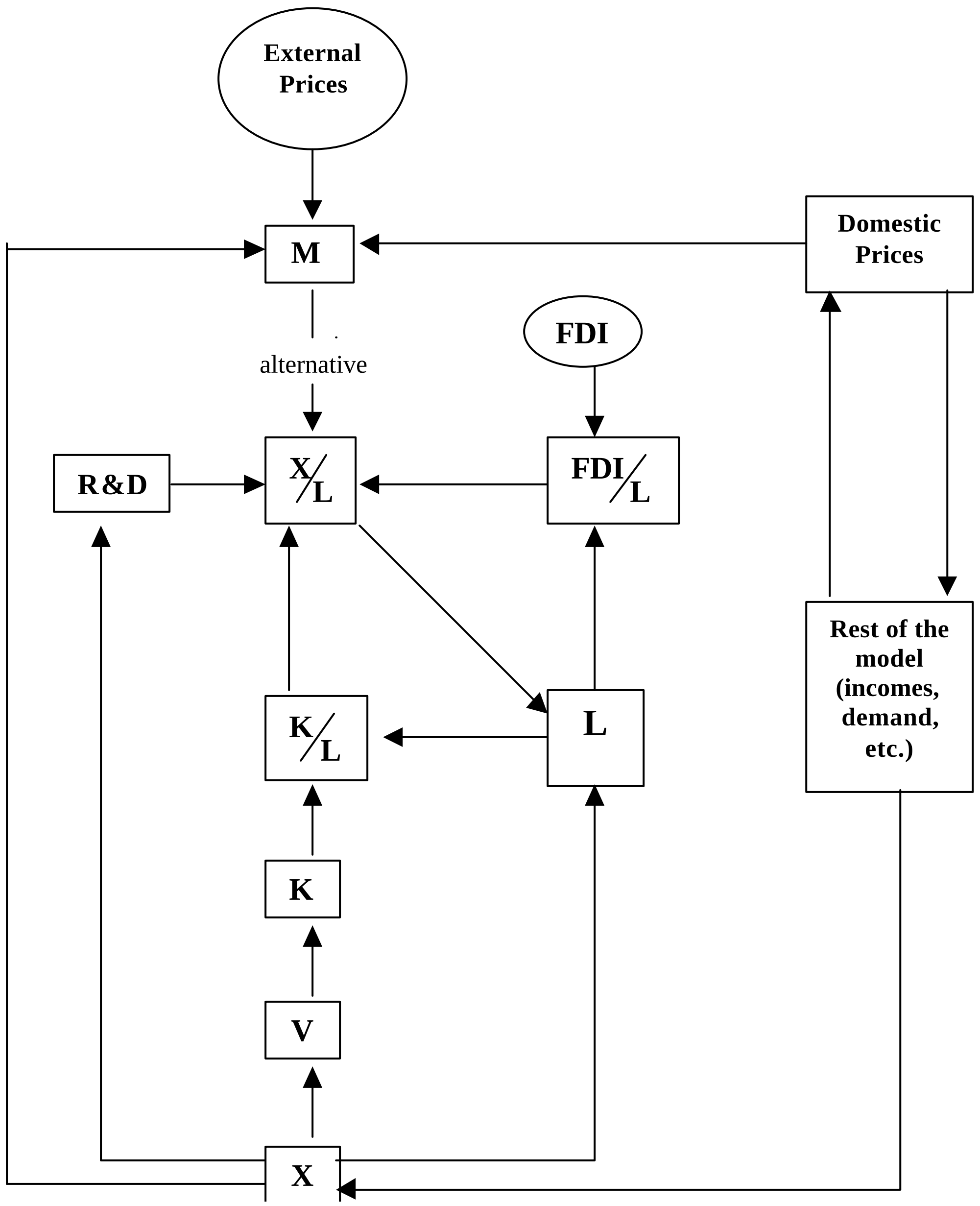
$$\frac{X_t}{L_t} = A_t\left(\frac{K_t}{L_t}\right)^a . \tag{11}$$

Then we replaced TFP to get a form of (10):

$$\frac{X_t}{L_t} = e^{a_0 + b \cdot RDC_{t-k} + g \cdot \frac{FDI_{t-s}}{L_{t-s}}}\left(\frac{K_t}{L_t}\right)^a . \tag{12}$$

The concept of new labor productivity equations and their connections with other parts of the model is shown on Fig.2. As an alternative for the FDI we have put imports of investment goods, although we haven't considered testing it yet.

Fig. 2 Labor productivity equations in IMPEC (concept)



10 Estimation results

According to the formula (12) we have estimated different variants of 27 sectoral equations. The form of the equation in terms of G printouts presented below can be written as:

$$LVAEMPi = a_0 + aLCAPEMPi + bRDC[k] + gFDIEMPi[s] \qquad (13)$$

$LVAEMPi$ - log of value added (constant prices of 1995) per employee (full time equivalent) in sector i;

$LCAPEMPi$ - log of capital stock (constant prices of 1995) per employee in sector i;

RDC - domestic R&D capital stock (constant prices of 1995);

$FDIEMPi$ - foreign direct investment in current prices (USD) per employee in sector i.

Alternatively, equations (13) were estimated for labor productivity defined as output per employee ($LOUTEMP$).

There is no information available on R&D capital stock at sectoral level, so in all equations the same global data were used. In this case, there is no way to investigate technology spillovers. There are no data on patents.

R&D data were taken from Florczak et al. (2001). R&D capital stock was calculated as:

$$RDC_t = (1-d)RDC_{t-1} + RD_t \ , \qquad (14)$$

RD_t - R&D expenditures in year *t*,

d - rate of knowledge depreciation, set to 0.05.

The relation between RDC and labor productivity (b) appeared to be negative and insignificant, in almost every sector. Testing different time lags didn't help much. In Poland, expenditures for R&D are relatively low, especially after 1990, and they haven't risen significantly in last years. Domestic firms are to small to finance advanced research (there are few exceptions). Big foreign companies usually concentrate their research in their home countries. There are some cases of eliminating R&D departments in Polish firms, after they were bought by foreign companies. Equations were reestimated without RDC. The best fits for each branch are shown below.

Agriculture, hunting and forestry

```
SEE   = 0.04 RSQ   = 0.3265 RHO =  -0.22 Obser  =    8 from 1992.000
SEE+1 = 0.04 RBSQ  = 0.0571 DW  =   2.44 DoFree =    5 to   1999.000  MAPE  = 0.39
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp0102    - - - - - - - - - - - - - - - - - -     8.51 - - - - - - - - - - - -
1 intercept        3.06307     7.4   0.36    1.48      1.00          0.874
2 lcapemp0102      1.62528    21.8   0.63    1.33      3.31  1.110   1.554    1.21
3 fdiemp0102[3]   37.13274    15.3   0.01    1.00      0.00  0.917   1.283    1.65
```

Fishing

```
SEE   = 0.19 RSQ   = 0.2096 RHO =  -0.08 Obser  =    8 from 1992.000
SEE+1 = 0.18 RBSQ  = 0.0779 DW  =   2.17 DoFree =    6 to   1999.000  MAPE  = 1.83
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp3       - - - - - - - - - - - - - - - - - -     8.93 - - - - - - - - - - - -
1 intercept       11.56869   146.6   1.30    1.27      1.00          5.521
2 lcapemp3        -0.75908    12.5  -0.30    1.00      3.48 -0.458  -1.261    1.59
```

Mining and quarrying

```
SEE   = 0.06 RSQ   = 0.7650 RHO =  -0.09 Obser  =    8 from 1992.000
SEE+1 = 0.06 RBSQ  = 0.6711 DW  =   2.17 DoFree =    5 to   1999.000  MAPE  = 0.54
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp0407    - - - - - - - - - - - - - - - - - -    10.14 - - - - - - - -  - - -
1 intercept        8.32752   123.6   0.82    4.26      1.00          4.473
2 lcapemp0407      0.40073     7.8   0.17    3.58      4.20  0.201   0.899    8.14
3 fdiemp0407[3]    1.62702    89.2   0.01    1.00      0.08  0.803   3.592   12.90
```

Manufacture of food products, beverages and tobacco products

```
SEE   = 0.04 RSQ   = 0.9563 RHO =   0.11 Obser  =    8 from 1992.000
SEE+1 = 0.04 RBSQ  = 0.9388 DW  =   1.78 DoFree =    5 to   1999.000  MAPE  = 0.32
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp0809    - - - - - - - - - - - - - - - - - -     9.90 - - - - - - - - - - - -
1 intercept        6.27315   163.4   0.63   22.87      1.00          5.448
2 lcapemp0809      0.97072    67.3   0.36    2.44      3.64  0.536   2.998   54.67
3 fdiemp0809[2]    0.04382    56.2   0.01    1.00      2.00  0.480   2.682    7.19
```

Manufacture of textiles, wearing apparel and furriery

```
SEE   = 0.05 RSQ   = 0.9003 RHO =   0.31 Obser  =    8 from 1992.000
SEE+1 = 0.05 RBSQ  = 0.8604 DW  =   1.38 DoFree =    5 to   1999.000  MAPE  = 0.38
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 loutemp1012   - - - - - - - - - - - - - - - - - -    10.32 - - - - - - - - - - - -
1 intercept       9.75827   342.9   0.95   10.03      1.00          9.647
2 lcapemp1012     0.12958     1.2   0.03    9.72      2.76  0.050   0.352   22.58
3 fdiemp1012      0.85593   211.7   0.02    1.00      0.24  0.941   6.602   43.58
```

Manufacture of wood and wooden products

```
SEE   = 0.09 RSQ   = 0.7683 RHO =   0.07 Obser  =    8 from 1992.000
SEE+1 = 0.09 RBSQ  = 0.7296 DW  =   1.86 DoFree =    6 to   1999.000  MAPE  = 0.65
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 loutemp13     - - - - - - - - - - - - - - - - - -    10.94 - - - - - - - - - - - -
1 intercept       8.31759   484.6   0.76    4.32      1.00         14.109
2 lcapemp13       0.83635   107.7   0.24    1.00      3.14  0.876   4.460   19.89
```

Manufacture of pulp and paper with publishing and printing

```
SEE   = 0.05 RSQ   = 0.9598 RHO =  -0.06 Obser  =    8 from 1992.000
SEE+1 = 0.05 RBSQ  = 0.9437 DW  =   2.12 DoFree =    5 to   1999.000  MAPE  = 0.37
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 loutemp1415   - - - - - - - - - - - - - - - - -    11.62 - - - - - - - - - - -
1 intercept       8.93308   454.4   0.77   24.88      1.00         12.194
2 lcapemp1415     0.65744    78.5   0.22    4.11      3.84  0.473   3.307   59.69
3 fdiemp1415[1]   0.04515   102.8   0.01    1.00      3.55  0.565   3.946   15.57
```

Manufacture of coke, refined petroleum products and derivatives

```
SEE   = 0.18 RSQ   = 0.6638 RHO =   0.32 Obser  =    7 from 1992.000
SEE+1 = 0.18 RBSQ  = 0.5966 DW  =   1.36 DoFree =    5 to   1998.000  MAPE  = 1.42
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp16      - - - - - - - - - - - - - - - - -    10.44 - - - - - - - - - - -
1 intercept       6.09306   120.8   0.58    2.97      1.00          4.401
2 lcapemp16       0.81981    72.5   0.42    1.00      5.30  0.815   3.142    9.87
```

Manufacture of chemical and chemical products

```
SEE   = 0.03 RSQ   = 0.9836 RHO =   0.46 Obser  =    8 from 1992.000
SEE+1 = 0.03 RBSQ  = 0.9771 DW  =   1.08 DoFree =    5 to   1999.000  MAPE  = 0.19
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp17      - - - - - - - - - - - - - - - - -    10.53 - - - - - - - - - - -
1 intercept       9.11407   473.2   0.87   61.13      1.00         12.621
2 lcapemp17       0.25484    21.5   0.11    5.73      4.63  0.242   1.541  150.32
3 fdiemp17        0.04420   139.5   0.02    1.00      5.24  0.763   4.866   23.67
```

Manufacture of rubber and plastic products

```
SEE   = 0.10 RSQ   = 0.8721 RHO =   0.01 Obser  =    8 from 1992.000
SEE+1 = 0.10 RBSQ  = 0.8209 DW  =   1.98 DoFree =    5 to   1999.000  MAPE  = 0.73
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp18      - - - - - - - - - - - - - - - - -    10.27 - - - - - - - - - - -
1 intercept       6.82364    84.0   0.66    7.82      1.00          3.454
2 lcapemp18       0.86967    22.8   0.31    2.95      3.70  0.342   1.592   17.05
3 fdiemp18        0.12632    71.6   0.02    1.00      1.82  0.670   3.119    9.73
```

Manufacture of other non-metallic mineral products

```
SEE   = 0.13 RSQ   = 0.6944 RHO =   0.58 Obser  =    8 from 1992.000
SEE+1 = 0.13 RBSQ  = 0.6434 DW  =   0.85 DoFree =    6 to   1999.000  MAPE  = 1.04
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp19      - - - - - - - - - - - - - - - - -     9.87 - - - - - - - - - - -
1 intercept       4.68416    68.8   0.47    3.27      1.00          3.332
2 lcapemp19       1.37086    80.9   0.53    1.00      3.78  0.833   3.692   13.63
```

Manufacture of basic metals and metals products

```
SEE   = 0.14 RSQ   = 0.6140 RHO =   0.49 Obser  =    8 from 1992.000
SEE+1 = 0.14 RBSQ  = 0.5497 DW  =   1.03 DoFree =    6 to   1999.000  MAPE  = 1.16
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp2021   - - - - - - - - - - - - - - - - - -   10.11 - - - - - - - - - - -
1 intercept      -2.38365     2.9  -0.24    2.59      1.00         -0.590
2 lcapemp2021     3.00537    61.0   1.24    1.00      4.16  0.784   3.089    9.54
```

Manufacture of machinery and equipment, electrical machinery, precision and optical instruments

```
SEE   = 0.09 RSQ   = 0.9332 RHO =   0.48 Obser  =    8 from 1992.000
SEE+1 = 0.09 RBSQ  = 0.9065 DW  =   1.03 DoFree =    5 to   1999.000  MAPE  = 0.86
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp2226   - - - - - - - - - - - - - - - - - -    9.80 - - - - - - - - - - -
1 intercept       6.67290    18.4   0.68   14.98      1.00          1.417
2 lcapemp2226     0.73900     3.2   0.28    7.08      3.66  0.093   0.568   34.94
3 fdiemp2226[1]   0.29162   166.1   0.04    1.00      1.46  0.899   5.515   30.41
```

Manufacture of transport equipment

```
SEE   = 0.04 RSQ   = 0.9642 RHO =  -0.22 Obser  =    8 from 1992.000
SEE+1 = 0.04 RBSQ  = 0.9499 DW  =   2.43 DoFree =    5 to   1999.000  MAPE  = 0.34
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp2728   - - - - - - - - - - - - - - - - - -    9.60 - - - - - - - - - - -
1 intercept       5.96245   117.9   0.62   27.96      1.00          4.329
2 lcapemp2728     0.90004    50.3   0.37    1.30      3.97  0.666   2.509   67.40
3 fdiemp2728      0.00807    14.2   0.01    1.00      7.80  0.327   1.231    1.52
```

Manufacture of furniture and other manufacturing

```
SEE   = 0.12 RSQ   = 0.6951 RHO =   0.41 Obser  =    8 from 1992.000
SEE+1 = 0.12 RBSQ  = 0.5732 DW  =   1.18 DoFree =    5 to   1999.000  MAPE  = 1.02
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp29     - - - - - - - - - - - - - - - - - -    9.70 - - - - - - - - - - -
1 intercept       9.45859  2327.0   0.98    3.28      1.00         54.223
2 lcapemp29       0.01500     0.5   0.00    3.27      2.33  0.056   0.226    5.70
3 fdiemp29[3]     1.78007    80.7   0.02    1.00      0.12  0.831   3.367   11.33
```

Recycling

```
SEE   = 0.12 RSQ   = 0.1850 RHO =   0.32 Obser  =    8 from 1992.000
SEE+1 = 0.11 RBSQ  = 0.0492 DW  =   1.36 DoFree =    6 to   1999.000  MAPE  = 0.90
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp30     - - - - - - - - - - - - - - - - - -   10.65 - - - - - - - -  - - -
1 intercept       9.29112   239.6   0.87    1.23      1.00          7.949
2 lcapemp30       0.36594    10.8   0.13    1.00      3.73  0.430   1.167    1.36
```

Electricity, gas and water supply

```
SEE   = 0.05 RSQ   = 0.7614 RHO =   0.53 Obser  =    8 from 1992.000
SEE+1 = 0.04 RBSQ  = 0.7216 DW  =   0.93 DoFree =    6 to   1999.000  MAPE  = 0.40
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp3132   - - - - - - - - - - - - - - - - - -    10.38 - - - - - - - - - - - -
1 intercept       6.10282   174.0   0.59    4.19      1.00          6.248
2 lcapemp3132     0.71901   104.7   0.41    1.00      5.94  0.873   4.376   19.15
```

Construction

```
SEE   = 0.04 RSQ   = 0.8979 RHO =   0.53 Obser  =    8 from 1992.000
SEE+1 = 0.04 RBSQ  = 0.8808 DW  =   0.95 DoFree =    6 to   1999.000  MAPE  = 0.39
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp33     - - - - - - - - - - - - - - - - - -    10.05 - - - - - - - - - - - -
1 intercept       7.66110   854.9   0.76    9.79      1.00         23.261
2 lcapemp33       0.99270   212.9   0.24    1.00      2.41  0.948   7.262   52.74
```

Trade and repair

```
SEE   = 0.01 RSQ   = 0.9712 RHO =   0.35 Obser  =    8 from 1992.000
SEE+1 = 0.01 RBSQ  = 0.9664 DW  =   1.30 DoFree =    6 to   1999.000  MAPE  = 0.09
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp3436   - - - - - - - - - - - - - - - - - -    10.39 - - - - - - - - - - - -
1 intercept       9.67698  7694.5   0.93   34.74      1.00        190.911
2 lcapemp3436     0.28319   489.4   0.07    1.00      2.53  0.986  14.227  202.42
```

Hotels and restaurants

```
SEE   = 0.02 RSQ   = 0.9591 RHO =  -0.22 Obser  =    8 from 1992.000
SEE+1 = 0.02 RBSQ  = 0.9427 DW  =   2.44 DoFree =    5 to   1999.000  MAPE  = 0.23
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp37     - - - - - - - - - - - - - - - - - -     9.59 - - - - - - - - - - - -
1 intercept       8.69877   577.8   0.91   24.44      1.00         14.989
2 lcapemp37       0.30382    16.2   0.08    2.10      2.67  0.358   1.322   58.59
3 fdiemp37[1]     0.12833    44.9   0.01    1.00      0.66  0.635   2.343    5.49
```

Transport, storage and communication

```
SEE   = 0.03 RSQ   = 0.9439 RHO =  -0.05 Obser  =    8 from 1992.000
SEE+1 = 0.03 RBSQ  = 0.9215 DW  =   2.10 DoFree =    5 to   1999.000  MAPE  = 0.24
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 loutemp3842  - - - - - - - - - - - - - - - - - -    10.81 - - - - - - - - - - - -
1 intercept       3.35745    17.3   0.31   17.84      1.00          1.371
2 lcapemp3842     1.33033    66.0   0.68    2.48      5.53  0.533   2.964   42.09
3 fdiemp3842[1]   0.25991    57.6   0.01    1.00      0.39  0.489   2.723    7.42
```

Financial intermediation

```
SEE   = 0.18 RSQ   = 0.7206 RHO =   0.45 Obser  =    8 from 1992.000
SEE+1 = 0.16 RBSQ  = 0.6741 DW  =   1.11 DoFree =    6 to   1999.000  MAPE  = 1.79
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp4345   - - - - - - - - - - - - - - - - - -     9.00 - - - - - - - - - - - -
1 intercept       6.78293   396.8   0.75    3.58      1.00         11.919
2 lcapemp4345     0.65787    89.2   0.25    1.00      3.38  0.849   3.934   15.48
```

Real estate and business activities

```
SEE   = 0.02 RSQ   = 0.9787 RHO =   0.07 Obser  =    8 from 1992.000
SEE+1 = 0.02 RBSQ  = 0.9751 DW  =   1.87 DoFree =    6 to   1999.000  MAPE  = 0.12
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp4650   - - - - - - - - - - - - - - - - - -    10.43 - - - - - - - - - - - -
1 intercept       2.95574   185.8   0.28   46.87      1.00          6.558
2 lcapemp4650     1.26276   584.6   0.72    1.00      5.92  0.989  16.589  275.21
```

Public administration

```
SEE   = 0.03 RSQ   = 0.4460 RHO =   0.65 Obser  =    8 from 1992.000
SEE+1 = 0.03 RBSQ  = 0.3537 DW  =   0.70 DoFree =    6 to   1999.000  MAPE  = 0.19
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp51     - - - - - - - - - - - - - - - - - -    10.57 - - - - - - - - - - - -
1 intercept       8.44865   271.9   0.80    1.81      1.00          8.774
2 lcapemp51       0.52749    34.4   0.20    1.00      4.01  0.668   2.198    4.83
```

Education

```
:
SEE   = 0.02 RSQ   = 0.8303 RHO =  -0.37 Obser  =    8 from 1992.000
SEE+1 = 0.02 RBSQ  = 0.8020 DW  =   2.74 DoFree =    6 to   1999.000  MAPE  = 0.17
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 lvaemp52     - - - - - - - - - - - - - - - - - -     9.30 - - - - - - - - - - - -
1 intercept       7.98260  1242.2   0.86    5.89      1.00         32.786
2 lcapemp52       0.45195   142.7   0.14    1.00      2.92  0.911   5.418   29.36
```

Health and social work

```
SEE   = 0.04 RSQ   = 0.5700 RHO =  -0.32 Obser  =    8 from 1992.000
SEE+1 = 0.04 RBSQ  = 0.4983 DW  =   2.64 DoFree =    6 to   1999.000  MAPE  = 0.35
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 loutemp53  - - - - - - - - - - - - - - - - - -      10.85 - - - - - - - - - - - -
1 intercept       8.95789  1334.2   0.93    2,33      1.00         35,044
2 lcapemp53       0.26521    52.5   0.07    1.00      2.71  0.755   2.820    7.95
```

Other community, social and personal service activities

```
SEE   = 0.03 RSQ   = 0.5395 RHO =  -0.44 Obser  =    8 from 1992.000
SEE+1 = 0.02 RBSQ  = 0.4628 DW  =   2.88 DoFree =    6 to   1999.000  MAPE  = 0.24
Variable name     Reg-Coef  Mexval  Elas   NorRes     Mean   Beta  t-value  F-Stat
0 loutemp5457  - - - - - - - - - - - - - - - - - -    10.85 - - - - - - - - - - - -
1 intercept       10.34745  2127.0  0.95    2.17      1.00         54.496
2 lcapemp5457      0.13681    47.4  0.05    1.00      3.67  0.735   2.652    7.03
```

In most cases we were able to obtain reasonable results, however, some elasticities seem to be to low. In 11 branches FDI appeared significant. In some cases explanatory variables are not significant. The reasons for this can be found in Tab. 1 and 2. For example in branch 4-7, mining and quarrying we can see growth in labor productivity in terms of permanently decreasing production. This growth in LP is the result of restructurization process, which leads to reduction in employment. In this branch the FDI are relatively small. Dramatic reductions could be observed in branch 3. Output and employment go down faster than capital stock, which makes the K/Q grow (this branch accounts for only 0,02% of total value added). Elasticity for metallurgy (20-21) seem too high. This is another exceptional branch, where a special restructurization program has been started.

11 Conclusions

In most equations the capital per employee is the only explanatory variable, so any driving force like technological progress, or TFP is missing. Developing the concept presented on fig. will be concentrated on more detailed investigations on factors determining TFP. This means the estimation of domestic R&D expenditures at sectoral level and including imported R&D capital, embodied in machinery and equipment, especially in these sectors, where FDI are nonexistent or insignificant. Analyzing the technological spillovers seem to be impossible because the data are lacking.

We have only mentioned about the capacity utilization problem, but it is worth some empirical investigations.

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