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I. ARTICLES

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LONG-TERM SIMULATION MODEL FOR A KNOWLEDGE-BASED ECONOMY

Development of market economies towards the economies based on knowledge implies the construction of new long-term macroeconometric models. The structure of the new long-term W8D model for Poland is presented. Being a complete model, it covers the blocks of equations explaining final demand and the production process as well as financial flows. The equations explain both the long-term relationships and the dynamic adjustments using ECM. The model is of medium-size, including 235 equations, of which 111 are stochastic. They are mostly non-linear, dynamic and compose a simulations system.

The consumption and investment function estimates are shown. The paper discusses the notions of extended production function and total factor productivity (TFP). The TFP represents the impacts of new technologies being endogenized, as well as human capital. The discussion covers the measurement issues and explanation of the role of domestic and foreign R&D expenditures, as well as educational expenditures. The price and wages equations as well as incomes explaining the expenditures close the model. The discussion is extended to include proposals to construct new submodels explaining the sectors of research and education and also the ICT industries, as well as the ecological issues.

Keywords: Knowledge economy, technical progress, production functions, total factor productivity, R&D expenditures, human capital

JEL: C51, C52, E17, 011, 040, 047

1. INTRODUCTION

Over the last ten years the economics community has agreed that contemporary market economies tend towards knowledge-based economies. This concept has been formulated in contrast to an industrial economy system that prevailed in the last centuries (Smith, 2002).

There is vast literature based on new theories of endogenous growth aimed to explain – at a world-wide level – the differences in the rates of growth of particular countries and the issues in their convergence. This is based on an analysis of international cross-section data and emphasizes the

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role of particular factors of growth. Its non-technical excellent summary can be found in Helpman (2004). The applications of the results of this research to studies of economic growth of single economies are rather exceptional, except for the US economy (see Jorgenson et al., 2003 and Richards, 2000) and for the Polish economy (see Welfe, ed., 2001, 2008a). It has a practical aspect: the authorities and the scientific community of a country need to have an instrument that will help to construct scenarios of long-term economic growth for 20-30 years ahead.

Nearly all these studies were concentrated on the supply side of the economy. Of course, the knowledge of a long-term, extended production function with endogenous TFP being dependent on knowledge capital embodied in fixed capital and labour is a prerequisite of such studies. However, this instrument allows to generate potential output only. It may considerably diverge from effective output which represents realizations of final demand, underlying business cycle fluctuations. Hence, to be used in empirical analysis and simulation exercises, we need to construct a complete model that contains both the final demand and the total supplies. That makes possible to estimate the likely disequilibria: output gap, unemployment, foreign trade deficits etc. The model should be closed by introduction price, wage and financial flows sector (Welfe, 2008b).

All this justifies the need for the construction of extended, long term macroeconometric models for single economies. We tried to show their suggested structure using as an example the annual long-term macroeconometric models W8D built for the Polish economy. Their characteristic is provided in the following section. Next sections of this paper contain discussions of properties of alternative measures of major determinants of economic growth, the alternative approaches to their explanation with an attempt to show the interdependencies within the whole economic system[1]. The role of investment in fixed capital and knowledge capital is discussed in the light of multiplier analysis. The applications in scenario analyses based on model simulations are provided at the end of the paper[2].

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[1] For a comprehensive discussion see Welfe, ed. (2007).

[2] This article presents an abbreviated, updated version of my paper on Long-term Simulation Model for Knowledge based Economies presented to the International Atlantic Economic Conference, March 11-14, 2009, Rome.

2. THE MACROECONOMETRIC MODELS OF A KNOWLEDGE-BASED ECONOMY

The quantitative mechanisms that underlie the growth of a knowledge-based economy can be described empirically by means of adequately expanded macroeconometric models (see Garratt et al., 2006). Such models should draw on economic growth theory which has been enjoying its renaissance, and especially on the endogenous growth theory (see Grossman, Helpman (1991), Barro, Sala-i-Martin (1995), Aghion, Howitt (1999), and more recently Nahuis (2003), Tokarski (2001, 2007)).

The long-term macroeconometric models built along these lines, extended to include processes in which knowledge capital is generated and used, seem to be the most relevant tools of long-term economic analysis. Their structure may follow the framework of the mainstream models outlined by Klein et al. (1999).

These models specify the final demand equations along neo-Keynesian lines, but the potential output and demand for the factors of production, as well as impacts of technological progress they generate referring to the neoclassical theory of production (Solow, 1957). This approach draws on the early theories of growth developed by Harrod and Domar and on the concept of models of production possibility frontier that have recently been developed by Jorgenson (2000). The stylized empirical model of growth by W. Welfe (2005) follows a similar approach.

Empirical investigations in Poland referring to the above developments draw on the concept of an empirical model of economic growth developed by Welfe (2000). This concept gave rise to the building of the long-term macroeconometric models of the Polish economy W8D (see Welfe ed., 2001), 2004 and recently W8D 2007 (2008b, 2009a)).

The new, long-term model W8D 2007 was estimated using 1970-2005 sample and 1980-2005 for financial time-series. It is a complete structure. Its quantitative description is shown in table 1. It is one sectoral, medium size model. The core of its simulation version comprises several blocks of equations, traditionally following the familiar classification of economic activities. The blocks explain:

- final demand, including exports and imports,
- the supply side, including potential output, and the primary factors of production,
- impact of technological progress (TFP),
- prices, wages and financial flows.

Table 1

Major characteristics of the model W8D-2007

Characteristics	The number of variables/equations
Variables total	393
- excluding dummies	258
- exogenous (E)	157
- excluding dummies	22
- endogenous	235
Equations total	235
- stochastic (B)	111
- identities (I)	124
Lags, leads	
- maximal lag	8
- lags total (L)	165
Endogenous variables	
- presimultaneous	24
- jointly determined	80
- post simultaneous	131
Feedback variables	7
Equations by blocks	
- final demand-total	64
- production factors	17
- technical progress	40
- potential output	7
- average wages and incomes, prices and deflators	48
- financial flows	48
- macrocharacteristics	11

Source: Welfe, W. (ed.), *Makroekonometryczny [...]*, 2009a.

The final demand block explains private and government consumption, investments and foreign trade. In the next blocks, the long-run potential output is generated, depending on fixed capital, labour and TFP determinants, i.e. human capital per employee and cumulative R&D expenditures, both domestic and foreign. The direct and indirect channels of the transfer of foreign knowledge capital – via imports – are distinguished. The indirect channels comprise knowledge capital embodied in imports of investment goods and/or imports of high-tech and low-tech products.

The role of investment as a factor determining an increase in potential output as well as in final demand is especially emphasized. This offers the possibility of studying potential business cycle fluctuations.

The last blocks of the model are prices and financial flows. Prices react to disequilibria and changes in costs, while wages are formed in the course of negotiations. The financial flows are explained within particular institutional sectors.

We shall constrain further discussion to the specification of investment and production functions playing the central role in the functioning of the model. For the specification of remaining equations see W. Welfe (2008b) and W. Welfe (ed.) (2009a)[3].

The parameters of the equations were estimated using two-step Engle-Granger procedure; dynamic adjustments were obtained using ECM.

3. SPECIFICATION OF INVESTMENT FUNCTION

The investment function explaining demand for investment goods covers investment in fixed capital. Proposals have been formulated in the recent years to extend the notion of demand for investment goods to include investments in knowledge capital, i.e. R&D and educational expenditures, in addition to investments in fixed capital[4]. If such an extension were accepted,

[3] Full description of the specification of the models' equations can be found in Welfe (ed.) (2009a) (in Polish). The English summary is provided in a previous paper by W. Welfe (2008b). Because of scarcity of this exposition we omitted here the description of specification of consumer demand function, equations explaining the demand for production factors as well the prices and wages and also financial flows.

[4] Zienkowski (2003) suggests to introduce a new macro category called investment in development.

a pertinent modification of the SNA would be required, reducing the demand for consumer goods of public institutions and increasing total investments[5].

The specification of private enterprises' demand for investment goods starts with an accelerator. To put it simply, producer capacities expand in the long run following expected increase in the demand for products the producers can provide. This increase creates, allowing for restitution demand the potential demand for investment goods. It has to be adjusted for a likely change of the level of utilization of the available equipment. The perception of investment risks, changes in the profitability of investment projects and substitution between labour and capital has also an impact on the effective demand.

The expected future output is typically represented by output generated in the past. As for machinery and equipment, the Koyck transformation leading to a reduced form of the investment demand function can be used, where the explanatory variables are being confined to lagged investment (J_{t-1}) and current output X_t (see W. Welfe, A. Welfe 2004). The rate of capacity utilization (WX_t) may be obtained using several approximations (see the next section). The investment risk RJ_t can be approximated using various indicators, such as government deficit, government debt service, or a rate of inflation. The profitability of investment projects is usually expressed by a ratio of producer prices (PX_t) and user costs KI_t, the latter predominantly depending on the long-term interest rate RL_t. The rate of wages (WBP_t) and investment deflator (PJ_t) stands for the effects of substitution. Hence, a typical specification of the investment demand function is as follows:

$$J_t = AJ_{t-1}^{\alpha_1} X_t^{\alpha_2} WX_t^{\alpha_3} RJ_t^{\alpha_4} \left(PX_t / KI_t\right)^{\alpha_5} (WBP_t / PJV_t)^{\alpha_6} e^{\varepsilon_t} \tag{1}$$

where

$KI_t = PJ_t\left(RL_t + \delta\right)$, PJ_t is an investment deflator, RL_t is real long-term interest rate, WX_t is capacity utilisation rate, δ is the rate of depreciation.

In the W8D model the following elasticities were obtained for investment in machinery equipment: with respect to the output – long-run 1, but short-run 2. The long-run elasticity was calibrated assuming that the share of

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[5] Jorgenson adds the value of services provided by dwellings and consumer durables to the private sector's GDP (Jorgenson et al., 2002).

investments in GDP will tend to be constant. The large deviations of the investment rates of growth from the GDP rates of growth were explained in the short-run, showing that the growth of investment is twice as high as those of GDP. The elasticity with respect to the capacity utilization was in the long run 1.1, showing a nearly proportional adjustment; with respect to the wage-investment deflator in the long run 0.5 and only 0.1 in the short-run. The impact of rentability of investment projects had to be calibrated. The speed of dynamic adjustment was mild (-0.4).

4. MODELLING THE PROCESS OF PRODUCTION: THE EXTENDED PRODUCTION FUNCTION

Analysis of the production process implies the use of the production function. Following many authors, we recommend the double-log production function, i.e. a Cobb-Douglas function with constant returns to scale in its extended version:

$$X_t^P = BA_tK_t^{\alpha}N_t^{(1-\alpha)}e^{\varepsilon_t} \qquad (2)$$

where

X_t^P is potential output (GDP at the macroscale) in constant prices, B is a constant, A_t is total factor productivity (TFP), K_t is fixed capital, in constant prices, N_t is employment.

Estimating the function's parameters for a market economy is not a straightforward exercise, because observations represent effective output, i.e. the realization of the final demand X_t, and not potential output, and most frequently $X_t < X_t^P$. Therefore, changes in the rate of utilization of production potential must be addressed. In most cases, they originate from changes in final demand, i.e. from the business cycle fluctuations. The rate of capacity utilization is defined as

$$WX_t = X_t / X_t^P \qquad (3)$$

Allowing for the rate of utilization, we can redefine the production function (2) into:

$$X_t = BWX_tA_tK_t^{\alpha}N_t^{(1-\alpha)}e^{\varepsilon_t} \qquad (4)$$

To estimate the parameters of the above function, we need information on the rate of capacity utilization and total factor productivity. Several methods of estimating the rate of utilization are used: industrial surveys that ask direct questions about the level of utilization of machinery and equipment, as well as time worked (Grzęda-Latocha, 2005). Central banks use techniques involving analysis of the deviations from a GDP trend. Other procedures use the decomposition of the rate of utilization of fixed capital and employment (see W. Welfe, 1992).

5. THE DYNAMICS OF THE TOTAL FACTOR PRODUCTIVITY

Following the concept of Solow residual (Solow, 1957), total factor productivity is commonly used to represent the effects of knowledge capital absorption and widely applied to international comparisons. However, some measurement problems that constrain its use have not yet been solved (W. Welfe, 2002, 2007; J. Cornwall, W. Cornwall, 2002).

Firstly, TFP is computed using effective (i.e. observable) output and not potential output. Secondly, several studies, mainly sectoral, use the concept of gross output instead of value added. Further, output elasticities with respect to fixed capital are frequently calibrated and not estimated. All these issues are discussed in the literature; their summary can be found in W. Welfe (2002).

The tradition of modelling the TFP growth factors is quite short. Several questions still await their answers (Welfe, ed., 2009c). A frequently suggested way of explaining TFP dynamics is a decomposition of TFP changes into the effects of the free available capital of knowledge ($\overset{\circ}{A}{}_t^W$), the impacts of expanding knowledge capital embodied in fixed capital ($\overset{\circ}{A}{}_t^K$) and increasing human capital ($\overset{\circ}{A}{}_t^N$). Taking the production function (2), we have:

$$\overset{\circ}{A}_t = \overset{\circ}{A}{}_t^W + \alpha\,\overset{\circ}{A}{}_t^K + (1-\alpha)\,\overset{\circ}{A}{}_t^N\,, \tag{5}$$

where $(^\circ)$ is the rate of growth.

The effects of generally available knowledge capital (A_t^W) are either treated as exogenous (usually as an exponential function of time) or attributed to the growth of knowledge capital associated with improving quality of employment.

In the past, the effects of expanding knowledge capital embodied in fixed capital were treated as functions of time; successive generations of fixed capital were assumed to represent rising levels of technology. A simplification was occasionally applied, distinguishing only the share of "new" equipment. The stock of machinery and equipment was frequently used in lieu of total fixed capital. Recently, following the mass computerization of production and management processes, decomposition of fixed capital into computers, computer programs and tele-equipment has been suggested. This approach was used in studies exploring the growth of the US economy (Jorgenson, 2001; Jorgenson, Ho, Stiroh, 2003), and then in research on the OECD countries (Colecchia, Schreyer, 2002) and the Netherlands (Leeuwen, Wiel, 2003). It means, however, the removal of computerization effects from the notion of TFP.

When the starting point is decomposition of TFP dynamics as given by (5), the impact of TFP embodied in fixed assets (A_t^K) can be related, both directly and indirectly, to the effects of innovations and R&D past expenditures. In the first case, patent citations, publications, and technical proximity are used as the approximate variables explaining this impact. Viewed in broader terms, however, this impact depends on the anticipated results of R&D expenditures. The cumulative R&D expenditures – both domestic (BR_t^K) and foreign, transferred from abroad (BR_t^M) – are assumed to represent the capital of technical and organizational knowledge (Coe, Helpman, 1995). Further efforts are necessary to answer many specific questions in this area, especially these concerning the transfer of foreign R&D.

The direct and indirect channels through which R&D is transferred are distinguished. The expanding systems of telephone lines, closer technological proximity, more frequent use of patents, etc., stimulate the direct transfer of R&D (Lee, 2005), whereas imports of commodities, i.e. of intermediate and investment goods, represent its indirect transfer (Xu, Wang, 1999). The indirect transfer of knowledge can be summarized by computing the weighted sum of R&D expenditures incurred by the country *j*:

$$BR_t^M = \sum_j w_j BR_{tj}^K , \tag{6}$$

where w_j represents a weight assigned to R&D expenditures of the country j .

The weights can stand for particular countries' shares in the total imports of the analyzed country, or rather for the ratios of imports from these countries (i.e. their exports) to their GDPs (Lichtenberg, van Pottelsberghe, 1998). The weights can be linked with the imports of intermediate goods (transfer of technology), with the imports of investment goods (transfer of new machines, etc.), which seems a better approach (Bayoumi et al., 1999), or with total imports, when their decomposition is not possible. This approach was used in earlier versions of W8D models for the Polish economy. However, in the most recent version of the model the imports were decomposed into groups of commodities that differ by the level of technological advancement (Welfe, 2008b, 2009a).

In the last 15 years, the discussed research has been given international dimension and its scope includes now not only the industrialized countries, but also the developing ones (Engelbrecht, 1997, Bayoumi et al. 1999). However, the role of foreign direct investment (FDI) in stimulating TFP dynamics continuous to be debatable. It is also necessary to explore further the impact of domestic R&D expenditures and human capital on the rate of absorption of the transferred foreign capital of knowledge (Cincera, Pottelsberghe 2001). An extension of research programmes to cover TFP development in sectors or branches involves the introduction of intersectoral transfers of knowledge capital.

The above relationships are multiplicative. Hence, the first approximation we can write is:

$$\ln A_t^K = \beta_o \ln BR_t^K + \beta_1 \gamma \ln BR_t^M , \qquad (7)$$

where γ is a weight representing the share of imports, i.e. the degree of openness of the economy.

In the model W8D 2007 for Poland, the elasticities with regard to domestic R&D capital were close to 0.3, which is in line with the results reported by other authors for industrialized countries, whereas with regard to foreign R&D capital they exceeded 0.6, which was found characteristic for less developed countries.

6. EFFECTS OF INCREASING HUMAN CAPITAL

Earlier investigations evaluating the impacts of expanding human capital on economic growth produced inconclusive results. The main reason was that they used inconsistent data on the schooling years.

In general, the scope (i.e. definition) of human capital varies in terms of its coverage. The narrow definition, most frequently used in empirical research, accentuates the differences between the levels of employees' education. The broad version allows for the impacts of learning by doing, health status, etc. (see Benabou, 2002). In either case, the measurement problems need an adequate solution. Unfortunately, many international projects use simplified measures of human capital, i.e. shares of employees with tertiary education, shares of employees with secondary and tertiary education, or sometimes numbers of students leaving school or simply being educated. This situation has improved in the last years, as more adequate information on the number of schooling years has become available (Fuente, 2004). Notwithstanding, only few researchers take advantage of the newly developed summary characteristics of human capital per employee.

These characteristics of human capital (H_t) are designed as the weighted sums of employees with different educational levels i:

$$H_t = \sum_i \mu_i N_{it}, \tag{8}$$

where i is the level of education and μ_i is a weight.

The weights may represent:

a) an average number of schooling years, thus H_t stands for total schooling years, or

b) average unit costs of schooling; in this case H_o denotes total educational expenditure,

c) average wages per employee with educational level i; here H_t is an estimate of the total wage bill.

In most cases, the weights represent the number of schooling years. However, the third approach, where the weights reflect the market efficiency of the level of education, seems to be the most appropriate, treating human capital as a factor of production (W. Welfe et. al., 2002). It was used in all W8D models of the Polish economy. It is worthwhile to note that the elasticity of TFP with regard to human capital per employee exceeded 1.

Human capital per employee is obtained by dividing total human capital by the total number of employees:

$$h_t = H_t / N_t \tag{9}$$

Seeking relationships between investments in human capital and educational expenditure is a difficult task. To make this search effective, a submodel describing the educational process and related expenditures has been built (see Welfe et. al., 2002).

7. THE MULTIPLIERS

The simulation version of the model was used to support the medium and long-term forecasting and scenario analyses extended to the year 2030, or even beyond, until 2040, if the model solutions and the multiplier analysis demonstrate satisfactory stability.

The properties of the model were analysed by means of multiplier analysis that revealed the major economic mechanisms. We shall concentrate on ex-ante multipliers analysing the impact of 10% shocks in one most important variable only: investment in fixed capital being due to foreign financing (say EU transfers, FDI) (fig. 2.). The figures will be shown respectively for the major macro variables: household consumption (C), investment in fixed capital (JA), final demand (XFD), exports (E), imports (M), GDP (X), potential GDP (XNK) calculated by assuming full utilization of fixed capital [6].

We constructed a long-term forecast to the year 2030 first. The multipliers were calculated by means of models' simulation, using this baseline forecast. Impulse and sustained multipliers were computed.

The impulse multipliers show a decline, which approaches zero in 5-8 years, except for potential output that starts declining in 5-6 years. The sustained multipliers present an interesting picture. Initially, because of the accelerator the investments grow from 15% to 35% after 6 years.

Then they decline because of declining capacity utilization and stabilize around 20%. Consumption follows this pattern with a considerable delay. As imports substantially grow, the GDP increase is lagged attaining its maximum in 10 years. For the midpoint of the period, the elasticity of GDP with regard to investment is close to 1. Notice that the potential GDP increases with a longer lag, but stabilizes at nearly 20%.

Hence, there is a long-run tendency for a decline in capacity utilization, which negatively affects investment growth. However, it would not be justified to conclude that the model predicts overinvestment, as we did not allow for any relevant increase in exports.

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[6] For detailed information see Welfe ed. (2009b), where the results of multiplier analysis are presented, showing the likely impact of shocks in world demand, budget expenditures, wages, exchange rates, interest rates as well as in knowledge capital.

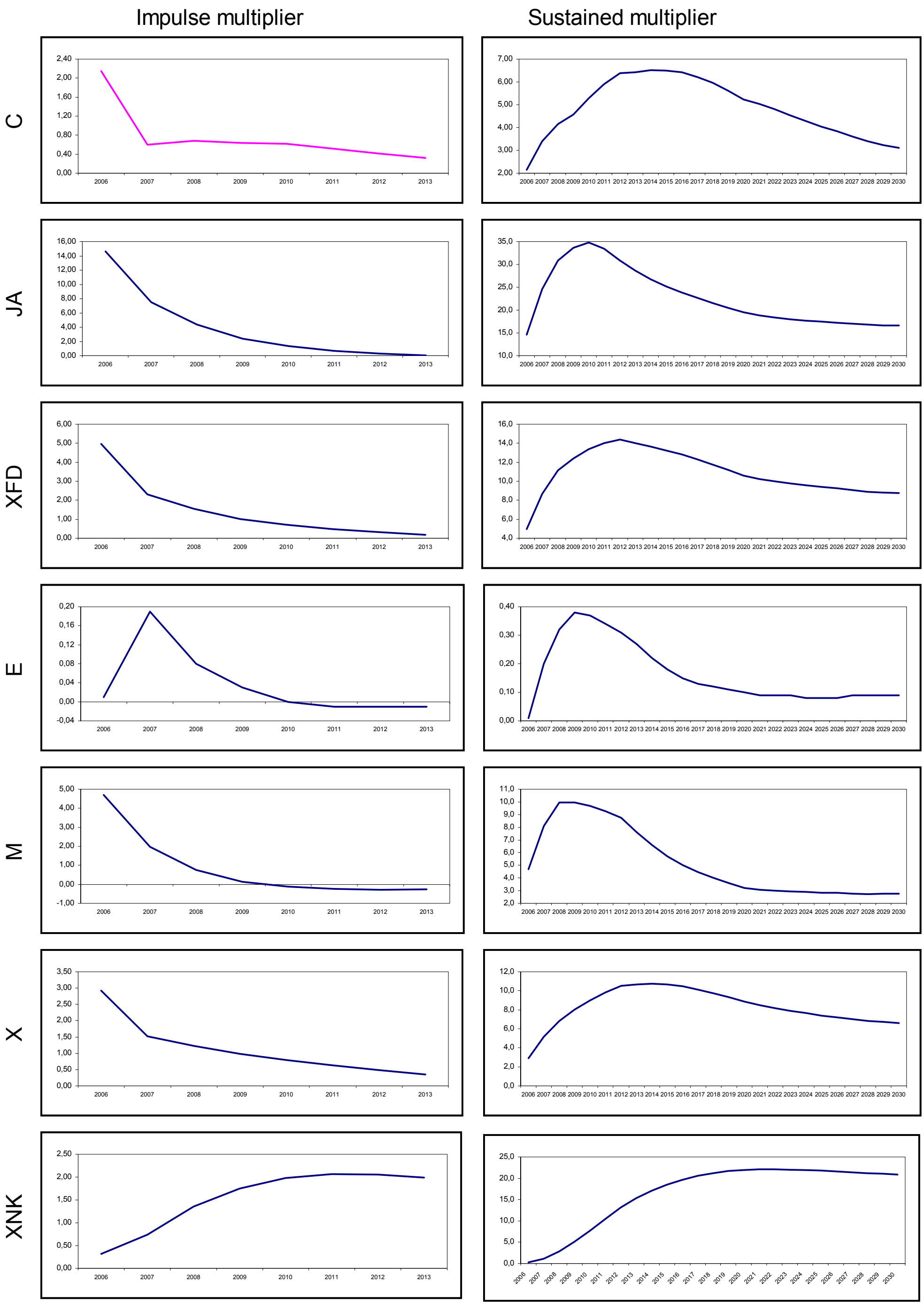

Fig. 1. 10% increase in investment outlays
Source: Welfe, W. (ed.), *Prognozy […]*, 2009b.

8. LONG-TERM SCENARIO ANALYSES BASED ON MODEL SIMULATION

The construction of the new model helped to launch a new series of long-term forecasts and scenario analyses underpinned by the model-based simulations. At the beginning we distinguished two scenarios only. In the optimistic variant we assumed a high long-run increase in fixed capital and in domestic R&D expenditures, better absorption of transferred foreign expenditures on R&D, and growth of human capital stimulated by larger financial allocations to the tertiary and post-graduate education. We assumed high rates of export growth stabilizing after 2015 at 9%. In the pessimistic variant – the deterioration of these factors was assumed. The assumption with regard to the growth of exports were not pessimistic enough. We were unable to foresee the shock that occurred in 2009 due to the world recession. The specific assumptions are shown in table 2. Our aim was to delimitate the spectrum of likely growth paths. It opened the possibility of constructing more "realistic" scenarios situating the developments in between.

The outcome of the simulations for the period up to the year 2030 is demonstrated in figures 2-5. They show the impacts of the above assumptions on the major macrovariables[7].

The *optimistic* scenario generates very high rates of growth of GDP – initially up to 8% and then going down to 5-6% at the end of simulation period. They are cyclical (fig. 2). The deviations from the baseline forecast are substantial: from 12% in 2013 up to above 50% in 2030.

The above high rates of growth are mainly due to an assumed increase in investment expenditures (fig. 3). They reveal a cyclical behaviour. They initially grow up to 17%, then they decline to 5% in 2025. These expenditures will be higher than forecasted by 22% already in 2013, but twice as high in 2030. The indirect impact of investment growth on consumption shows an initial increase by 4-5%, declining to 1.5-2.5%, which brings its level by 14% above the forecast in 2013, and by 5% in 2000.

[7] Because of the limited space, the tables presenting the results of all simulations are available only in the monograph W. Welfe (ed.) (2009b).

Table 2

Assumptions for the scenarios of economic development up to the year 2030

Macrovariables Scenarios	**2010**	**2015**	**2020**	**2025**	**2030**
Investment GDP rate In % c.p.					
optimistic	26.5	35.0	38.0	35.0	35.0
forecast	23.9	33.4	32.9	31.3	31.0
pessimistic	22.0	20.0	18.0	18.0	18.0
FDI GDP rate In % c.p.					
optimistic	4.2	4.0	4.0	3.5	3.0
forecast	3.1	2.8	2.1	1.5	1.1
pessimistic	0.4	1.4	1.3	0.8	0.7
Transfers net from EU in % GDP c.p.					
optimistic	3.5	3.2	3.0	2.8	2.8
forecast	3.5	3.2	3.0	2.8	2.8
pessimistic	3.5	3.2	3.0	2.8	2.8
Exports SNA rate of growth in %					
optimistic	10.0	12.0	9.0	9.0	9.0
forecast	7.5	11.2	5.2	7.3	4.0
pessimistic	5.0	5.0	4.5	4.0	4.0
Expenditures on education GDP ratio in % c.p.					
optimistic	5.0	4.8	4.7	4.7	4.8
forecast	4.5	4.3	4.2	4.0	4.0
pessimistic	3.8	3.5	3.1	2.7	2.5
R&D expenditures GDP ratio in % c.p.					
optimistic	1.00	2.00	2.60	2.80	3.2
forecast	0.79	1.15	2.00	2.00	2.00
pessimistic	0.76	0.75	0.65	0.60	0.50
Increase of elasticity of absorbtion of foreign R&D					
optimistic	40	60	80	100	100
forecast	20	30	40	50	60
pessimistic	0	0	0	0	0

Source: Welfe, W. (ed.), *Prognozy […],* 2009b.

Altogether the domestic final demand would exceed the baseline forecast by 14% in 2013 and by 40% in 2030. The dynamics of the net exports reflects the changes in assumed exports and calculated imports. After initial decline it is systematically growing, thus positively affecting the current account.

On the supply side the high rates of growth of potential GDP are noticed, considerably exceeding the forecast (fig. 4). They oscillate around 8% being higher than those for effective GDP. Hence, the capacity utilization has a declining tendency, negatively affecting the investment growth. In total, potential GDP is higher by 50% than forecasted by the end of period.

Despite the impact of rising investment, the TFP growth plays a significant role (fig. 5). Its rates of growth come up from 2.8% to 3.4% at the end of period. This is due to assumed rising domestic R&D capital and rising efficiency in the absorption of foreign R&D capital. The rate of growth of employment is declining because of the high increase in labour productivity. The unemployment rates decline to 6%.

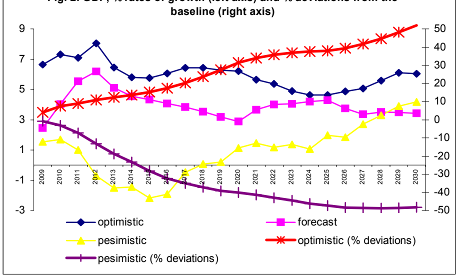

Fig. 2. GDP, % rates of growth (left axis) and % deviations from the baseline (right axis)

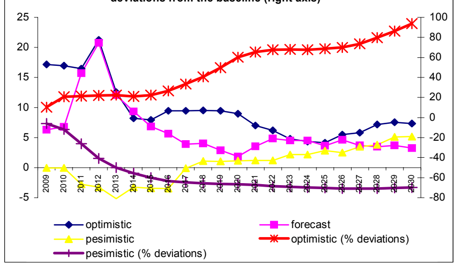

Fig. 3. Investment outlays, % rates of growth (left axis) and % deviations from the baseline (right axis)

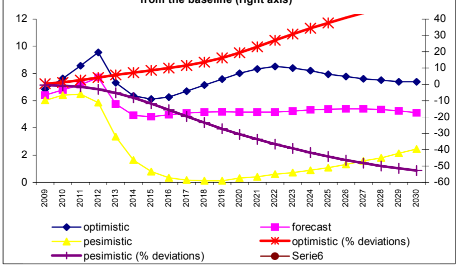

Fig. 4. Potential GDP, % rates of growth (left axis) and % deviations from the baseline (right axis)

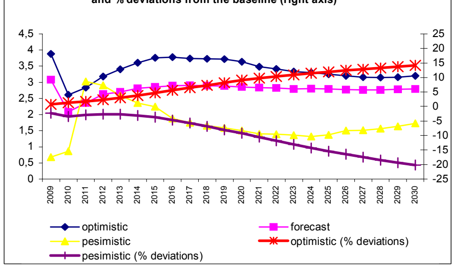

Fig. 5. Total factor productivity (TFP), % rates of growth (left axis) and % deviations from the baseline (right axis)

Source: Welfe, W. (ed.), *Prognozy […],* 2009b.

Turning now to *pessimistic* scenario, where low levels of investment in fixed capital and knowledge capital were assumed – the rates of growth would be initially negative (-2%) (fig. 2). The recession would be over in 7 years. The rates of growth would reach 2% in 2025 only, and 4% in 2030 owing to the results of recovery. Hence, the GDP level would be lower by ca 50% than the forecast by the end of simulation period.

This result is mainly due to assumed decline in investment activities, initially by -5% (fig. 3). In the middle of the period they would rise to 2% and only in the last 5 years up to 5%. Nevertheless, in that period they would be lower than forecasted by 60-70%. The level of consumption stagnates.

Hence, the domestic final demand after an initial decline by 2% would show an increase by the end of period. The net exports exhibit a rising tendency that mitigates to some extent the negative impact of domestic demand.

Potential GDP shows all the time positive rates of growth, however not exceeding 1% (fig. 4). This is mainly because of the declining rates of growth of fixed capital. The labour productivity rates of growth are low, but sufficient to sustain a systematic decline of employment. Hence, the unemployment rates rise dramatically from 10% to nearly 20% in the last years of simulation period. The TFP rates of growth are declining due to low R&D expenditures (fig. 5).

FINAL COMMENTS

The simulation analyses open the floor for constructing many alternative scenarios that would take into account the factors of development other than investment in fixed capital and knowledge capital. However, the advantage the presented framework has is that it allows showing a clear distinction between the factors of growth and the results of the simulations exercise.

One of the important applications of this exercise is the possibility of calculating the time in which a particular economy will reach the GDP per capita levels of developed, industrial economies. For instance, these calculations show that Poland may have a chance to reach the average level of the EU-15 countries in 2030 only in the optimistic scenario, while in the pessimistic scenario it would remain at the 46% level.

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