LONG-TERM MACROECONOMETRIC MODEL FOR THE POLISH ECONOMY

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Abstract: Development of market economies towards economies based on knowledge implies the construction of new long-term macroeconometric models. The structure and use of the long-term W8D model for Poland was shown. This is a complete model that explains production and the factors its growth including R&D and human capital and also final demand allowing for studies of potential disequilibria. It is closed by equations explaining prices, wages and financial flows. The simulation version is includes 235 equations, of which 111 are stochastic. It is used in long-term growth scenarios up to the year 2030.

Keywords: Knowledge Capital, R&D, Human Capital, Macromodelling, Multipliers, Scenarios
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INTRODUCTION

Over the last years the economics community agreed that the 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 theories of endogenous growth aimed to explain – at the world-wide level – the differences in the rates of growth of particular countries. It is based on an analysis of international cross-section data. 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 Polish economy (see Welfe, ed. [2001], [2009a]). 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 analyzing factors of growth and the resulting potential output. It may, however, 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 (W. Welfe [2008a]).

We tried to show the suggested structure of such models 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 contain discussions of properties of alternative measures of major determinants of economic growth, the alternative approaches to their explanation showing 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.

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 the 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

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

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 [2009a].

The new model is a complete structure. Its quantitative description is shown in table 1. It is one sectoral, medium size model. Its simulation version comprises several blocks of equations, traditionally following the familiar classification of economic activities. The blocks explain: a) final demand, including exports and imports, b) the supply side, including potential output, and the primary factors of production, c) impact of technological progress (TFP), d) prices, wages and financial flows.

Many well known economic interrelationships are established within and between the above blocks. The role of investment as a factor determining an increase in potential output as well as in final demand is especially emphasized. It offers the possibility of studying potential business cycle fluctuations.

Table 1. Major characteristics of the model W8D-2007

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

Source: own elaboration

Hence, we shall constrain the further discussion to the specification of investment and production functions playing the central role in the functionimg of the model. For the specification of remaining equations see W.Welfe [2008b].

SPECIFICATION OF INVESTMENT FUNCTION

The investment function explaining demand for investment goods covers the investment in fixed capital. 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 effect 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. 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:

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

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: with respect to the output – long-run 1, but short-run 2, and with respect to the capacity utilization: long run 1.1.

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:

$$X_t^P = B A_t K_t^{\alpha} N_t^{(1-\alpha)} e^{\varepsilon_t} \tag{2}$$

where: X_t^P is potential output (GDP at the macroscale) in constant prices, 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:

$$X_t = B WX_t A_t K_t^{\alpha} N_t^{(1-\alpha)} e^{\varepsilon_t} \qquad (4)$$

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]).

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 been solved yet (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 and many questions still await their answers. 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. 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 as given by (5), the impact of TFP embodied in fixed assets (A_t^K) can be related, to the anticipated effects of past R&D expenditures. The cumulative R&D expenditures (R&D capital)– 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]).

The direct and indirect channels through which R&D is transferred from abroad 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, 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 distinguished 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 (W. Welfe [2008b]).

In the last 15 years, the discussed research has been given international dimension. Its scope includes now not only the industrialized countries, but also the developing ones (Engelbrecht, [1997], Bayoumi et al. [1999]). However, the role of FDI in stimulating TFP dynamics continuous to be debatable. It seems 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]).

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 w.r. 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 w.r. to foreign R&D capital they exceeded 0,6, which was found characteristic for less developed countries.

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 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, or with secondary and tertiary education etc. 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 :

$$H_t = \sum_i \mu_i N_{it}, \qquad (8)$$

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

The weights may represent:

a) an average number of schooling years, b) average unit costs of schooling; c) average wages per employee with educational level i. 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 worthwile to note that the elasticity of TFP w.r. to human capital per employee exceeded 1.

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

$$h_t = H_t / N_t \qquad (9)$$

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]).

THE MULTIPLIERS AND SCENARIOS

The simulation version of the model was used to support the medium and long-term forecasting and scenario analyses extended to the year 2030. The properties of the model were analysed by means of multiplier analysis that revealed the major economic mechanisms. We shall concentrate here 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 (J), exports (E), imports (M), GDP (X), potential GDP (XNK)[2].

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

The impuls 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

[2] For the detailed information see Welfe ed. [2009b].

years. For the midpoint of the period the elasticity of GDP w.r. to investment is close to 1. Notice that the potential GDP increases with a longer lag, but stabilizes at nearly 20%.

Fig. 1. 10% increase in investment outlays
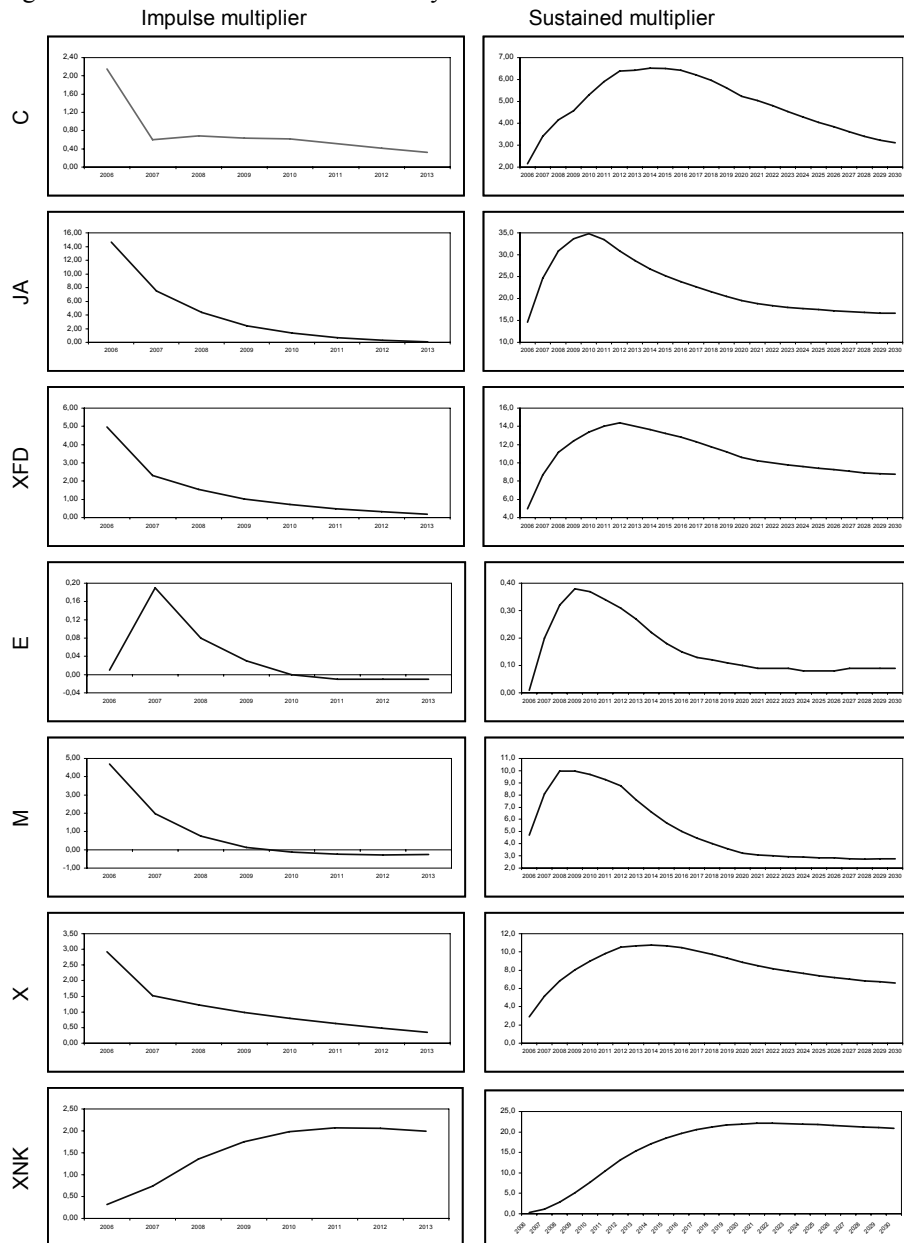
Source: own inwestigation

Hence, there is a long-run tendency for a decline in capacity utilization, which negatively affects the 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.

Table 2. Assumptions of 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 UE 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: own inwestigation

The multiplier analysis helped to launch a new series of long-term forecasts and scenario analyses underpinned by the model-based simulations. We distinguished two scenarios only. In the optimistic variant we assumed 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. In the pessimistic variant- the deterioration of these factors was assumed. The specific assumptions are shown in table 2.

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[3]

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. 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 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. Taking into account the indirect impact of investment growth the domestic final demand would exceed the baseline forecast by 14% in 2013 and by 40% in 2030.

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 growing efficiency in the absorbtion 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%.

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 by 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 raise 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.

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

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

sustain a systematic decline of employment. Hence, the unemployment rates rise dramatically from 10% to nearly 20% in the last years of simulation period.

Figure 5.The TFP rates of growth are declining being the results of low R&D expenditures
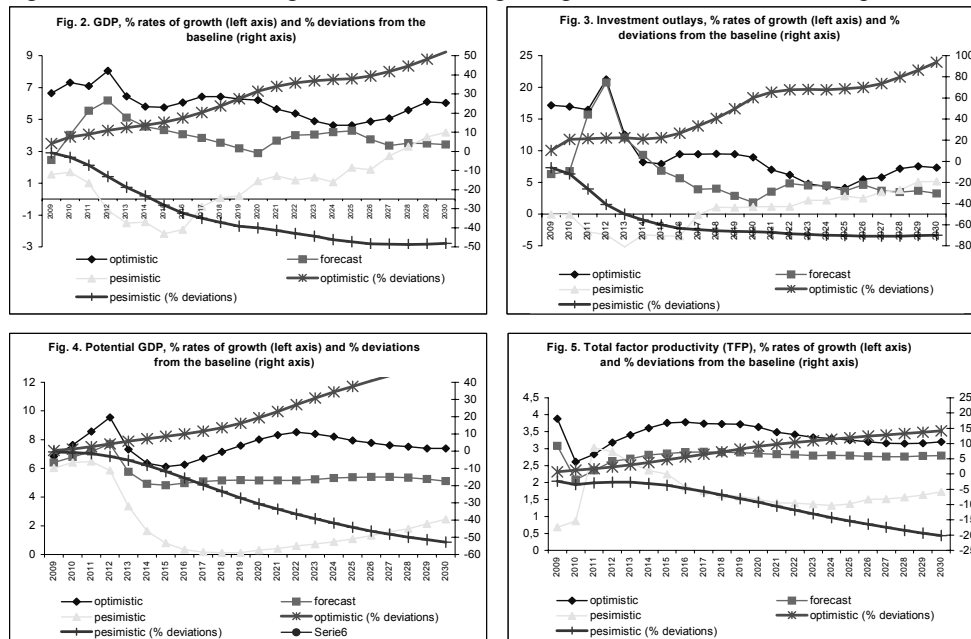
Source: own inwestigation

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 excercise.

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Długookresowy model makroekonometryczny gospodarki polskiej.

Streszczenie: Rozwój współczesnych gospodarek rynkowych w kierunku gospodarek opartych na wiedzy implikuje konieczność budowy nowych długookresowych modeli makroekonometrycznych. Jako przykład pokazano strukturę i wykorzystanie długookresowego W8 modelu dla Polski. Model ten jest kompletny, objaśnia zarówno produkcję, jak i czynniki jej wzrostu, uwzględniając nakłady na B+R i kapitał ludzki, a także popyt finalny, co uniemożliwia wykazywanie potencjalnych źródeł nierównowagi. Model zamykają równania cen i płac oraz objaśniające przepływy finansowe. Symulacyjna wersja modelu zawiera 235 równań, w tym 111 stochastycznych. Model jest używany w budowie długookresowych scenariuszy rozwoju Polski do 2030r.

Słowa kluczowe: kapitał wiedzy, nakłady na B+R, kapitał ludzki, makromodelowanie, mnożniki, scenariusze