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An update of the macroeconometric model of the Polish economy NECMOD

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Abstract

This paper presents an update of the structural macroeconometric model of the Polish economy NECMOD. The updated version of the model is, similarly as its predecessor, used at the National Bank of Poland for forecasting and policy simulation exercises. NECMOD is a hybrid, medium-scale and partially forward-looking quarterly model with its structure rooted in the economic theory. Great emphasis has been put on modelling of the supply side of the economy and mechanisms that introduce high persistency of shocks.

The present version of NECMOD was estimated on the data covering a period from 1995 to 2008. Its main advantage, as compared to the previous version, is a more detailed and coherent approach to the modelling of the external sector block. Now, secular changes in the exchange rate and foreign trade dynamics are explained jointly with reference to the taste-for-variety theory. Moreover, the current version of the model better reflects interdependencies between domestic and external sector, i.e. via exchange rate - wealth channel.

JEL classification: E10, E17, E20, E50, E60

Keywords: Polish economy, macroeconometric model, macroeconomic model

Non-technical summary

In the direct inflation targeting regime, availability of timely and good-quality forecasts is of vital importance to monetary authority. To provide policy makers with accurate forecasts, a model should account for a wide range of factors shaping an economy. Thus the model should well reflect both structural changes and key monetary policy transmission channels. Therefore, forecasting models, in order to better address current issues of interest, should evolve together with the developments in the underlying economy. To follow actual changes in the Polish economy, in its real and nominal side, an update of NECMOD was introduced.

NECMOD is a hybrid, medium-scale and partially forward-looking quarterly macroeconometric model with significant emphasis put on modelling the supply side of the Polish economy. It encompasses most of important elements that facilitate assessment of the state of the macroeconomy, including GDP and its components, labour market, nominal side (costs and prices), external sector and exchange rate, fiscal and monetary variables. NECMOD, with its fully-fledged labour market block (with participation rates and unemployment equilibrium rate endogenously determined) and disaggregated treatment of capital assets (including household real estate capital) reflects the supply side of the economy in a comprehensive manner.

Recently, the model has been further enhanced, foremost in areas that raised particular interest within the year after the publication of the first version of the model. The changes include rebuilding of the external sector block. Now, the foreign trade and exchange rate block accounts in a more comprehensive way for the processes of economic convergence as well as trade integration of the Polish economy into European and global environment. These two important processes are explained jointly and coherently with reference to the taste-for-variety theory. Dynamics of trade volumes and the exchange rate are strongly influenced by preference shocks of Polish and foreign importers, and they are sensitive to the external balance and business cycle swings. Finally, the pace of integration may be affected by global economic situation.

Another new feature of NECMOD is a more precise definition of households' wealth, enabling better reflection of consumer behaviour via the wealth channel.

Advances have been made not only in the degree of sophistication of the model's structure but also in data preparation procedures as well as in the forecast risk analysis. In particular, an introduction of new seasonal adjustment algorithm improved the process of redistribution of discrepancies between seasonally adjusted time series, tied by (statistical or definitional) identities.

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Introduction

This paper presents an update of NECMOD - the structural macroeconometric model of the Polish economy in use at the National Bank of Poland (NBP). NECMOD is a medium-scale quarterly macroeconometric model that can be classified as a hybrid structure, i.e. compromising theoretical consistency and coherence with the empirical data. The NBP's staff developed NECMOD - a construction tailored to analysing and forecasting a converging economy - after Poland's accession to the European Union, which was accompanied by acceleration of globalisation processes.

NECMOD reflects in a comprehensive manner the supply side of the economy with its fully-fledged labour market block (with participation rates and unemployment equilibrium rate endogenously determined) and the disaggregated treatment of capital assets in the economy. The development of the supply side was motivated *inter alia* by the dynamic evolution of the labour market during transition and after EU accession, as well as by the necessity to account for macroeconomic effects of an inflow of different EU structural funds. Moreover, significant volatility in the housing market, with housing bust following housing boom in 2004-2008, necessitated distinguishing household real estate capital and explicit formulation of housing investment demand and supply functions in order to pursue the proper evaluation of both the potential product and households' wealth. The development of the labour market in the model triggered positive spillovers to other blocks of NECMOD, including distortionary taxation in the fiscal block affecting labour demand and supply, costs and investment decisions of agents. Explicit forward-looking expectations are another characteristic feature of NECMOD. Together with their backward-looking counterparts, they are built into price - costs and interest rate blocks of the model.

Still, in a fast changing economic environment, there is a constant need to follow current processes underlying both real and nominal sides of the economy. In 2009, due to changes in the economic conditions, some model areas were further enhanced to better reflect the developments which are currently driving the Polish economy and are expected to be not less important in the future. These include the introduction of:

- the block of external sector with exchange rate determination derived from the taste-for-variety theory,

- more precise definition of household wealth,

- higher level of fiscal sector sophistication,

- refurbished specification of the dynamics of inventories.

One of the aims of this paper is to shed light on the above-mentioned improvements in NECMOD. The specification of the model has not changed significantly since its last publication. Therefore, the description of the model is abbreviated to the necessary minimum. The focus of this paper is to clarify the introduced modifications. For the detailed description of the NECMOD see Budnik et al. (2009).

Here, we also discuss technical issues in a more detailed manner, which can be useful for macro forecasters. These include foremost seasonal adjustment procedure and fan chart construction. As regards the former, as before, variables that enter the model are seasonally adjusted in a way that preserves identities resulting from definitions of

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the aggregated categories. Now, the process has been further improved and a new, non-iterative algorithm has been introduced. As regards a fan chart construction, we provide an extended description of data sources used and more in depth explanation of the procedure.

Next section deals with technical aspects of the preparation of data suitable for macroeconomic forecasting, including seasonality issues. Although Section 3 depicts the structure of the model block by block, including details of all behavioural equations after model re-estimation. Section summarises also long-term properties of the model. The new elements of NECMOD are given unabridged treatment. Section 4 comments on impulse responses of NECMOD. Risk analysis is a topic of Section 5 and Section 6 concludes.

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Data and seasonal adjustment

For forecasting purposes consistency between disaggregated and aggregated data should be retained in the process of seasonal adjustment. The use of the standard seasonal adjustment methods results in discrepancies that occure after aggregation of variables and, for that reason, we use joint seasonal adjustment methods. After defining problems associated with the seasonal adjustment of the aggregated series and recalling the previous iterative solution used to tackle this problem, in this section we introduce a new algorithm of the joint seasonal adjustment.

2.1   Problems with aggregated series[1]

Seasonally adjusted series may be required to satisfy a few simultaneous constraints:

- additivity (e.g. GDP and its components),

- non-linear constraints (e.g. deflators, nominal and real values),

- end-of-year constraint (yearly sum of raw data equals sum of adjusted series).

Finally, we want to keep as good quality of seasonal adjustment as possible. For that reason discrepancies resulting from separate seasonal adjustment cannot be attributed to a single variable. They should rather be distributed among all series in a given block.

In NECMOD, problems with aggregated series occur in three groups of variables that correspond to three model blocks: labour market, the National Accounts and fiscal sector, with different types of constraints binding for each group:

Table 1: Constraints binding groups of variables

Group	Number of variables and relations	Constraints
Labour market	16 variables 8 equations	additivity
Fiscal variables	49 variables 13 equations	additivity end-of-year constraints
National Accounts	20 variables 8 equations	additivity non-linear constraints

Variables from labour market group should fulfil additivity constraint. Next to the additivity constraint, an additional end-of-year constraint for fiscal sector variables makes the problem of their seasonal adjustment two-dimensional, but still linear: at any given time variables have to be consistent with model identities and to sum up to given budget

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[1]For general description of seasonal adjustments and problems with aggregated seasonal series see Budnik et al. (2009)

categories in yearly terms. For the National Accounts data nonlinear restrictions are binding, i.e., the deflator of GDP should be equal to the nominal GDP divided by the real GDP. The same relation should be satisfied for each of GDP components. At the same time, nominal or real GDP should be a sum of its components. Presence of both nonlinear and linear constraints complicates the problem of the joint adjustment of seasonal series even further.

2.2 Iterative procedure

One of the solutions to this problem, followed in Budnik et al. (2009) was an iterative procedure of redistributing discrepancies from each constraint to all related variables. The procedure consisted of two steps. First, all series were seasonally adjusted with TRAMO/SEATS or X-12-Arima methods[2]. Second, seasonally adjusted time series were subsequently iteratively transformed in order to decompose discrepancies between postulated identities and composite variables obtained as a sum of the components. The proportion of the deviation from identities attributable to a particular time series was either proportional to relative value of the variable in this period (and therefore time-varying) or given by experts as a constant (chosen on the basis of the evaluation of volatility and the average value of variables, the quality of first step seasonal adjustment and correlation of variables with related discrepancies). In each iteration, only part of the total discrepancy from each constraint (usually 10%) was attributed to all related variables. Using small steps and large number of iterations resulted in convergence of the algorithm and obtaining coherent results.

One of the main advantages of that method was stability of the results (given parameters of models that were used for first-step seasonal adjustment of time series) and proportional distribution of discrepancies to all related variables.

Still, weighting system used to distribute the discrepancies could lead to unsatisfactory results. Specifically, for the weights set by experts as constants (i.e. for the National Accounts data) there was no revision mechanism that would automatically adjust past weights. Additionally, weights proportional to value of elements of a variable were performing poorly when used in seasonal adjustment of series with high variation and with values close to or below zero (i.e. the government balance). Moreover, weights set in the procedure described above did not account for the quality of the seasonal adjustment of time series in the first step. And finally, due to an iterative nature of the method, the results were dependent on parameters of the algorithm, namely on:

- size of iteration step,

- number of iterations,

- order of equations.

2.3 Joint seasonal adjustment method

A new algorithm was developed in order to eliminate shortcomings of the method described above. The most important modification introduced was withdrawal from the use of an

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[2]In each NECMOD re-estimation round, new seasonal models are built for each series.

iterative procedure in favour of an analytical solution. The analitical solution of joint seasonal adjustment problem makes the algorithm independent of its parameters (and also proves faster in finding the solution). This method is inspired by ideas put forward by van der Ploeg (1982). He proposed a method of imposing linear constraints to ensure consistency of the National Accounts data. The system of weights proposed in van der Ploeg (1982) was based on variance-covariance matrix. The method was flexible enough to be implemented for any aggregated variables as long as they were expected to fulfil only linear constraints.

In this paper we introduce an approach that generalises the method proposed by van der Ploeg (1982) to non-linear constraints that appear in the National Accounts data, where consistency between deflators, nominal and real values is required. Another important contribution is a standardisation of weights, so that they are homogenous for all variables, automatically updated and account not only for variation but also the quality of seasonal adjustment of time series as measured by several statistics described in detail in this section.

2.4   Technical details of the algorithm

In the first step all time series subject to joint seasonal adjustment procedure are individually adjusted with TRAMO-SEATS method[3]. The discrepancies are then redistributed using the balancing algorithm.

In order to balance series in each group the following formula is used:

$$y_t^{bal} = y_t - S \cdot A \cdot (A' \cdot S \cdot A)^{-1} \cdot (A' \cdot y_t - a') \tag{1}$$

where:

y_t^{bal} - vector of balanced seasonally adjusted variables in period t

y_t - vector of unbalanced seasonally adjusted variables in period t

S - modified variance-covariance matrix

A - matrix of linear constraints

a - vector of autonomous terms related to linear constraints

Matrix S is modified so that covariances equal zero while variances are replaced with weights.

$$S = \begin{pmatrix} weight_1 & 0 & 0 & 0 & 0 \\ 0 & \ddots & 0 & 0 & 0 \\ 0 & 0 & weight_i & 0 & 0 \\ 0 & 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & 0 & weight_n \end{pmatrix}$$

Weights are constant in time and reflect both amplitude of fluctuations of raw time series and the quality of seasonal adjustment (given by eight statistics) of a variable[4]:

---

[3]The requirement of homogenous method (e.g. TRAMO-SEATS) was needed to keep comparable weights of joint adjustment.

[4]Weights are updated jointly with models of seasonal adjustment from the first-step of the procedure

$$weight_i = std(|y_t - y_{t-4}|) \cdot \frac{10}{8} \cdot \Sigma_{j=1}^{8} \cdot \left| \frac{statistic_j - optimalvalue_j}{limitvalue_j - optimalvalue_j} \right| \tag{2}$$

where:

$statistic_j$ - is one from the list: Ljung-Box on residuals, Box-Pierce on residuals, Ljung-Box on squared residuals, Box-Pierce on squared residuals, normality, skewness, kurtosis, percentage of outliers.

$limitvalue_j$- the limits of the confidence intervals for the concerned test statistics (with highest confidence levels, e.g. 0.1%)

$optimalvalue_j$- the optimal values for the concerned test statistics: 3 for kurtosis and 0 for other statistics.

Conditioning weights on test statistics reflecting quality of seasonal adjustment in the first step helped to improve quality of variables after whole procedure of joint seasonal adjustment. Series that were seasonally adjusted with statistically poorly matched ARIMA models were updated with higher share of discrepancies than those adjusted with better suited models. Dependence of weights on the standard deviation of a variable supports a redistribution of discrepancies to time series with a higher variation. As standard deviation is calculated for the absolute year-on-year changes, it prevents the algorithm from giving too high shares of deviations to variables with relatively low values in absolute terms.

Due to a presence of non-linear constraints (deflators), joint adjustment of National Accounts data cannot be made using the analytical solution described above (1). Instead we use optimisation function[5], which minimises: $(y_t^{bal} - y_t) \cdot S^{-1} \cdot (y_t^{bal} - y_t)$ subject to linear constraints: $A \cdot y_t^{bal} = 0$ and nonlinear constraints: $nominal_i = real_i \cdot deflator_i$. Matrix S is built similarly as the matrices for labour market and fiscal variables. In this way algorithm for National Accounts deals with all types of constraints and, at the same time, is coherent with the methods applied for other blocks.

Another difficulty with joint adjustment procedures is the presence of unbalanced panels of data which are supposed to fulfil a set of restrictions in a sample period. For example, population variables are available for longer time span than the number of participants and non-participants on the labour market.

Therefore, in each period t only those restrictions are kept for which observations of related variables are available. In our example, for periods where data for the number of participants and non-participants are missing, additivity constraint shall be imposed on sub-population variables, but not on active and non-active population. We deal analogously with end-of-year constraints - algorithm adjusts series only in those years for which all four quarters are available.

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during each model re-estimation.

[5]Optimisation function uses trust-region-reflective algorithm.

3

Structure of the model[6,7]

3.1 Production sector

Production function constitutes the core of the supply side of the model. It combines factor inputs (labour and productive capital) with a Cobb-Douglas technology (3). Corporate and public capital, accumulated in line with perpetual inventory idea [(5) and (6)], are bundled into productive capital under assumption of imperfect substitutability (4)[8].

Long-run demand for labour is residually derived from production function.

Long-run demand of enterprises for the corporate capital follows from the equalization of the marginal product with the real user cost of capital (7). The real user cost of capital is tied to the level of the real interest rate and adjusted for depreciation rate, tax shield (net effective corporate tax burden) and plausible reduction of the user cost of capital in line with the inflow of the EU structural funds allocated for the development of private enterprises and farming investments (8). Public capital investments, in turn, is a sum of government expenditure and the structural funds allocated for the development of infrastructure.

Enterprises in the economy keep constant proportion of inventories stock to the level of production taking into account alternative costs of inventories accumulation proxied by the real interest rate.

Labour supply, variation of labour costs and expenditure on the active labour market policy, as well as structural funds aimed at human capital development, contribute to the short-run fluctuations of labour demand. Investment demand in the short run is characterized high inertia. The energy prices surrogate costs of investment. The financial position of enterprises serves as proxy for financial accelerator effect (16). Public investments evolve with nominal GDP changes. Finally, short-run variation of inventories is tied to changes in the level of sales.

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[6]For the description of estimation approach see the previous version of the model [Budnik et al. (2009)]. For most of the equations, OLS technique is used with standard errors assumed to follow a white noise process. Equations with forward looking elements are estimated with GMM - the choice of instruments is then guided by the literature. J-statistics indicate that the null hypothesis that the overidentifying restrictions are satisfied can not be rejected. Finally, for equations estimated jointly SUR approached is followed. It should be stressed that in some cases we sacrifice sound statistical properties of the single equation to superior simulation properties of the whole model. For example, it is the case with LM test statistics (or Q test statistics for systems of equation) for serial correlation. If it was not possible to tackle correlation without loosing desired model simulation properties we kept potentially biased specifications (it is important in cases where lagged dependent variables are present in the set right-hand-side variables).

[7]Detailed definitions of variables used in this section can be found in Appendix. Lower case letters denote natural logarithms. Stars refer to levels of variables consistent with the relevant cointegrating relationship. Standard errors of parameters are reported below their point estimates in parenthesis.

[8]For details of calibration and gross/net capital relation see Budnik et al. (2009)

3

Long-run solution

Production function

$$GDP_t = TFP\_TREND_t \cdot EMP_t^{0.67} \cdot KN_t^{1-0.67} \tag{3}$$

$$KN_t = \left(0.70^3 \cdot KN\_P_t^{-2} + (1-0.70)^3 \cdot KN\_G_t^{-2}\right)^{-\frac{1}{2}} \tag{4}$$

Capital accumulation

$$\begin{aligned} K\_P_t = {} & (1 - LIK\_P_t) \cdot K\_P_{t-1} + 0.30 \cdot GFCF\_P_t \\ & + 0.20 \cdot GFCF\_P_{t-1} + 0.22 \cdot GFCF\_P_{t-2} \\ & + 0.09 \cdot GFCF\_P_{t-3} + 0.08 \cdot GFCF\_P_{t-4} \\ & + 0.06 \cdot GFCF\_P_{t-5} + 0.05 \cdot GFCF\_P_{t-6} \end{aligned} \tag{5}$$

$$\begin{aligned} K\_G_t = {} & (1 - LIK\_G_t) \cdot K\_G_{t-1} + 0.14 \cdot GFCF\_G_t \\ & + 0.15 \cdot GFCF\_G_{t-1} + 0.18 \cdot GFCF\_G_{t-2} \\ & + 0.18 \cdot GFCF\_G_{t-3} + 0.15 \cdot GFCF\_G_{t-4} \\ & + 0.12 \cdot GFCF\_G_{t-5} + 0.09 \cdot GFCF\_G_{t-6} \end{aligned} \tag{6}$$

Marginal product and user cost of capital

$$MPK_t = 0.70^3 \cdot (1 - 0.67) \cdot \frac{GDP\_POT_t}{KN_t} \cdot \left(\frac{KN_t}{KN\_P_t}\right)^3 \tag{7}$$

$$RUCC_t = \frac{R\_RATE_t/4 + DISC\_P_t}{(1 - G\_CORP\_TR_t)(1 + G\_CORP\_EU_t)} \tag{8}$$

$$\begin{aligned} R\_RATE_t = {} & 0.50 \cdot I\_3MR\_PVA_t \\ & + 0.50 \cdot (I\_5Y_t - INF\_TARGET_{t+1}) \end{aligned} \tag{9}$$

$$\begin{aligned} G\_CORP\_TR_t = {} & (1 - \frac{EMP\_A_t}{EMP_t}) \cdot (GR\_CIT\_TR_t \\ & - \frac{GE\_SUB\_NOFARM\_N_t + GE\_CAP\_TRANS\_N_t}{OPSURP\_N_t}) \\ & + \frac{EMP\_A_t}{EMP_t} \cdot GR\_FARM\_TR_t \end{aligned} \tag{10}$$

$$G\_CORP\_EU_t = \frac{TRANS\_GFCF\_P\_N_t + TRANS\_GFCF\_F\_N_t}{GFCF\_P_t \cdot PVA_t}$$

$$(11)$$

Public investments

$$GFCF\_G_t = GE\_GFCF_t + \frac{TRANS\_GFCF\_G\_N_t}{PGFCF\_G_t} \qquad (12)$$

$$\Delta ge\_gfcf_t = \Delta gdp_t \qquad (13)$$

Inventories

$$STOCK_t = (0.78 - 0.55 \cdot I\_3MR\_PVA_t) \cdot GDP\_POT_t \qquad (14)$$

$$INV_t = STOCK_t - STOCK_{t-1} \qquad (15)$$

Financial position of enterprises

$$
\begin{aligned}
FINACC_t = \ & (OPSURP\_N_t + KN\_P_t \cdot PGDP_t \cdot DISC\_P_t \\
& -GR\_FARM\_N_t - GR\_CIT\_N_t \\
& +GE\_SUB\_NOFARM\_N_t \\
& +GE\_CAP\_TRANS\_N_t - YD\_NOS\_N_t \\
& -YD\_PRO\_NOGINT\_N_t \\
& +G\_REF_t \cdot OFE\_N_t + GE\_INT\_NRES\_N_t \\
& +CAB\_INC\_EUR\_NOREM_t \cdot S\_EUR\_PLN_t) \\
& /GDP\_N_t
\end{aligned}
\qquad (16)
$$

$$
\begin{aligned}
OPSURP\_N_t = \ & GDP\_N_t - GR\_PROD\_TAX\_N_t \\
& -YD\_WF\_N_t - GR\_CORP\_N_t \\
& -GR\_OTAX\_CORP\_N_t \\
& -KN\_P_t \cdot PGDP_t \cdot DISC\_P_t
\end{aligned}
\qquad (17)
$$

3

3

Short-run solution

Investment demand

$$\Delta gfcf\_p_t \;=\; \underset{(0.51)}{0.32} \cdot (MPK_{t-1} - RUCC_{t-1}) + \underset{(0.05)}{0.39} \cdot gfcf\_p_{t-1} \quad (18)$$

$$+0.39^{3/2} \cdot \Delta gfcf\_p_{t-2} + (1 - 0.39 - 0.39^{3/2})\Delta gdp_t$$

$$-\underset{(0.02)}{0.02}(\Delta_4(p\_ener_t + s\_usd\_pln_t - pva_t)$$

$$+\underset{(0.2)}{0.1} \cdot \Delta FINACC_t$$

$$-\underset{(0.01)}{0.05}(I01Q1 + I01Q2 - I02Q3 - I06Q2)$$

Adjusted R^2 = 0.62
S.E. of regression = 0.022
LM test (p-value) = 0.11
Estimation sample: 1996q1 - 2008q4

Labour demand

$$\Delta emp_t \;=\; \underset{(0.10)}{0.37} \cdot \Delta emp_{t-1} \qquad\qquad\qquad (19)$$

$$+(1 - \underset{(0.10)}{0.37}) \cdot \Delta log(LF_t(1 - NAWRU_t))$$

$$-\underset{(0.03)}{0.07} \cdot (-(gdp_{t-1} - 0.67 \cdot emp_{t-1}$$

$$+(1 - 0.67) \cdot kn_{t-1} - tfp\_trend_{t-1})/0.67)$$

$$+\underset{(0.09)}{0.10} \cdot (\Delta gdp - \Delta tfp\_trend_t/0.67)$$

$$+\underset{(0.64)}{7.64}\Delta \sum_{i=0}^{4} \frac{ALMP\_N_{t-i-1}}{PGDP_{t-i-1} \cdot GDP\_POT_{t-i-1}}$$

$$-\underset{(0.06)}{0.02}(\Delta(wage\_n_t + gr\_corp\_tr_t - pva_t) - \Delta tfp\_trend_t/0.67)$$

Adjusted R^2 = 0.74
S.E. of regression = 0.003
LM test (p-value) = 0.001
Estimation sample: 1997q1 - 2008q4

Inventories

$$\Delta stock_t = \underset{(0.07)}{0.83} \cdot \Delta stock_{t-1} + (1 - \underset{(0.07)}{0.83}) \cdot sales_t \qquad (20)$$
$$- \underset{(0.02)}{0.05} \cdot (STOCK_{t-1} - STOCK^*_{t-1})/GDP\_POT_{t-1}$$

Adjusted R^2 = 0.69
S.E. of equation = 0.006
LM test (p-value) = 0.13
Estimation period: 1996q1 - 2008q4

3

3.2 Households sector

Households in the model meet decisions about their consumption and investments. They own enterprises, residential capital and debt issued by the government. Their wealth is proportionate to corporate and housing capital as well as the net foreign assets excluding government debt possessed by non-residents.

The level of consumption is determined according to the permanent income hypothesis. The permanent income is proxied by the weighted average of wealth and real disposable income of households. In recent years households increased their indebtness levying ratio of their liabilities to assets, which means that positive balance of interests payments between households and financial sector diminished. To capture this effect, we decided to introduce the additional control variable in the consumption function, namely the difference between financial assets and liabilities of households normalised by their nominal wealth.

Demand for residential capital is proportional to the level of consumption and the real user cost of housing capital[9]. Still, changes in the population structure may violate the stability of the relationship leading to a change in preferences between consumption level and residential capital accumulation observed at the aggregate level. Residential capital supply is assumed to depend on the potential output and the relative prices of houses.

Households' disposable income is a sum of remuneration from work (aggregate wages) plus social security and social assistance benefits net of income and property taxes and social security contributions. Disposable income also includes gross operating surplus generated by micro-firms and farmers, property income including interests on public debt owned by residential households, general government expenditure on social relief in kind, direct transfers to farmers financed from the Common Agricultural Policy funds or co-financed by the government, as well as the balance of remittances.

Households' nominal income from property excluding interests on public debt is in the long run a function of nominal GDP, real interest rate and wealth. The relation is

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[9]As a result, monetary policy affects housing investments through long-term interest rates—we do not model mortgage market in more detailed way.

corrected with the ratio of households financial liabilities to assets. Households' nominal income from operating surplus is expected to be proportional to GDP.

In the short run fluctuations of consumption depend on real interests rate and disposable income changes. Residential investments in the short run exhibits some degree of inertia. Finally, prices of residential capital depend on the cost of residential capital, consumer and property prices and on the output gap. The latter element allows for higher volatility of housing prices as compared to other prices in the business cycle.

3

Long-run solution

Consumption

$$
\begin{aligned}
conp_t \; = \; & 0.86 \cdot yd_t + (1 - 0.86) \cdot wealth_t - 0.35 \qquad (21) \\
& -0.16 \cdot I\_3MR\_CPI_t \\
& +0.24 \cdot HH\_NET\_WEALTH\_RATIO_t
\end{aligned}
$$

Residential investments and prices

$$
\begin{aligned}
gfcf\_h_t \; = \; & -3.50 + gdp\_pot_t + 0.27 \cdot (pgfcf\_h_t \qquad (22) \\
& -0.32 \cdot GR\_VAT\_TR_t - pva_t)
\end{aligned}
$$

$$
\begin{aligned}
k\_h_t \; = \; & 0.22 + conp_t - 0.07 \cdot (rucc\_h_t + pgfcf\_h_t - cpi_t) \quad (23) \\
& +2.03(POP\_M_t / POP_t)
\end{aligned}
$$

$$
\begin{aligned}
RUCC\_H_t \; = \; & (I\_H_t - INF\_TARGET_t + PREMIUM_t)/4 \qquad (24) \\
& +DISC\_H_t
\end{aligned}
$$

$$
K\_H_t \; = \; (1 - LIK\_H_t) \cdot K\_H_{t-1} + \sum_{i=0}^{8} GFCF\_H_{t-i} \qquad (25)
$$

Disposable income

$$
\begin{aligned}
YD_t \;=\; & (YD\_WF\_N_t + GE\_UNEMP\_N_t \cdot (1 - GR\_CORP\_TR_t) \\
& + GE\_PENSIONS\_N_t \\
& + GE\_FAMILY\_N_t \cdot (1 - 0.16 \cdot GR\_CORP\_TR_t) \qquad (26) \\
& + GE\_PRERETIRE\_N_t + GE\_SOCSECURITY\_N_t \\
& + GE\_RELIEF\_REST\_N_t + GE\_RELIEF\_KIND\_N_t \\
& + TRANS\_CAP\_N_t + GE\_SUB\_FARM\_N_t \\
& - GR\_EMP\_N_t - GR\_FARM\_N_t - GR\_HC\_N_t \\
& - GR\_PIT\_N_t - GR\_PIT\_CIT\_N_t - GR\_OTAX\_HH\_N_t \\
& + REM\_BALANCE_t \cdot S\_EUR\_PLN_t + YD\_NOS\_N_t \\
& + YD\_PRO\_NOGIT\_N_t + GE\_INT\_RES\_N_t)/CPI_t
\end{aligned}
$$

$$
\begin{aligned}
yd\_pro\_nogint\_n_t \;=\; & gdp\_n_t - 4.67 \qquad\qquad\qquad (27) \\
& + 1.26 \cdot (WEALTH_t/GDP_t) \cdot I\_3M_t \\
& + 2.11 \cdot HH\_NET\_WEALTH\_RATIO_t
\end{aligned}
$$

$$
yd\_nos\_n_t \;=\; -1.33 + gdp\_n_t \qquad\qquad\qquad (28)
$$

Wealth

$$
\begin{aligned}
WEALTH_t \;=\; & (KN\_P_t \cdot PVA_t \cdot (1 + GR\_VAT\_TR_t) \qquad (29) \\
& + KN\_H_t \cdot PGFCF\_H_t + G\_DEBT\_RES\_N_t \\
& + NFA_t - G\_DEBT\_NRES\_N_t)/CPI_t
\end{aligned}
$$

3

3

Short-run solution

Operating surplus and property income

$$\Delta yd\_nos\_n_t = \Delta gdp\_n_t - \underset{(0.09)}{0.34}(yd\_nos\_n_{t-1} - yd\_nos\_n^*_{t-1})$$
$$- \underset{(0.02)}{0.16}(I99Q2 - I99Q3) \tag{30}$$

Adjusted R^2 = 0.69
S.E. of equation = 0.03
LM test (p-value) = 0.006
Estimation period: 1995q2 - 2008q4

$$\Delta yd\_pro\_nogit\_n_t = \underset{(0.06)}{-0.17} \cdot (yd\_pro\_nogit\_n_{t-1} - yd\_pro\_nogit\_n^*_{t-1})$$
$$+ \underset{(0.12)}{0.77} \cdot \Delta yd\_pro\_nogit\_n_{t-1}$$
$$+ (1 - \underset{(0.11)}{0.77}) \cdot \Delta gdp\_n_{t-1} \tag{31}$$

Adjusted R^2 = 0.50
S.E .of equation = 0.04
LM test (p-value) = 0.34
Estimation period: 1997q2 - 2008q4

Consumption

$$\Delta conp_t = \underset{(0.04)}{0.86} \cdot (\Delta tfp\_trend_t/0.67) + (1 - \underset{(0.04)}{0.86}) \cdot \Delta yd_t$$
$$- \underset{(0.06)}{0.21} \cdot (conp_{t-1} - conp^*_{t-1}) \tag{32}$$
$$- \underset{(0.07)}{0.06} \cdot \Delta(I\_3MR\_CPI_t)$$

Adjusted R^2 = 0.08
S.E. of equation = 0.005
LM test (p-value) = 0.11
Estimation period: 1997q2 - 2008q4

Residential investments and prices

$$\Delta gfcf\_h_t = \Delta gdp\_pot_t - \underset{(0.09)}{0.24} \cdot (gfcf_{t-1} - gfcf^*_{t-1}) \qquad (33)$$

$$- \underset{(0.04)}{0.18} \cdot (I02Q2_t - I02Q3_t) + \underset{(0.18)}{0.32} \cdot \Delta(pgfcf\_h_{t-1}$$

$$- 0.32 \cdot GR\_VAT\_TR_t - pva_{t-1})$$

Adjusted R^2 = 0.43
S.E. of equation = 0.054
LM test (p-value) = 0.29
Estimation period: 1996q1 - 2008q4

$$\Delta pgfcf\_h_t = \underset{(0.04)}{0.34} \cdot \Delta cpi_t + (1 - \underset{(0.04)}{0.34}) \cdot \Delta pgfcf\_h_{t-1} \qquad (34)$$

$$- \underset{(0.08)}{0.09} \cdot (k\_h_{t-1} - k\_h^*_{t-1})$$

$$- \underset{(0.03)}{0.08} \Delta(0.08 + I\_H_t - \Delta_4 pgfcf\_h_{t-1}) + \underset{(0.07)}{0.16} \cdot GAP_t$$

$$+ \underset{(0.01)}{0.04} \cdot (I03Q1_t - I03Q2_t)$$

$$+ \underset{(0.01)}{0.05} \cdot (I06Q1_t + I06Q2_t + I06Q3_t + I06Q4_t)$$

Adjusted R^2 = 0.93
S.E. of equation = 0.009
LM test (p-value) = 0.09
Estimation period: 1996q3 - 2008q4

3.3 Labour supply

The approach we take to model labour supply in NECMOD refers to discouragement and marginal worker effects. Labour supply is modelled separately for three age groups to better assess different factors impinging upon participation rates of workers of different ages. The actual and equilibrium participation rates, derived on the basis of the specification, reflect changes in the activity rates for population subgroups jointly with changes in population structure.

Long-run solution

Labour force 15-24

$$\frac{LF\_Y_t}{POP\_Y_t} = 1 - 0.36 \cdot \overline{UNRATE}_t \tag{35}$$
$$-0.03 \cdot (1 - D99Q1_t) + 0.01 \cdot (1 - D97Q1_t)$$
$$-0.3 \cdot (GR\_EMP\_TR_t + GR\_PIT\_TR_t$$
$$+GR\_HC\_TR_t) - 0.3 \cdot (GR\_VAT\_TR_t$$
$$+W\_CORE_t \cdot GR\_GAM\_TR_t + (W\_ENER_t$$
$$+W\_CORE_t) \cdot GR\_EXT\_TR_t) - 0.009 \cdot minw_t$$
$$-1.54 \cdot STUDENT_t - 0.01 \cdot rr\_rem_t$$

Labour force 25-44

$$\frac{LF\_M_t}{POP\_M_t} = 0.89 + 0.02 \cdot \overline{UNRATE}_t \tag{36}$$
$$-0.01 \cdot rr\_nfl\_m_t$$
$$-0.1 \cdot (GR\_EMP\_TR_t + GR\_PIT\_TR_t$$
$$+GR\_HC\_TR_t) - 0.1 \cdot (GR\_VAT\_TR_t$$
$$+W\_CORE_t \cdot GR\_GAM\_TR_t + (W\_ENER_t$$
$$+W\_CORE_t) \cdot GR\_EXT\_TR_t)$$
$$-0.01 \cdot (1 - D99Q1_t) + 0.003 \cdot (1 - D97Q1_t)$$

Labour force 45+

$$\frac{LF\_O_t}{POP\_O_t} = -0.40 - 0.28 \cdot \overline{UNRATE}_t \tag{37}$$
$$-0.18 \cdot rr\_nfl\_o_t - 0.3 \cdot (GR\_EMP\_TR_t$$
$$+GR\_PIT\_TR_t + GR\_HC\_TR_t)$$
$$-0.3 \cdot (GR\_VAT\_TR_t$$
$$+W\_CORE_t \cdot GR\_GAM\_TR_t + (W\_ENER_t$$
$$+W\_CORE_t) \cdot GR\_EXT\_TR_t)$$
$$+WORK\_AGE_t - 0.09 \cdot rr\_relief\_kind_t$$
$$+0.04 \cdot (1 - D97Q1_t)$$

$$\frac{LF_t}{POP_t} = \frac{POP\_Y_t}{POP_t} \cdot \frac{LF\_Y}{POP\_Y} + \frac{POP\_M_t}{POP_t} \cdot \frac{LF\_M_t}{POP\_M_t}$$
$$+ \frac{POP\_O_t}{POP_t} \cdot \frac{LF\_O_t}{POP\_O_t} \tag{38}$$

Short-run solution

Labour force 15-24

$$\Delta lf\_y_t = \underset{(0.15)}{-0.30} \cdot \left(\frac{LF\_Y_{t-1}}{POP\_Y_{t-1}} - \left(\frac{LF\_Y_{t-1}}{POP\_Y_{t-1}} \right)^* \right)$$
$$+ \Delta pop\_y_t + \underset{(0.18)}{0.42} \cdot (\Delta(wage\_n_{t-1} - cpi_{t-1})$$
$$- \Delta tfp\_trend_{t-1}/0.67) + \underset{(0.03)}{0.05} \cdot \Delta minw_t \tag{39}$$

Adjusted R^2 = 0.35
S.E. of equation = 0.011
LM test (p-value) = 0.10
Estimation period: 1996q1 - 2008q4

Labour force 25-44

$$\Delta lf\_m_t = \underset{(0.13)}{-0.40} \cdot \left(\frac{LF\_M_{t-1}}{POP\_M_{t-1}} - \left(\frac{LF\_M_{t-1}}{POP\_M_{t-1}} \right)^* \right) \tag{40}$$
$$+ \underset{(0.09)}{0.15} \cdot \Delta lf\_m_{t-1} + \underset{(0.09)}{(0.15)^2} \cdot \Delta lf\_m_{t-2}$$
$$+ (1 - \underset{(0.09)}{0.15} - \underset{(0.09)}{0.15^2}) \cdot \Delta pop\_m_t - \underset{(0.01)}{0.01} \cdot \Delta rr\_nfl\_m_t$$

Adjusted R^2 = 0.69
S.E. of equation = 0.002
LM test (p-value) = 0.02
Estimation period: 1996q1 - 2008q4

Labour force 45+

$$
\begin{aligned}
\Delta lf\_o_t \;=\; & -\underset{(0.05)}{0.14} \cdot \left(\frac{LF\_O_{t-1}}{POP\_O_{t-1}} - \left(\frac{LF\_O_{t-1}}{POP\_O_{t-1}} \right)^{*} \right) \\
& + \Delta pop\_o_t - \underset{(0.03)}{0.08} \cdot \Delta rr\_nfl\_o_t \\
& - \underset{(0.03)}{0.04} \cdot \Delta rr\_relief\_kind_t \\
& + \Delta WORKAGE_t + \underset{(0.10)}{0.08} (\Delta wage\_n_{t-1} \\
& - \Delta cpi_{t-1} - \Delta tfp\_trend_{t-1}/0.67)
\end{aligned}
\tag{41}
$$

Adjusted R^2 *=0.32*
S.E. of equation = 0.007
LM test (p-value) = 0.018
Estimation period: 1996q1 - 2008q4

3.4 Labour market

Wages are set in the bargaining process between firms and workers. This process is represented by long-run labour demand and supply curves that together with short-term dynamics of labour productivity and the unemployment rate, determine behaviour of wages. Once evaluated at equilibrium, labour demand and supply uniquely define NAWRU.

The responsiveness of NAWRU to cyclical and structural changes is mainly tied to labour share in GDP and semi-elasticity of wages with respect to unemployment. As the former coefficient increases and the latter decreases, larger part of adjustment in the labour market takes place through employment as compared to adjustment taking place through wages. Additionally, being related to the state variables, NAWRU exhibits hysteretic behaviour.

In the long run, NAWRU (jointly with the equilibrium participation rate) converge to the stable equilibrium, fully determined by institutional (fiscal and demographic) variables.

In the short-run wages are sticky. Their deviations from the long-term path are associated with the growth rate of labour productivity and changes in unemployment rate. Employment also exhibits certain degree of inertia. Short-run dynamics of employment is also tied to changes in the aggregate demand and real labour costs.

<div style="border:1px solid #ccc; padding:1em; background:#f0f2ef;">

Long-run solution

Wages

$$
\begin{aligned}
wage\_n_t \;=\; & 5.51 + (1/0.67) \cdot tfp\_trend_t + cpi_t \qquad\qquad (42) \\
& -0.5 \cdot (GR\_VAT\_TR_t \\
& + (W\_ENER_t + W\_CORE_t) \cdot GR\_EXT\_TR_t \\
& + W\_CORE_t \cdot GR\_GAM\_TR_t) \\
& -0.88 \cdot UNRATE_t + 0.06 \cdot rr\_unemp_t \\
& +0.5 \cdot (GR\_PIT\_TR_t + GR\_HC\_TR_t + GR\_EMP\_TR_t) \\
& -0.5 \cdot GR\_CORP\_TR_t - 0.11 \cdot rr\_rem_t \\
& +5.51 \cdot \Delta pop\_y_t + 0.47 \cdot \frac{POP\_Y_t}{POP_t} \cdot minw_t
\end{aligned}
$$

NAWRU

$$
\begin{aligned}
NAWRU_t \;=\; & (1 - 0.67 + 0.88)^{-1} \cdot ((cpi_t - pva_t + (0.08/0.68) \cdot D04Q3 \\
& -0.5 \cdot (GR\_VAT\_TR_t + (W\_ENER_t \qquad\qquad (43) \\
& + W\_CORE_t) \cdot GR\_EXT\_TR_t \\
& + W\_CORE_t \cdot GR\_GAM\_TR_t)) + 0.5 \cdot (GR\_PIT\_TR_t \\
& + GR\_HC\_TR_t + GR\_EMP\_TR_t + GR\_CORP\_TR_t) \\
& +0.06 \cdot rr\_unemp_t + 0.47 \cdot \left(\frac{POP\_Y_t}{POP_t}\right) \cdot minw_t \\
& +0.47 \cdot (pimp_t^c + GR\_TAR\_TR_t - pva_t \\
& -\left(\frac{EMP\_A_t}{LF_t}\right) + (1 - 0.67) \cdot (lf_t - k\_n_t) \\
& +((1/0.67) - 1) \cdot tfp\_trend_t + 0.5 \\
& -0.11 \cdot rr\_rem_t)
\end{aligned}
$$

</div>

3

Short-run solution

Wages

$$\Delta wage\_n_t = \underset{(0.02)}{-0.05} \cdot (wage\_n_{t-1} - wage\_n^*_{t-1}) \qquad (44)$$

$$+ \underset{(0.03)}{0.05} (pva_{t-1} - pva^*_{t-1}) + \underset{(0.12)}{0.73} \cdot \Delta wage\_n_{t-1}$$

$$+ (1 - \underset{(0.12)}{0.73}) \cdot \Delta cpi_{t-1} + (1 - \underset{(0.11)}{0.73}) \cdot (\Delta gdp_{t-1} - \Delta emp\_na_{t-1})$$

$$- \underset{(0.21)}{0.28} \Delta UNRATE_{t-1}$$

Adjusted R^2 = 0.74
S.E. of equation = 0.007
LM test (p-value) = 0.001
Estimation period: 1996q1 - 2008q4

3.5 External sector

The external sector of the model is based on the fundamental equilibrium exchange rate model, where trade integration of the country realtes to the taste-for-variety theory. Countries are assumed to produce and exchange differentiated goods and the potential product is used as an approximation for variety of products at offer. Therefore, export activity is proportionate to the potential product and import intensity to the potential product of trade partners. The attractive feature of the modelling approach is the implied exchange rate appreciation tied to the country's convergence. The model appears to properly map the trend exchange rate appreciation in Poland and other countries at the lower stages of economic development as compared to their main trading partners and delivers coherent explanation of the phenomenon in a one-sector economy framework. The solution implemented in the model closely refers to the paper by Rubaszek (2009), who was the first to develop a partial equilibrium exchange rate model for Poland with trade based on taste-for-variety theory.

Specification of the external sector is the furthest reaching change in the NECMOD model as compared to its original version. It offers a number of advantages over the former set-up. The former specification of the external sector block separated driving forces of observed trend exchange rate appreciation and the progressing integration of the Polish economy. Trend exchange rate appreciation was described by the gap between the potential output of Poland and its trade partners. The gap between potential outputs, however, was introduced in an *ad hoc* fashion to account for historical trends interpreted as a manifestation of the Balassa-Samuelson effect. The deepening integration of Polish economy was approximated by the introduction of linear trends into export and import ratios to GDP. The other trait of the former specification was its supply-side specification

of export volumes. Exports were assumed to be roughly proportionate to the domestic potential output as the demand for exports was unlimited. The assumption appeared to unsatisfactorily mimic exports dynamics after the reduction of foreign demand rooted in the financial market crunch of 2008. Finally, the equilibrium exchange rate consistent with stable current account to GDP ratio did not enter the exchange rate equation. In fact, convergence of both variables was not assured and highly non-linear formula for fundamental equilibrium exchange rate (FEER) was used mainly for studying persistent shifts in the exchange rate levels in the forecasting exercises.

In the current version of NECMOD, the process of world trade integration is closely tied to GDP level convergence. As long as the difference between potential GDP of Poland and its trade partners prevail and growth rate of Polish economy outpaces growth rates of Western European countries and the United States, the equilibrium rate shall appreciate. The equilibrium exchange rate assures stabilisation of foreign assets to GDP ratio at its equilibrium level. The net foreign assets accumulation equation sums up current account balances over periods and explicitly accounts for the valuation effects. The target current account balance is defined as the current account balance consistent with convergence of the net foreign assets to GDP ratio to its steady-state value. It depends on the speed of the net foreign assets convergence and long-run levels of inflation and GDP growth at home and abroad. Accordingly, the equilibrium exchange rate is determined as an exchange rate consistent with the target current account. Degree of pass-through of the real exchange rate into trade prices and price elasticity of export and import volumes shall jointly determine the optimal response of the exchange rate to the potential growth rates divergence and deterioration or improvement of the net foreign assets.

It is worth noting that properties of the model are such that, in line with medium term appreciation of the Polish zloty, import and export prices decrease in relation to producer prices, while terms-of-trade gradually worsen. Still, to assure that home prices are in the long-run driven solely by the unit labour cost dynamics, trend decline in relative import prices does not impact producer and consumer prices relations (and stationarity of the equilibrium employment rate is also maintained) which has been achieved via introduction of appropriate adjustment in price equations.

Long-run solution

Equilibrium exchange rate

$$
\begin{aligned}
\Delta s\_reer\_eq_t \ = \ & ((1 - 1.51)/(1 + 0.78 \cdot 0.52 + 1.52 \cdot 0.66 - 0.52 - 0.66) \\
& \cdot (\Delta gdp\_pot_t - \Delta gdp\_ext\_pot_t) \qquad\qquad (45) \\
& + (1/(1 + 0.78 \cdot 0.52 + 1.52 \cdot 0.66 - 0.52 - 0.66)) \\
& \cdot (\Delta TCAB_t - \Delta CAB\_TRANS\_INC\_GDP_t)/OPEN_t \\
& + (1/(1 + 0.78 \cdot 0.52) + 1.52 \cdot 0.66 - 0.52 \\
& - 0.66)) \cdot \Delta GR\_TAR\_TR_t
\end{aligned}
$$

3

Export and import prices

$$pexp_t = pva\_ext_t + s\_neer_t - 3.02 - 0.52 \cdot s\_reer_t \quad (46)$$
$$+0.07 \cdot D04Q3$$

$$pimp_t = pva_t - GR\_TAR\_TR_t - 4.08 + 0.66 \cdot s\_reer_t \quad (47)$$
$$+0.04 \cdot D04Q3$$

$$pimp\_core_t = (pimp_t - 0.07 \cdot (p\_oil_t + s\_usd\_pln_t) \quad (48)$$
$$-0.03 \cdot (p\_gas_t + s\_usd\_pln_t))/0.90$$

Exports and imports

$$gdp\_exp_t = gdp\_ext_t - 19.78 + 1.51 \cdot gdp\_pot_t \quad (49)$$
$$-0.78 \cdot (pexp_t - (pva\_ext_t + s\_neer_t))$$
$$+0.22 \cdot D04Q03$$

$$gdp\_imp_t = gdp_t - 12.2 + 1.51 \cdot gdp\_ext\_pot_t \quad (50)$$
$$-1.52 \cdot (pimp_t + GR\_TAR\_TR_t - pva_t)$$
$$+0.04 \cdot D04Q3$$

Balance of payments

$$NFA_t = NFA_{t-1} + NFA_{t-1} \cdot \left(\frac{S\_NEER_t}{S\_NEER_{t-1}} - 1 \right) \quad (51)$$
$$+CAB_t \cdot S\_EUR\_PLN_t$$

$$NFA_t\_GDP_t = NFA_t/GDP\_N_t \quad (52)$$

$$CAB_t = CAB\_NT_t$$
$$+CAB\_TRANS\_EUR\_NOREM_t$$
$$+CAB\_INC\_EUR\_NOREM_t \quad (53)$$
$$+REM\_BALANCE_t$$

$$CAB\_NT_t = (GDP\_EXP_t \cdot PEXP_t \qquad (54)$$
$$-GDP\_IMP_t \cdot PIMP_t)$$
$$/S\_EUR\_PLN_t$$

$$CAB\_TRANS\_EUR\_NOREM_t = TRANS\_EU\_EUR_t \qquad (55)$$
$$-GE\_EU\_EUR_t$$

$$CAB\_TRANS\_INC\_GDP_t = (CAB\_TRANS\_EUR\_NOREM_t$$
$$+CAB\_INC\_EUR\_NOREM_t$$
$$+REM\_BALANCE_t) \qquad (56)$$
$$\cdot S\_EUR\_PLN_t/GDP\_N_t$$

$$CAB\_GDP_t = \frac{CAB_t \cdot S\_EUR\_PLN_t}{GDP\_N_t} \qquad (57)$$

$$CAB\_INC\_EUR\_NOREM_t = -(GE\_INT\_NRES\_N_t$$
$$/S\_EUR\_PLN_t) \qquad (58)$$
$$+((1+I\_5Y\_EUR_{t-1})^{0.25}-1)$$
$$\cdot(NFA_{t-1}+G\_DEBT\_NRES\_N_t)$$
$$/S\_EUR\_PLN_{t-1}$$

$$TCAB_t = 0.025 \cdot (-2.6 - NFA\_GDP_{t-1}) + NFA\_GDP_{t-1}$$
$$\cdot(((1+INF\_TARGET_t)^{0.25})-1+\Delta gdp\_pot_t) \qquad (59)$$
$$-NFA\_GDP_{t-1} \cdot ((1+INF\_TARGET_t)^{0.25}$$
$$-1-0.005)/((1+INF\_TARGET_t)^{0.25}+\Delta gdp\_pot_t)$$

3

3

Short-run solution

Exchange rate

$$
\begin{aligned}
\Delta s\_reer_t \;=\; & -\underset{(0.12)}{0.33} \cdot (s\_reer_{t-1} - s\_reer\_eq_{t-1} - \underset{(0.05)}{1.86}) \qquad (60)\\
& -\underset{(0.32)}{0.69} \cdot (I\_3MR\_PVA_t - I\_3MR\_EXT_t)\\
& -\underset{(0.52)}{1.67} \cdot GAP_{t-1} - \underset{(2.12)}{2.27} \cdot \Delta G\_BALANCE\_GDP_t\\
& -\underset{(0.59)}{0.18} \cdot \Delta CAB\_GDP_t\\
& -\underset{(0.78)}{0.67} \cdot (I\_5Y_t - INF\_TARGET_t - I\_5Y\_EUR_t + 0.02)
\end{aligned}
$$

Adjusted $R^2 = 0.31$
S.E. of equation = 0.041
LM test (p-value) = 0.04
Estimation period: 2001q1 - 2008q4

Export and import prices

$$
\begin{aligned}
\Delta pexp_t \;=\; & -\underset{(0.09)}{0.42} \cdot (pexp_{t-1} - pexp^*_{t-1})\\
& +\underset{(0.18)}{0.38} \cdot \Delta pva_{t-1} + \underset{(0.10)}{0.26}\Delta s\_reer_t \qquad (61)
\end{aligned}
$$

Adjusted $R^2 = 0.24$
S.E. of equation = 0.030
Q test (p-value) = 0.041
Estimation period: 1995q3 - 2008q4

$$
\begin{aligned}
\Delta pimp_t \;=\; & -\underset{(0.08)}{0.33} \cdot (pimp_{t-1} - pimp^*_{t-1}) \qquad (62)\\
& +\underset{(0.17)}{0.41} \cdot \Delta pva_{t-1} + \underset{(0.09)}{0.34}\Delta s\_reer_t\\
& +\underset{(0.02)}{0.02}\Delta(0.7 \cdot (p\_oil_{t-1} + s\_usd\_pln_{t-1})\\
& +0.3 \cdot (p\_gas_{t-1} + s\_usd\_pln_{t-1}))
\end{aligned}
$$

Adjusted $R^2 = 0.27$
S.E. of equation = 0.028
Q test (p-value) = 0.041
Estimation period: 1995q3 - 2008q4

Exports and Imports

$$\Delta gdp\_exp_t = \Delta gdp\_ext_t - \underset{(0.07)}{0.12} \cdot (gdp\_exp_{t-1} - gdp\_exp^*_{t-1}) \quad (63)$$

$$+ \underset{(0.15)}{0.36} \cdot \Delta(gdp\_exp_{t-1} - gdp\_ext_{t-1})$$

$$- \underset{(0.14)}{0.26} \cdot \Delta(pexp_{t-1} - pva_{t-1}) + \underset{(1.34)}{0.29} \cdot \Delta(gdp\_ext_{t-1}$$

$$- \frac{tfp\_ext_{t-1}}{0.67}) + \underset{(0.32)}{0.78} \cdot \Delta gdp\_pot_{t-1}$$

Adjusted R^2 = 0.02
S.E. of equation = 0.027
LM test (p-value) = 0.009
Estimation period: 1996q2 - 2008q4

$$\Delta gdp\_imp_t = gdp_t - \underset{(0.05)}{0.13} \cdot (gdp\_imp_{t-1} - gdp\_imp^*_{t-1}) \quad (64)$$

$$- \underset{(0.09)}{0.55} \cdot \Delta(pimp_t + GR\_TAR\_TR_t - pva_t)$$

$$+ \underset{(0.22)}{2.16} \cdot \Delta log((0.4 \cdot GFCF_t + 0.2 \cdot CONP_t + 0.5 \cdot CONGOV_t$$

$$+ 0.4 \cdot GDP\_EXP_t)/TFP\_TREND_t^{1/0.67})$$

Adjusted R^2 = 0.73
S.E. of equation = 0.022
LM test (p-value) = 0.27
Estimation period: 1995q2 - 2008q4

3.6   Aggregate demand and supply

The product of the economy is linked with its demand-side components via standard National Accounts identity. GDP deflator is derived as ratio of the nominal to the real product[10]. The potential output is derived from the production function, where effective labour supply is approximated by population corrected for the equilibrium unemployment and the equilibrium participation rate.

---

[10]Import and export prices are adjusted so that the equilibrium exchange rate movements tied to the real convergence of the economy do not introduce a trend into GDP deflator.

3

GDP identity

$$GDP_t = CONP_t + CONGOV_t + GFCF\_P_t + GFCF\_G_t \tag{65}$$
$$+GFCF\_H_t + INV_t + GDP\_EXP_t - GDP\_IMP_t$$

$$
\begin{aligned}
GDP\_N_t &= CONP\_N_t + CONGOV\_N_t + GFCF\_N_t \\
&\quad +INV\_N_t + GDP\_EXP\_N_t - GDP\_IMP\_N_t \\
&= CPI \cdot CONP_t + PCONGOV_t \cdot CONGOV_t \\
&\quad +GFCF\_N_t + PVA_t \cdot INV_t + PEXP_t^c \cdot GDP\_EXP_t \\
&\quad -PIMP_t^c \cdot GDP\_IMP_t
\end{aligned}
\tag{66}
$$

Aggregated investment demand

$$GFCF_t = GFCF\_P_t + GFCF\_G_t + GFCF\_H_t \tag{67}$$

$$
\begin{aligned}
GFCF\_N_t &= PVA_t \cdot (1 + GR\_VAR\_TR_t) \cdot GFCF\_P_t \\
&\quad +PGFCF\_G_t \cdot GFCF\_G_t \\
&\quad +PGFCF\_H_t \cdot GFCF\_H_t
\end{aligned}
\tag{68}
$$

GDP deflator

$$PGDP_t = \frac{GDP\_N_t}{GDP_t} \tag{69}$$

Potential output

$$
\begin{aligned}
GDP\_POT_t &= (LF\_EQ_t \cdot POP_t \cdot (1 - NAWRU_t))^{0.67} \\
&\quad \cdot (K\_N_t)^{(1-0.67)} \cdot TFP\_TREND_t
\end{aligned}
\tag{70}
$$

$$GAP_t = \frac{GDP_t}{GDP\_POT_t} - 1 \tag{71}$$

3.7 Costs and prices

Price block of the model is based on the cost theory of prices. Core inflation and value-added deflator depend on unit labour costs and import prices. The price block is closed with equations representing food and energy prices that relate home food and energy price inflation to commodity prices in the world markets, as well as overall price level in the domestic market[11].

In the short run, the behaviour of core inflation and the deflator is influenced by inflation expectations (both backward- and forward-looking), short-run unit labour costs and import prices developments.

3

Long-run solution

Value-added deflator

$$
\begin{aligned}
pva_t \;=\; & -3.38 + 0.68 \cdot ulcna_t + (1 - 0.68) \cdot (pimp_t^c \\
& + GR\_TAR\_TR) + 0.09 \cdot D04Q3 \qquad (72)
\end{aligned}
$$

CPI

$$
\begin{aligned}
\frac{CPI_t}{CPI_{t-4}} \;=\; & W\_CORE_t \cdot \frac{CORECPI_t}{CORECPI_{t-4}} + W\_FOOD_t \cdot \frac{FOODCPI_t}{FOODCPI_{t-4}} \\
& + W\_ENER_t \cdot \frac{ENERCPI_t}{ENERCPI_{t-4}} \qquad (73)
\end{aligned}
$$

Core CPI

$$
\begin{aligned}
corecpi_t \;=\; & -3.19 + 0.53 \cdot ulcna_t \qquad\qquad\qquad\qquad (74) \\
& + (1 - 0.53) \cdot (pimp\_core_t^c + GR\_TAR\_TR) \\
& + GR\_VAT\_TR_t + GR\_GAM\_TR_t \\
& + GR\_EXT\_REST\_TR_t + 0.6 \cdot BS\_TREND_t
\end{aligned}
$$

---

[11]Import and commodity prices are suitably corrected for the equilibrium exchange rate movements to assure that in the long-run the relation of domestic production costs and prices remains unaffected by the trend exchange rate appreciation originating in the real convergence of the economy.

3

Food prices

$$foodcpi_t \;=\; 1.32 + 0.41 \cdot (p\_food_t + s\_usd\_pln_t - s\_reer\_eq_t)$$
$$+0.41 \cdot GR\_VAT\_TR_t + (1-0.41) \cdot corecpi_t \qquad (75)$$

Energy prices

$$enercpi_t \;=\; 0.66 + 0.27 \cdot (p\_ener_t + s\_usd\_pln_t - s\_reer\_eq_t \quad (76)$$
$$+GR\_VAT\_TR_t) + GR\_EXT\_ENER\_TR_t$$
$$+(1-0.27) \cdot (corecpi_t - GR\_EXT\_REST\_TR_t)$$

Short-run solution

Value-added deflator

$$\Delta pva_t \;=\; (1+\overline{INF\_TARGET}_{t+2})^{0.25} - 1) \cdot (1 - \underset{(0.06)}{0.10} - \underset{(0.05)}{0.21} - \underset{(0.06)}{0.31})$$
$$+\underset{(0.06)}{0.10} \cdot \Delta pva_{t-1}$$
$$+\underset{(0.05)}{0.21} \cdot pva_{t+1} + 0.682 \cdot \underset{(0.06)}{0.31} \cdot \Delta ulcna_{t-1} \qquad (77)$$
$$+(1-0.682) \cdot \underset{(0.06)}{0.31} \cdot \Delta(pimp^c_{t-1} + GR\_TAR\_TR_{t-1})$$
$$-\underset{(0.01)}{0.05} \cdot (pva_{t-1} - pva^*_{t-1}) + \underset{(0.004)}{0.04} \cdot I04Q2_t$$

Adjusted R^2 = 0.45
S.E. of equation = 0.008
J statistic(p-value) = 0.1
Estimation period: 1997q4 - 2008q4
Instrument set includes three lags of: $\Delta pva, \Delta wage, ULC, GAP$

Core inflation

$$\Delta corecpi_t = (1 + \overline{INF\_TARGET}_{t+2})^{0.25} - 1) \cdot (1 - \underset{(0.05)}{0.34} - \underset{(0.06)}{0.52}$$

$$- \underset{(0.01)}{0.03}) + \underset{(0.05)}{0.34} \cdot \Delta corecpi_{t-1} \qquad (78)$$

$$+ \underset{(0.06)}{0.52} \cdot \Delta corecpi_{t+1} + \underset{(0.01)}{0.03} \cdot 0.53 \cdot \Delta ulcna_{t-1}$$

$$+ \underset{(0.01)}{0.03} \cdot (1 - 0.53) \cdot \Delta(pimp\_core^c_{t-1} + GR\_TAR\_TR_{t-1})$$

$$- \underset{(0.01)}{0.02} \cdot (corecpi_{t-1} - corecpi^*_{t-1})$$

Adjusted R^2 = 0.93
S.E. of equation = 0.003
J statistic(p-value) = 0.1
Estimation period: 1997q4 - 2008q4
Instrument set includes three lags of: $\Delta corecpi, \Delta wage, ULC, GAP$

Food prices

$$\Delta foodcpi_t = \underset{(0.12)}{0.58} \cdot \Delta foodcpi_{t-1} + \underset{(0.12)}{0.39} \cdot \Delta corecpi_{t-1} \qquad (79)$$

$$- \underset{(0.04)}{0.13} \cdot (foodcpi_{t-1} - foodcpi^*_{t-1})$$

$$+ (1 - \underset{(0.12)}{0.58} - \underset{(0.12)}{0.38})$$

$$\cdot \Delta(p\_food_t + s\_usd\_pln_t - s\_reer\_eq_t)$$

Adjusted R^2 = 0.48
S.E. of equation = 0.011
LM test (p-value) = 0.081
Estimation period: 1996q2 - 2008q4

Energy prices

$$\Delta enercpi_t = \underset{(0.12)}{0.25} \cdot \Delta enercpi_{t-1} - \underset{(0.06)}{0.10} \cdot (enercpi_{t-1} - enercpi^*_{t-1}) \qquad (80)$$

$$+ \underset{(0.02)}{0.04} \cdot \Delta(p\_ener_t + s\_usd\_pln_t - s\_reer\_eq)$$

$$+ (1 - \underset{(0.12)}{0.25} - \underset{(0.02)}{0.04}) \cdot \Delta(corecpi_t - GR\_EXT\_REST\_TR_t)$$

$$+ (1 - \underset{(0.12)}{0.25}) \cdot \Delta GR\_EXT\_ENER\_TR_t$$

Adjusted R^2 = 0.25
S.E. of equation = 0.015
LM test (p-value) = 0.19
Estimation period: 1996q2 - 2008q4

3.8 Fiscal sector

Both expenditure and revenue side of the fiscal sector are modelled separately at a relatively very detailed level. Here, we will concentrate on differences in comparison with the previous model version.

In the current version of the model social benefits have been divided into more subcategories in order to enrich analysis of the impact of social benefits on the labour market. In the previos version of the model social benefits other than social transfers in kind were divided into expenditures on pensions, unemployment benefit expenditures, and other social relief expenditures. Now the latter has been replaced with its subcomponents - family benefits, preretirement benefits, social insurance benefits, i.e. health, maternity benefits and expenditure on social assistance - e.g. social pensions, housing benefits.

All the four new variables enter the nominal disposable income of households. Apart from social assistance benefits they affect government revenues via personal income tax and compulsory health care contribution. And finally, only family benefits influence social security contributions paid by employers and employees.

General government debt has been divided into four categories, distinguished by both currency denomination and debt ownership. Each subcomponent of debt is now modelled separately with debt accumulation equation in which corresponding part of current budget deficit adds itself up to the existing stock of debt of a given category (foreign debt accumulation is also affected by changes in the exchange rate).

Cost of debt servicing is modelled for domestic and foreign currency denominated debt separately. Formula for servicing cost of domestic debt takes into account average debt duration, while that for foreign debt is affected by exchange rate movements. Costs of resident and non-resident debt are shared according to the ownership structure.[12]

Long-run solution

General government revenues

$$
\begin{aligned}
GR\_N_t \;=\; & GR\_PROD\_TAX\_N_t + GR\_INC\_TAX\_N_t \quad (81) \\
& + GR\_TCONTR\_N_t + GR\_PROP\_INC\_N_t \\
& + GR\_OTHER\_CURT\_N_t + GR\_OUTPUT\_N_t \\
& + GR\_CAP\_TRANS\_N_t
\end{aligned}
$$

---

[12]Thanks to the new division of debt and, accordingly, new formulas for costs of debt servicing, disposable income is now able to capture only the cost of resident debt.

General government expenditure

$$
\begin{aligned}
GE\_N_t \;=\;& GE\_RELIEF\_KIND\_N_t + GE\_SOC\_CASH\_N_t \\
&+GE\_SUB\_FARM\_N_t + GE\_SUB\_NOFARM\_N_t \\
&+GE\_OTHER\_TRANS\_N_t + GE\_EU\_N_t \qquad (82) \\
&+GE\_FIN\_N_t + GE\_WF\_N_t + GE\_CON\_N_t \\
&+GE\_GFCF\_N_t + GE\_CAP\_TRANS\_N_t
\end{aligned}
$$

Social expenditure

$$
\begin{aligned}
GE\_SOC\_CASH\_N_t \;=\;& GE\_PENSIONS\_N_t \qquad\qquad (83) \\
&-(1 - G\_REF_t) \cdot OFE\_N_t \\
&+GE\_UNEMP\_N_t + GE\_FAMILY\_N_t \\
&+GE\_PRERETIRE\_N_t \\
&+GE\_RELIEF\_REST\_N_t \\
&+GE\_SOCSECURITY\_N_t
\end{aligned}
$$

General government balance and debt

$$
G\_BALANCE\_N_t \;=\; GR\_N_t - GE\_N_t \qquad (84)
$$

$$
\begin{aligned}
G\_DEBT\_N_t \;=\;& G\_DEBT\_DOM\_RES\_N_t \qquad (85) \\
&+G\_DEBT\_DOM\_NRES\_N_t \\
&+G\_DEBT\_FOR\_RES\_N_t \\
&+G\_DEBT\_FOR\_NRES\_N_t
\end{aligned}
$$

$$
\begin{aligned}
G\_DEBT\_DOM\_RES\_N_t \;=\;& G\_DEBT\_DOM\_RES\_N_{t-1} \quad (86) \\
&-GDEBT\_DOM\_RES_t \\
&\cdot (G\_BALANCE_t + GE\_PRIV\_N_t)
\end{aligned}
$$

$$
\begin{aligned}
G\_DEBT\_DOM\_NRES\_N_t \;=\;& G\_DEBT\_DOM\_NRES\_N_{t-1} \, (87) \\
&-GDEBT\_DOM\_NRES_t \\
&\cdot (G\_BALANCE_t + GE\_PRIV\_N_t)
\end{aligned}
$$

$$G\_DEBT\_FOR\_RES\_N_t = G\_DEBT\_FOR\_RES\_N_{t-1} \quad (88)$$
$$\cdot (GDEBT\_EXCHANGE_t^t$$
$$/GDEBT\_EXCHANGE_{t-1}^{t-1})$$
$$-GDEBT\_FOR\_RES_t$$
$$\cdot (G\_BALANCE_t + GE\_PRIV\_N_t)$$

$$G\_DEBT\_FOR\_NRES\_N_t = G\_DEBT\_FOR\_NRES\_N_{t-1} \quad (89)$$
$$\cdot (GDEBT\_EXCHANGE_t^t$$
$$/GDEBT\_EXCHANGE_{t-1}^{t-1})$$
$$-GDEBT\_FOR\_NRES_t$$
$$\cdot (G\_BALANCE_t + GE\_PRIV\_N_t)$$

$$GDEBT\_DOM\_RES_t + GDEBT\_DOM\_NRES_t \quad (90)$$
$$+GDEBT\_FOR\_RES_t + GDEBT\_FOR\_NRES_t = 1$$

$$GDEBT\_EXCHANGE_t^s = GDEBT\_EUR_s \cdot S\_EUR\_PLN_t \quad (91)$$
$$+(1 - GDEBT\_EUR_s) \cdot S\_USD\_PLN_t$$

Costs of debt service

$$GE\_FIN\_N_t = GE\_INT\_RES\_N_t \quad (92)$$
$$+GE\_INT\_NRES\_N_t$$
$$= GE\_INT\_DOM\_N_t$$
$$+GE\_INT\_FOR\_N_t$$

$$GE\_INT\_FOR\_N_t \propto \sum_{i=1}^{5} G\_DEBT\_FOR\_N_{t-4i} \quad (93)$$
$$\cdot I\_5Y\_EUR_{t-4i} \cdot (GDEBT\_EXCHANGE_{t-4i}^t$$
$$/GDEBT\_EUR_{t-4i})$$

$$\frac{GE\_INT\_DOM\_N_t}{G\_DEBT\_DOM\_N_t} \propto W\_SHORT\_DOM_t \cdot I\_3M_t \quad (94)$$
$$+(1 - W\_SHORT\_DOM_t) \cdot \overline{I\_5Y_t}$$

3.9 The monetary authority and interest rates

The long-term interest rate is modelled as the weighted average of the expected future short-term interest rates (in line with expectation hypothesis of the term structure of interest rates) augmented with a term premium. The short-run interest rate is determined by the estimated monetary policy rule with its specification based on a Taylor type reaction function.

In order to follow the behaviour of the monetary aggregates the money demand function has been introduced. The equation that governs money demand is based on the quantitative theory of money and does not influence other equations of the model. For the modelling perspective M3 has been chosen, as the broadest and the least volatile money aggregate. It is assumed that in the long run money demand depends on nominal GDP (scale variable) and nominal short and long interests rates spread (between 3 months WIBOR I_3M and 5 years government bonds I_5Y) as a proxy for opportunity cost of holding money. Short-term fluctuations are driven by nominal GDP changes and, nominal exchange rate (S_NEER), as recently many loans are denominated in foreign currencies.

3

Long-run solution

Money demand

$$m3_t = 1.25 \cdot (I\_3M_t - I\_5Y_t) + 1.47 \cdot gdp\_n_t - 5.25 \qquad (95)$$

Short-run solution

Monetary policy rule

$$
\begin{aligned}
I\_3M_t \;=\;& \underset{(0.02)}{0.86} \cdot I\_3M_{t-1} + (1 - \underset{(0.02)}{0.86}) \cdot (I\_3MR\_EQ_t + INF_{t+1} \quad (96) \\
&+ \underset{(0.36)}{1.04} \cdot (INF_{t+1} - \overline{INF\_TARGET}_{t+3}) + \underset{(0.15)}{0.29} \cdot GAP_t)
\end{aligned}
$$

Adjusted R^2 = 0.99
S.E. of equation = 0.005
J statistic(p-value) = 0.830
Estimation period: 2000q3 - 2008q3
Instrument set includes three to five lags of: $I\_3M, GAP, INF, I\_5Y - I\_3M$

Long-term interest rate

$$I\_5Y_t = \frac{1}{17} \cdot I\_3M_t + (1 - \frac{1}{17}) \cdot I\_5Y_{t+1} + \underset{(0.001)}{0.002} \qquad (97)$$

Adjusted R^2 = 0.94
S.E. of equation = 0.008
J statistic(p-value) = 0.614
Estimation period: 1999q1 - 2008q4
Instrument set includes two lags of: $GAP, I\_3M, I\_5Y - I\_3M, INF$

Money demand

$$\begin{aligned}
\Delta m3_t \;=\; & \underset{(0.09)}{-0.34} \cdot (m3_{t-1} - m3_{t-1}^*) \qquad (98) \\
& + \underset{(0.13)}{0.44} \cdot \Delta m3_{t-1} + \underset{(0.22)}{0.75} \cdot \Delta gdp\_n_t \\
& + \underset{(0.06)}{0.15} \cdot \Delta s\_neer_t
\end{aligned}$$

Adjusted R^2 = 0.35
S.E. of equation = 0.013
LM test (p-value) = 0.04
Estimation period: 2000q3 - 2008q4

3.10 Long-term properties

The current model version differs from the version published in 2008 primarily by the endogenisation of variables which have been henceforth assumed to be exogenous and enrichment of the model through the introduction of further linkages between its blocks. The endogenization mostly concerns current account components, while the latter affects trade, fiscal and household sector variables. Here we show how the long-run relationships linking the key variables in NECMOD, jointly determine the long-run solution of the model. In general, the main differences between subsequent model versions apply to the range of economic parameters that pin down the long-run equilibrium.

A few simplifying assumptions are imposed on the long-run dynamics of the key exogenous variables. Namely:

- all foreign nominal variables (commodity price indexes, value-added deflators in Poland's trading partners) grow at a common and constant rate,

- growth rate of foreign actual and potential GDP, as well as TFP growth, is fixed whereas foreign output gap is assumed to be zero,

- nominal interest rates abroad are constant,

- population of Poland and its age structure are constant,

- minimum wage rate is fully indexed to the average wage rate.

Two policy rules are incorporated in the model. Monetary policy rule based on Taylor scheme assures that in the long run the short-term real interest rate is equal to its equilibrium level[13]. The fiscal policy rule closes the fiscal balance. Once the fiscal balance is closed, fiscal revenue and expenditure are generated so that their ratios to GDP remain constant. In particular, as long as fiscal policy rule stays passive, all range of benefits evolves in line with the average wage, with tax and quasi-tax rates constant.

The transfers account balance reaches zero in the long run. Transfers to the EU budget constitute a constant fraction of the GDP, while the inflow of EU funds is assumed to decrease in line with the economic convergence of Poland to the point when net transfer balance closes. The income account balance as a fraction of GDP should stabilise once the net foreign assets position approaches its steady-state level. High balance of remittances entering both transfers and income accounts gradually closes together with GDP per capita growth in Poland.

The steady-state level of GDP is determined by:

- TFP level that grows at a rate which is gradually decreasing on the convergence path (and is equal to the productivity growth rate abroad once economic convergence is achieved),

- potential labour input proportional to population of the country corrected for the steady-state labour participation rate and steady-state equilibrium unemployment rate,

---

[13]To simplify the estimation and forecasting process the equilibrium real interest rate is treated as exogenous and approaches the level that prevails in the world as the process of growth convergence of Polish economy carries on.

- productive capital stock which in the long run is tied to the production function elasticities and the constant real user cost of capital.

The potential labour supply depends on institutional factors like replacement rates, tax and quasi-tax rates, minimum wage level and the real user cost of capital[14,15]. The latter depends in turn, on the net tax burden on corporate sector and the equilibrium interest rate. These equilibrium conditions imply that the long-run level of output per capita is a function of a range of (fiscal) policy variables and the model specific steady-state real interest rate.

In the long-run inflation rates of domestic prices, i.e. consumer price index, producer prices (approximated by the value-added deflator), investment prices and the GDP deflator, are equal and solely dependent on the evolution of the unit labour costs. Relative prices are therefore constant. As long as the growth convergence is at work and the real exchange rate appreciates, import and export prices are decreasing as compared to domestic prices, and then stabilize therafter.

Evolution of foreign trade prices and volumes both during convergence and on the steady-state path is tied to the evolution of the real exchange rate, which is set so that it equilibrates the net foreign assets position. In the long run, once the net foreign assets position reaches its steady-state level, trade balance closes and transition factors fade, the real exchange rate is constant and nominal exchange rate moves in line with inflation (target) differences between home and abroad.

Steady-state expenditure shares in output are initially derived from the production function elasticities with respect to labour and capital input. Therefore, labour income, jointly with social transfers, remains constant in relation to GDP. Given that wealth depends on the stock of corporate and housing capital, which are both fixed to GDP in the long run, constancy of workers' income to GDP implies that private consumption and housing investment to GDP ratios are constant. Public consumption and public investment are functions of fiscal expenditure and as such stabilise as a share of GDP. Inventories and corporate investments are tied to GDP by real interest rate and real user cost of capital, respectively, both constant in the long run.

Interestingly and in contrast to the previous model version the share of exports and imports in GDP increases both during convergence and after reaching the steady-state by the economy. In the steady-state the rate of adjustment of both shares is proportional to the world potential product growth rate. However, the continuous deepening of integration of the world economy does not impact the trade balance or the net exports contribution to growth.

---

[14]Once steady-state level of the unemployment rate is known, it might be shown that the steady-state level of the participation rate hinges on it and a set of fiscal and regulatory variables entering the labour force participation equation but not the wage equation.

[15]Contrary to the previous model version the steady-state employment does not depend on the steady-state real exchange rate.

4

Impulse response analysis[16]

4.1 Monetary impulse

The monetary impulse is defined as an unexpected one-quarter increase in the short-term interest rate by 100 basis points. Following the shock, the interest rate moves in line with the monetary feedback rule, staying above the baseline for 12 quarters as an effect of the smoothing mechanism. The fiscal rule is switched on. Impulse response functions of key macrocategories are given in Table 2.

Monetary policy tightening leads to a reduction in GDP growth rate, with the strongest effects observed in the fourth quarter after the shock. Contraction in economic activity is mainly related to a fall in investment demand (both corporate and residential) and net exports. Specifically, an increase in short-term interest rates triggers a shift in the long-run interest rates, which translates into higher costs of capital financing. At the same time, monetary policy tightening and subsequent rise in the interest rate disparity leads to zloty appreciation, and, consequently, to a fall in the net exports. Contractionary monetary policy effect on private consumption is limited. On the one hand, households postpone consumption and cut on housing expenditure when the real interest rates are higher. Lower housing demand depresses prices and value of households wealth, further aggravating consumption demand. On the other hand, consumption growth is sustained by zloty appreciation that leads to an increase in the value of households' wealth via improvement in net foreign assets.

As aggregate demand declines, firms reduce employment and wages to bring down their unit labour costs. Inflation is further reduced by lower growth rate of import prices, driven by domestic currency appreciation. The negative effects of interest rate shock on inflation are strongest in the fifth quarter after the shock.

In response to GDP growth decline and falling rate of inflation, monetary policy stance is eventually reversed as indicated by the Taylor rule. Economic activity restores and inflation increases as the economy converges to the path consistent with the baseline.

4.2 Exchange rate impulse

The exchange rate impulse is defined as an unexpected one-quarter appreciation of the real (and nominal) effective exchange rate of 10%. The simulation is conducted with both monetary and fiscal policy rules enabled. The results are reported in Table 3.

Exchange rate appreciation leads to a reduction in import prices and, consequently, to a fall in the core inflation rate. Food and energy inflation also decrease as prices of these commodities traded on the world markets fall when expressed in zlotys.

Concerning the real side of the economy, as domestically produced goods become less competitive, exports fall while imports increase, and thus negative contribution of net exports depresses output.

Just after the initial shock, exchange rate starts to depreciate converging to its equilibrium path. In the subsequent quarters the process of depreciation is reinforced by reaction of monetary policy (interest rate cuts in response to lower inflation and GDP

---

[16]In the simulation analysis model is solved deterministically with Broyden's algorithm implemented in EViews 6.0.

growth) and widened current account imbalance. Inflation and GDP components growth rates accelerate on their way back to baseline.

4.3   Government consumption impulse

The public consumption impulse is defined as a four-quarter unexpected cut in purchases of goods and services by the general government sector, equivalent to 1% of GDP. The simulation is conducted with monetary and fiscal policy rules switched on. The main impulse response functions are plotted in Table 4.

A reduction in purchases of goods and services by the general government sector leads to an immediate fall in GDP. The downward adjustments in wages and employment take place only gradually due to rigidities on the labour market. Therefore the unit labour costs and, consequently, inflation increase temporarily. Deterioration of economic conditions leads to the currency depreciation, which is eventually reversed due to lower budget deficit risk premium and following later return to the baseline fiscal policy. After the shock, inflation temporarily increases but inflation goes down as the adjustments on the labour market are completed amid falling growth rates of wages, employment and unit labour costs. In the reaction to this development interest rates are cut and inflation is rising on its return to the baseline.

4.4   GDP slowdown in the euro area

GDP slowdown in the euro-area impulse is defined as a gradual deceleration in y-o-y GDP growth in the euro area for a period of 2 years, where the deepest contraction is of the size of two standard deviations of GDP growth in euro-area economy in the 1995-2008 period (2.2 pp.) and is observed in the fourth and fifth quarter of the shock [17].

The euro-area represents 87% of the total external sector environment (in the model), thus the slowdown in GDP growth rate in this region translates into the moderation of external GDP growth almost to the same extent. An immediate reaction of the Polish economy to this shock is a reduction of exports growth. Due to high import content of exports and fall in imports following exports reduction, trade balance deteriorates only to a limited extent. Negative growth effects of decreasing net exports are magnified by lower inflow of remittances and, consequently, gradually worsening consumption growth.

In the reaction to the deteriorating current account balance there occurs a depreciation of the exchange rate. Also, lower growth of the potential output (associated with lower growth rate of investments and higher NAWRU) contributes to weakening of zloty. Currency depreciation jointly with dollar appreciation against the euro (that increase food and energy prices in euro) fuel inflation.

---

[17] Together with GDP growth reduction, impulse scenario assumes that inflation in the euro area will behave in line with the pattern determined by Phillips curve (with potential output unaffected by the shock) . Impulse response is considered with the monetary policy in the euro area adjusting according to a Taylor rule (with standard parameters). Consistently with the expectation hypothesis, long-term interest rates in the euro area move accordingly. Finally, the scenario assumes euro depreciation against dollar, with shock magnitude on USD/EUR cross rate implied by uncovered interest rate parity condition. To sum up, the following exogenous variables were shocked: output in the euro area, inflation in the euro area, euro-area short- and long-term interest rates, and euro/dollar exchange rate. Thus, it is assumed that the demand shock considered does not affect the potential of euro-area economy and world commodity prices.

Eventually, the trade balance and GDP growth improve, depreciation of the currency gradually reverses and inflation decelerates. Finally, monetary rule stabilises both output and price dynamics at the baseline level.

4.5   Migration

Migration has been defined as outflow of 1% of Polish population (over 300 thousands persons) accompanied by a later increase in an inflow of remittances[18, 19].

Outflow of labour force causes contraction of GDP growth in the first years after intensification of migration. In the longer run, potential GDP level stabilises at nearly 1% below the level in the benchmark scenario. Jointly with reduction of production capacity of the economy, outflow of workers cuts consumption and housing investment expenditure. This effect is only partially compensated by an increased inflow of remittances that enter disposable income of private households. Still, the reduction of aggregate demand is initially lower than the reduction of the potential product.

In the aftermath of migration outflow, two opposite effects take place in the labour market. First, in response to shrinking labour supply, labour market tightness increases, unemployment rate goes sharply down and real wage growth accelerates. Second, as capital stock in the short run remains intact, productivity of the workers who stayed in the country improves. The net effect of both mechanisms at work is a reduction of unit labour cost growth and moderation of inflation reinforced by appreciation of the real exchange rate. In the medium term, productive capital stock adjusts only gradually, especially as its growth is maintained by the inflow of structural funds[20]. The adjustment period extends for a few decades and involves persistent reduction of the equilibrium and the actual unemployment rates.

Lower production capacity due to lowering of labour force supply, exacerbated by fiscal tightening and tax increases, limits the range of goods offered at the world markets and shifts exports supply down. The exchange rate equilibrating the net foreign assets to GDP ratio adjusts to these developments and depreciates in the medium run.

---

[18]As emigration propensity is known to be different for diverse demographic groups, population outflow is unequally distributed among three age groups distinguished in the model. Namely, the propensity of migration is assumed to be the highest for workers aged 25 to 44, only slightly lower for younger workers and up to seven times lower for workers above 44. Moreover, as migration is assumed to be driven by a reduction of migration cost and not by cyclical factors, external assumptions remain unchanged in both benchmark and simulation scenarios. Remittance inflow and remittance balance are assumed to increase in aftermath of migration to above 220 Mio. EUR quarterly. This additional stream of remittances is (similarly as benchmark stream of remittances) indexed to inflation and GDP growth abroad and assumed to exogenously decrease by around 2% in each quarter due to the degeneration of linkages between migrants and family members left in Poland. Remittances balance gradually closes at even higher speed than the slowing down of remittances inflow in line with economic convergence of Poland.

[19]Because migration shock is introduced as a gradual outflow of population, it allows us to put aside the problem of the differences in relative propensity to migration for employed and non-employed and the direct effect of outflow of previously employed individuals would have on the labour market and the economy. Scenario describes rather stylised event when effects of higher migration pass-through into changes in employment and unemployment only gradually. Moreover, it is implicitly assumed that population structure changes due to outmigration have permanent character.

[20]As inflow of structural funds is assumed to depend mostly on GDP in the European Union, in the model it remains greatly unaffected by migration movements.

4.6   Inflow of structural investment funds

Impulse response function for the inflow of structural funds from the European Union aimed at the extension of infrastructure capacities has been derived under assumption of an expected inflow of respective structural funds in the magnitude of 1% GDP. Impulse might be compared to the temporary fifth-fold increase of this category.

Stronger inflow of infrastructural funds affects the economy via two channels, accelerating accumulation of productive capital and improving current account balance of Poland, which passes through into significant strengthening of the zloty. These two effects work in reverse directions in terms of the impact on economic activity. Investment facilitation boosts economic growth foremost in the short run. Imports volume sharply increases following positive aggregate demand impulse, the effect which is even more pronounced due to high import intensity of investments in Poland. Deterioration of trade balance is deepened by sharp zloty appreciation.

Even though, intensified productive capital accumulation has a positive impact on domestic demand, labour demand temporarily decreases due to the dominance of substitution effect between labour and capital in the short run. Labour productivity goes up sharply moderating increase of unit labour costs and prices in the economy.

It is only in the longer run that positive supply-side effects of the impulse fully set in. Higher public capital level increases productivity of private investments prolonging duration of the investment boom in the economy, which gradually starts to hinge on private investments. Higher labour productivity shifts labour demand upwards, leading to gradual reduction of the equilibrium unemployment and strengthening of the growth rate of the potential product.

4.7   Inflow of Common Agricultural Policy funds

Inflow of funds under the Common Agricultural Policy has been defined as the inflow in the magnitude of 1% GDP. This impulse might be compared to the temporary seven-fold increase of the category.

Subsidies to farmers in the general framework of the Common Agricultural Policy are assumed to primarily affect consumption and investment patterns of households. Stronger inflow of funds increases the real disposable income of households and, via current account channel, strengthens the currency. In fact, reaction of the economy to the impulse is a reflexion of an effect of a positive demand shock and a countervailing real exchange rate appreciation shock. Following the shock individual consumption growth accelerates, supported by higher current income of households and higher valuation of their wealth. Higher consumption demand translates into higher imports and deterioration of the trade gap and the net exports contribution to growth.

Strong currency dampens positive effects of higher expenditure of private households on the economic activity. First, it exacerbates worsening of the trade balance. Second, due to lower value of inflowing investment funds from the EU in the zloty, investment demand of firms and public sector goes down. In the short run positive effects dominate, though the longer the time perspective the more negative the net effect of the impulse on the economic activity. In the medium term, temporary deceleration of capital accumulation via supply-side channels exerts negative impact on economic growth.

4.8   House price impulse

House price impulse is defined as an unexpected one-quarter increase in housing demand that leads to approx. 10% increase in (y-o-y) growth rate of gross fixed residential capital formation deflator. Specifically, the impulse was introduced via an adjustment of a constant in the cointegrating equation for housing demand (eq. 23), which enters short-run equation describing the behaviour of house prices (eq. 34). In the simulation, the monetary and fiscal policy rules are both switched on. Impulse reaction functions of key macrocategories are given in Table 9.

Following the rise in housing demand and, consequently, increase in the growth rate of residential investments deflator, supply of houses increases and thus residential investments surges. It translates into faster growth of gross fixed capital formation and, consequently, GDP. As the wealth of households increases together with higher housing prices, consumption accelerates (by 0.4 pp in the sixth quarter after the shock and further strengthens positive growth effects of the shock). On the other hand, an increase in the growth rate of imports, being an outcome of high import content of investments partially counterveils increase in the GDP growth rate. GDP impact of housing demand shock translates into positive developments in the labour market, with growing wages and employment level.

On the nominal side, inflation remains almost unaffected — a slight decrease in the growth rate of CPI is associated with zloty appreciation originating in the improvement of growth prospects and initially lower growth rate of unit labour cost.

After the initial shock, housing demand decreases in response to higher housing prices. Due to high inertia in the residential investments, housing supply still grows faster than in the baseline, contributing to moderation in the growth rate of gross fixed residential capital formation deflator and faciliatating return of the modeled economy to the baseline path.

4
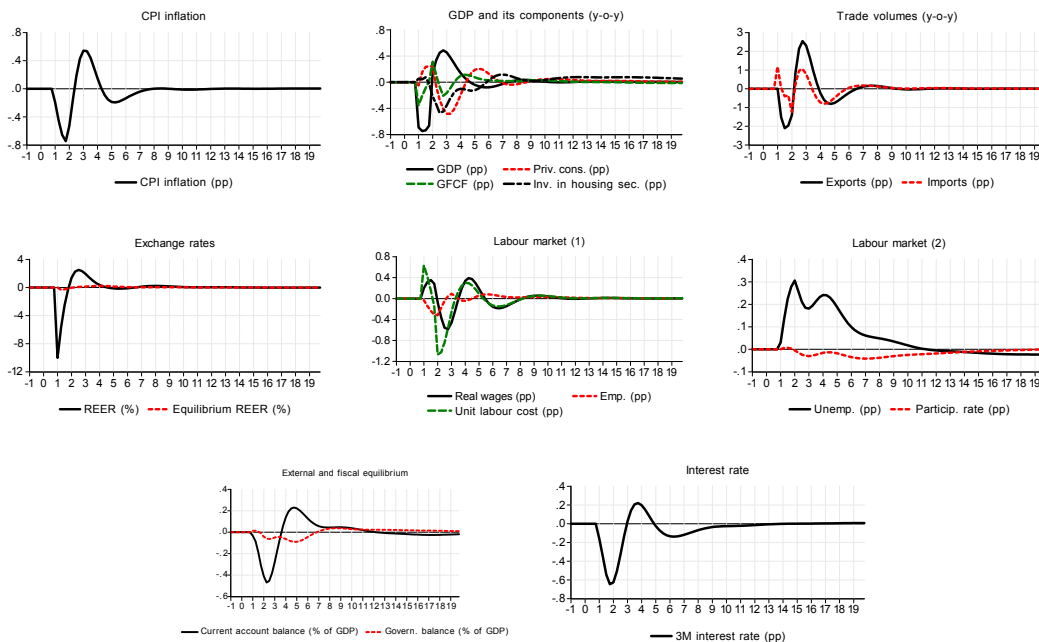
Table 2: Monetary impulse
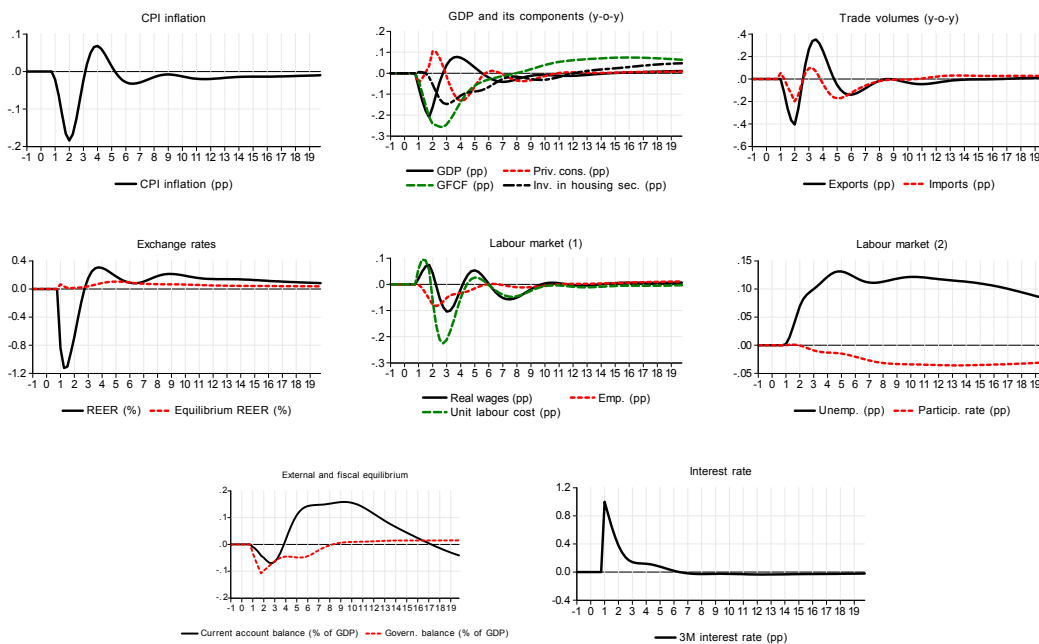
Table 3: Exchange rate impulse
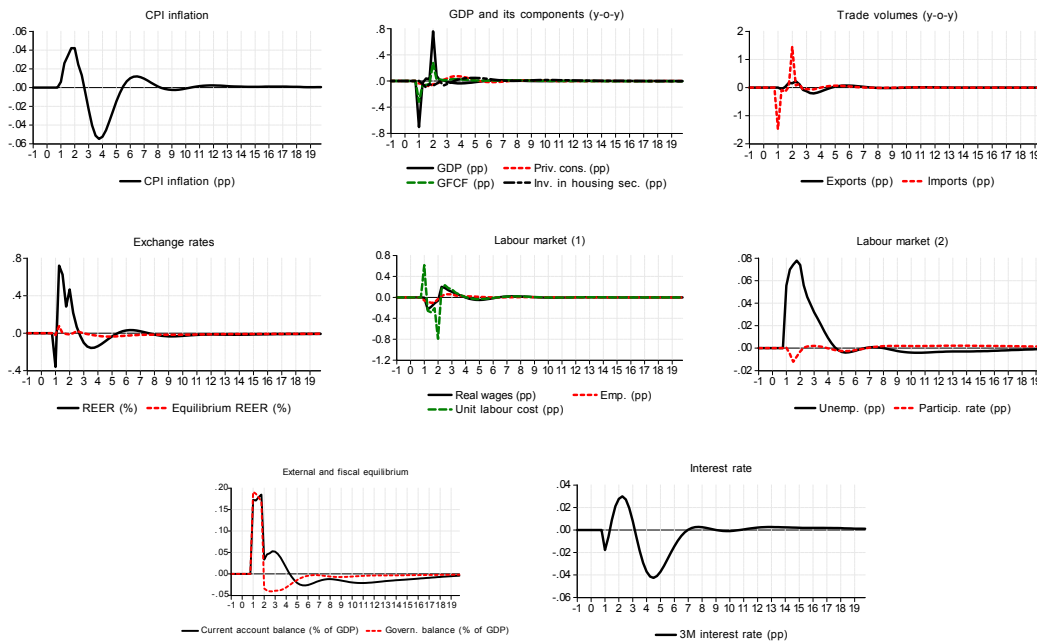
Table 4: Government consumption impulse
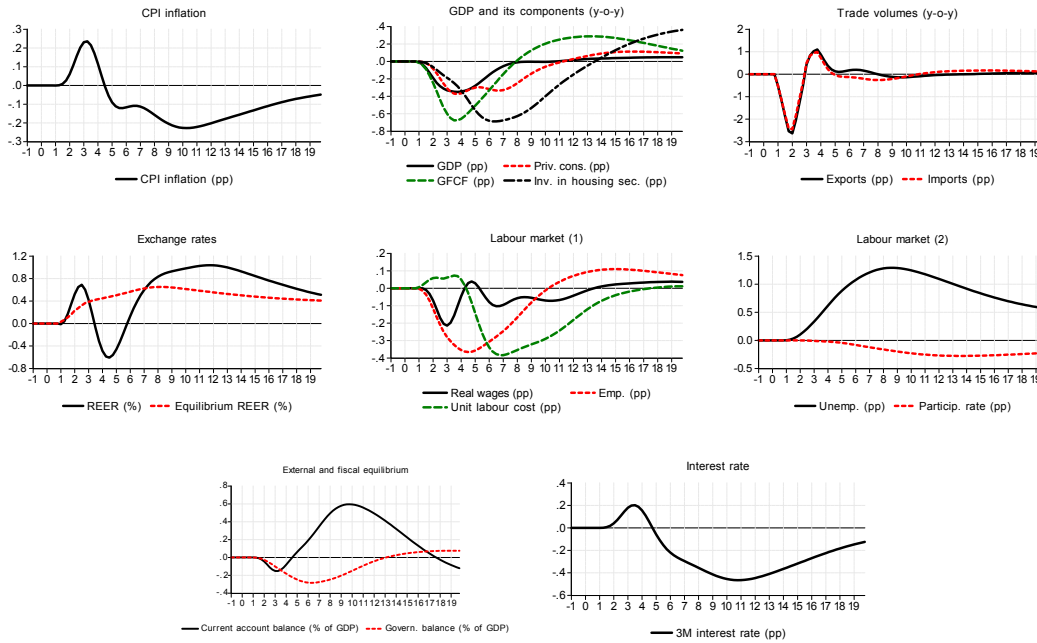

Table 5: GDP slowdown in the euro area

Table 6: Migration impulse response function

Year	1	2	3	5	10	15
Inflation rate (pp)	-0.22	-0.47	-0.17	0.11	0.05	0.02
GDP y-o-y (pp)	-0.04	-0.33	-0.10	0.03	-0.03	-0.04
GDP (%)	-0.04	-0.37	-0.47	-0.39	-0.54	-0.76
Private consumption y-o-y (pp)	-0.05	-0.06	-0.03	-0.04	-0.06	-0.05
Private consumption (%)	-0.05	-0.11	-0.14	-0.26	-0.42	-0.69
Gross fixed capital formation y-o-y (pp)	-0.06	-0.16	-0.05	-0.05	-0.14	-0.10
Gross fixed capital formation (%)	-0.06	-0.22	-0.27	-0.35	-0.96	-1.55
Housing investment y-o-y (pp)	-0.50	-0.05	0.14	-0.13	-0.18	-0.14
Housing investment (%)	-0.50	-0.55	-0.41	-0.53	-1.38	-2.15
Exports y-o-y (pp)	-0.34	-1.07	0.05	0.20	-0.03	-0.06
Exports (%)	-0.34	-1.40	-1.35	-0.70	-0.77	-1.03
Imports y-o-y (pp)	-0.41	-0.70	0.31	0.13	-0.11	-0.08
Imports (%)	-0.41	-1.11	-0.80	-0.28	-0.74	-1.21
Real exchange rate (%)	-0.09	-0.90	-0.18	0.05	0.09	0.28
Real equilibrium exchange rate (%)	1.22	0.30	0.28	0.40	0.54	0.60
Real wages y-o-y (pp)	0.18	0.23	-0.09	0.14	-0.01	-0.02
Employment y-o-y (pp)	-0.52	-0.33	0.20	0.05	-0.06	-0.05
ULC y-o-y (pp)	-0.58	-0.27	0.07	0.27	0.00	-0.01
Unemployment rate (pp)	-0.26	-0.45	-0.60	-0.67	-0.52	-0.39
Activity rate (pp)	-0.43	-0.73	-0.73	-0.69	-0.68	-0.72
Short term interest rate (pp)	-0.13	-0.41	-0.39	0.03	0.11	0.05
Fiscal balance to GDP (pp)	-0.04	-0.08	-0.03	-0.04	-0.10	-0.05
CA to GDP (pp)	0.03	-0.07	-0.24	-0.25	-0.06	0.08

Table 7: Investment funds impulse responce function

Year	1	2	3	5	10	15
Inflation rate (pp)	0.11	-0.12	-0.12	-0.08	0.01	0.04
GDP y-o-y (pp)	0.14	-0.17	0.20	0.04	0.07	0.06
GDP (%)	0.12	-0.05	0.15	0.33	0.62	0.94
Private consumption y-o-y (pp)	-0.03	0.01	-0.04	0.05	0.10	0.06
Private consumption (%)	-0.03	-0.02	-0.06	-0.05	0.36	0.73
Gross fixed capital formation y-o-y (pp)	4.10	-3.91	0.23	0.32	0.19	0.04
Gross fixed capital formation (%)	4.17	0.18	0.41	1.01	2.24	2.77
Housing investment y-o-y (pp)	0.00	0.26	-0.02	0.04	0.12	0.14
Housing investment (%)	0.00	0.26	0.24	0.21	0.68	1.42
Exports y-o-y (pp)	-0.06	-0.14	0.60	-0.10	0.07	0.09
Exports (%)	-0.09	-0.22	0.38	0.51	0.79	1.22
Imports y-o-y (pp)	1.61	-1.75	0.40	0.01	0.15	0.07
Imports(%)	1.62	-0.15	0.25	0.38	1.15	1.68
Real exchange rate (%)	-0.79	-0.56	0.83	0.07	-0.26	-0.45
Real equilibrium exchange rate (%)	-1.55	-0.15	-0.02	-0.14	-0.30	-0.35
Real wages y-o-y (pp)	-0.03	0.18	-0.01	0.01	0.05	0.03
Employment y-o-y (pp)	-0.05	-0.30	-0.06	0.13	0.08	0.05
ULC y-o-y (pp)	-0.12	-0.12	-0.40	0.05	0.08	0.06
Unemployment rate (pp)	0.05	0.31	0.33	0.04	-0.27	-0.42
Activity rate (pp)	0.00	0.01	-0.01	-0.03	0.02	0.08
Short term interest rate (pp)	0.09	-0.04	-0.17	-0.11	-0.01	0.06
Fiscal balance to GDP (pp)	0.07	-0.07	-0.07	0.05	0.09	0.06
CA to GDP (pp)	0.09	-0.07	-0.05	0.02	-0.24	-0.35

4

Table 8: CAP funds impulse response function

Year	1	2	3	5	10	15
Inflation rate (pp)	0.11	-0.18	-0.23	0.01	0.03	0.00
GDP y-o-y (pp)	0.07	-0.12	0.00	0.00	-0.01	-0.02
GDP (%)	0.05	-0.07	-0.08	-0.06	-0.08	-0.18
Private consumption y-o-y (pp)	0.48	0.05	-0.24	-0.09	0.00	-0.03
Private consumption (%)	0.49	0.54	0.29	0.03	0.04	-0.07
Gross fixed capital formation y-o-y (pp)	-0.10	-0.08	0.04	0.04	-0.08	-0.07
Gross fixed capital formation (%)	-0.12	-0.20	-0.16	-0.10	-0.31	-0.68
Housing investment y-o-y (pp)	-0.06	0.19	0.13	0.08	-0.06	-0.08
Housing investment (%)	-0.06	0.12	0.25	0.44	0.20	-0.15
Exports y-o-y (pp)	-0.06	-0.39	0.10	0.05	-0.01	-0.03
Exports (%)	-0.09	-0.48	-0.37	-0.12	-0.10	-0.23
Imports y-o-y (pp)	0.35	-0.18	-0.18	-0.02	-0.03	-0.05
Imports (%)	0.35	0.17	-0.01	-0.03	-0.08	-0.32
Real exchange rate (%)	-0.60	-0.85	0.23	0.04	-0.05	0.04
Real equilibrium exchange rate (%)	-1.43	0.14	0.15	0.04	0.04	0.07
Real wages y-o-y (pp)	-0.06	0.24	-0.03	-0.03	0.00	-0.01
Employment y-o-y (pp)	-0.07	-0.26	0.03	0.09	-0.02	-0.03
ULC y-o-y (pp)	-0.10	-0.12	-0.22	0.08	0.02	-0.02
Unemployment rate (pp)	0.06	0.30	0.24	-0.03	-0.04	0.07
Activity rate (pp)	0.00	0.00	-0.01	-0.03	0.01	0.00
Short term interest rate (pp)	0.09	-0.07	-0.24	-0.07	0.05	0.02
Fiscal balance to GDP (pp)	0.04	0.00	-0.04	0.04	-0.02	-0.03
CA to GDP (pp)	0.74	-0.37	-0.26	-0.10	-0.02	0.06

4

Table 9: House prices impulse

CPI inflation

GDP and its components (y-o-y)

Trade volumes (y-o-y)

— CPI inflation (pp)

— GDP (pp)   --- Priv. cons. (pp)
--- GFCF (pp)   -·- Inv. in housing sec. (pp)

— Exports (pp)   --- Imports (pp)

Exchange rates

Labour market (1)

Labour market (2)

— REER (%)   --- Equilibrium REER (%)

— Real wages (pp)   --- Emp. (pp)
--- Unit labour cost (pp)

— Unemp. (pp)   --- Particip. rate (pp)

External and fiscal equilibrium

Interest rate

— Current account balance (% of GDP)   --- Govern. balance (% of GDP)

— 3M interest rate (pp)

5

Risk analysis

The procedure of evaluating risk distributions around central projections of inflation and GDP growth has been already described Budnik et al. (2009). Here, only a short recollection of the main conceptual aspects of the procedure is given and the major emphasis is put on thorough description of its practical dimensions.

5.1 Procedure

Due to problems with quantifying various types of uncertainty in macroeconomic models, including risks of such different origins as uncertainty of future changes in the underlying structure of the economy, model misspecification or inaccuracies in the estimates of the model's parameters, past forecast errors seem to be a good catch-all proxy for the future uncertainty. Still, uncertainty may vary due to different reasons, e.g. change within a business cycle (being lower in the periods of higher growth and increasing during recessions). So, in the NBP's approach the uncertainty consistent with past forecast errors is adjusted with the anticipated changes in degree of uncertainty as compared to historical periods.

A need for adjustment of the uncertainty assessment based on past forecasting errors results as well from the assumption of a fixed reference interest rate under which NBP's projections are prepared. Past forecast errors are based on NBP's forecasts conditioned on interest rates consistent with market expectations. Assumption of no change in interest rates, i.e. no reaction of monetary authority to any changes in inflation and economic activity should result in greater variance/uncertainty of future inflation path[21].

To cope with the above-mentioned problems the following procedure is used.

1. First, we calculate model-based uncertainty with the use of stochastic simulations. These are conducted as described in Fair (2001), i.e. in each period expectations are formulated assuming knowledge about past and current shocks while future shocks are assumed to remain unknown (thus are set to their expected value of zero). Selected (see section 5.2.1) exogenous variables are shocked with impulses of historical magnitude. Taylor rule is enabled.

2. In the next step, the resulting uncertainty of inflation and GDP, evaluated by stochastic simulations, is compared to the risk estimated on the base of past forecast errors from the previous forecasting rounds. Discrepancy between the two is a measure of uncertainty sources unaccounted for in the simulations. This is done separately for inflation and GDP growth and for each forecasting horizon.

3. Next, we calculate an anticipated model-based uncertainty. The same exogenous variables are shocked again in stochastic simulations, but this time shocks are of magnitudes anticipated by economic experts or financial markets and Taylor rule is disabled.

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[21]The same may be not true for GDP growth, as monetary authority stabilising inflation may in the short-term increase the variance of GDP growth.

4. In the last step, we complement anticipated model-based uncertainty from step 3 with the uncertainty unaccounted for in the simulations [22] (obtained in step 2) to get a final estimate of future uncertainty.

Summing up, the final estimate of future uncertainty depends on three components:

- past forecast errors,

- the model's structure,

- the anticipated change in uncertainty of selected exogenous variables.

5.2 Determining the uncertainty of exogenous variables

Ex ante uncertainty of assumptions underlying projection of inflation and GDP is used in estimation of anticipated change in the overall uncertainty (as compared to past forecast errors). Below we give a more detailed description of series we shock in stochastic simulations.

5.2.1 Shocked time series

When choosing series to be shocked in stochastic simulations, the following criteria were taken into account:

- A selected variable should have prevailing impact on inflation and/or GDP growth (the property was assessed on the base of model multipliers);

- Uncertainty of the variable should be subject to non-negligable changes between forecasting rounds;

- Uncertainty of the selected time series should be feasible to measure and forecast.

Based on these criteria the following time series were selected:

- Crude oil price in the world markets

- Natural gas price in the world markets

- Coal price in the world markets

- EUR/USD exchange rate

- 3M interest rates in the euro area

- 3M interest rates in the USA

- Price of food commodities in the world markets

- Weighted GDP of the main trading partners

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[22] As this uncertainty cannot be quantified, we assume that it is fixed at the average historical level.

5

- Weighted potential GDP of the main trading partners

- Weighted value-added deflator of the main trading partners

It is worth noting that all of the above-mentioned variables describe foreign environment. This corresponds with the perception of Polish economy as a small open economy.

5.2.2 Data sources

Beyond think-tank forecasts and experts' opinions, an alternative way to assess uncertainty of variables is to turn to commodity and financial markets. It is possible to infer expected prices of underlying traded commodities or instruments as well as their risk distributions from derivative contracts (futures or options).

5.2.3 Estimating/evaluating uncertainty of shocked exogenous variables

Commodity price risk Natural gas, crude oil and coal prices in the international energy exchanges have been rising strongly over the last few years to decline sharply at the end of 2008. Energy prices volatility creates uncertainty for all market participants and has significant impact on the nominal and real side of the economy.

A way to assess expected future commodity prices is to derive them from the current futures price of the exchange-traded energy futures contracts. The most representative contracts for each raw material were chosen to serve as an international benchmark grade, namely: Brent Crude Oil futures and Natural gas futures (traded at NYMEX) and Richard's Bay coal futures (traded at ICE).

Figure 1: Brent oil price with market expectations from futures contracts.*
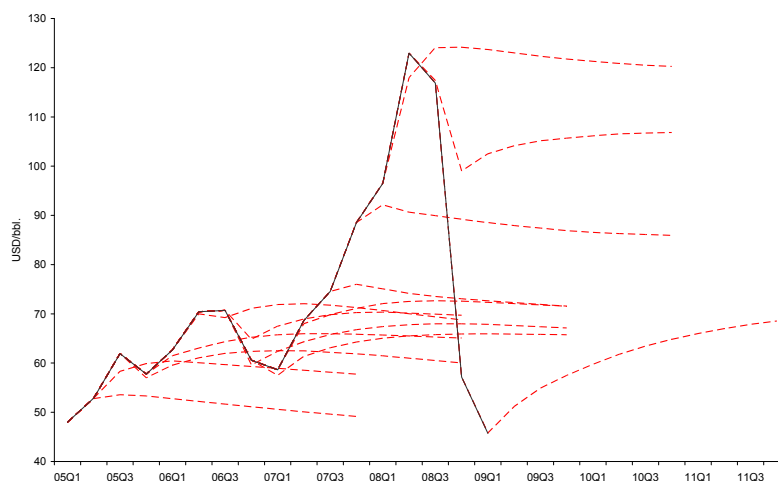
*Information collected on cut-off dates.

Uncertainty of anticipated energy prices is calculated on the basis of errors of similarly constructed historical forecast. In practice, we evaluate the average past error of market expectations about future energy prices for different durations of contracts. This

pure statistical approach can be then modified with expert judgement. The uncertainty assessment is conducted for each price variable separately.

To assess the risk of the spot prices forecast based on future contract prices the data on contracts traded on the day of the cut-off dates for consecutive forecasting rounds (from May 2005) were collected. Figure 1 displays the futures contracts for oil prices collected on cut-off dates.

Future raw material prices are assumed to follow log-normal distribution. The distribution has two desired properties. First, commodity price data tend to be highly skewed. Second, commodity prices have a theoretical minimum value (zero) but no theoretical maximum value.

Next, for each quarter of projection horizon differences between natural logarithms of adequate future price and realisations were calculated and assumed to follow normal distribution with zero mean and horizon-specific variance obtained with the approach coherent with the one used to calculate variance of the past errors for inflation and GDP.

Figure 2: Historical uncertainty concerning crude oil price forecasts.*

*Calculation from June 2009 forecasting round.

Experts use statistical description of past future prices based prediction errors as a reference point to assess anticipated changes in this uncertainty. They can scale the uncertainty bands in order to indicate i.e. that in the forecasting horizon some markets may be more/less volatile than in the past. They can as well change the balance between upwards and downwards risks for each quarter of their forecast.

EUR/USD exchange rate   Above-mentioned energy commodities, as well as food commodities in the world markets, are quoted in USD. At the same time, Polish currency behaves much more in line with EUR than with USD. Thus, prices of energy and food commodities quoted in PLN depend heavily on the EUR/USD exchange rate. That was the main rationale for introducing this cross-exchange rate to the risk analysis.

Uncertainty of the EUR/USD exchange rate is based on currency options contracts. Data are extracted from Bloomberg and cover current and all past cut-off dates. Unfortu-

nately data are available only for 4-quarter horizon, so for longer horizons trends need to be extrapolated. It was assumed that variance in the later quarters grows linearly, which corresponds with the assumption of white noise process.

3M interest rates in the euro area and in the US   Introduction of foreign short-term interest rates to the risk analysis is important mainly as they affect behaviour of exchange rates. Also, both interest rates - in the euro area and the US are shocked, instead of just one weighted interest rate of main trading partners of Poland. This allows (through cross-correlations of shocks) to catch influence of those interest rates on EUR/USD exchange rate.

Uncertainty of 3M interest rates in the euro area and the US is also (as for EUR/USD exchange rate) based on options contracts and the data also come form Bloomberg. This time data are available for 8-quarter horizon so less extrapolating needs to be done, but the procedure is the same as for EUR/USD exchange rate.

Other variables   Uncertainty of the remaining variables (namely: price of food commodities in the world markets and weighted GDP, potential GDP and value-added deflator of main trading partners) is given by experts. In their assessment of the uncertainty, experts use various available sources of information including their knowledge of the economic processes, sometimes backed by intuition.

5.3   Simulation of paths of exogenous variables

Experience gathered at the NBP indicates that ascribing 5th and 95th percentiles to respectively minimum and maximum forecast paths of the variable may well serve as an intuitive method of quantifying the uncertainty by experts. Distributions provided by experts can be asymmetrical - see example below for oil price.

Figure 3: Future uncertatinty concerning crude oil price forecast.*
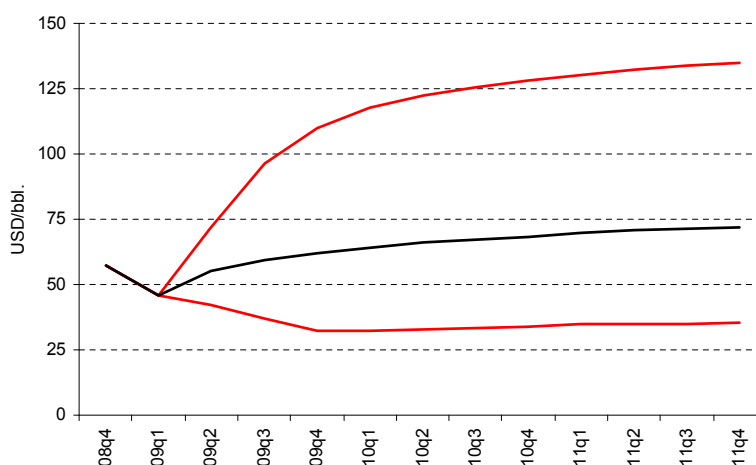
*Assumption for June 2009 forecasting round.

Importantly, significantly different data generating processes (DGPs) can be consistent with an expert forecast described in terms of central path and minimum and maximum bounds. Graphs below show ten exemplary paths of oil prices with different assumptions about DGPs, but in both cases expected value, 5th and 95th percentile for the distribution are the same.

Table 10: Ten exemplary oil price paths generated with the assumption of:

zero autocorrelation

zero autocorrelation
for first differences
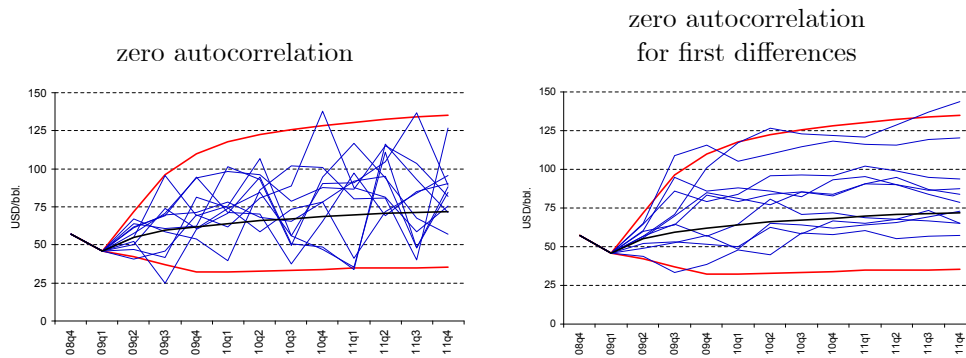
Intuitively, for each DGP of exogenous variables used in stochastic simulations, resulting uncertainty of inflation and GDP growth (fan charts) would be different. For that reason procedure of simulating exogenous variables needs to have the following properties:

- The expected value of simulated paths of variables conforms to central paths given by experts.

- The expected value of stochastic disturbances is zero.

- The autocorrelation of variables observed in the sample is retained.

- The cross correlation of shocks among particular variables is retained.

5.3.1   Data generating process (DGP)

Each variable (where exogenous variables are indexed by i) is assumed to be generated by the process of the form:

$$f(y_{i,t}) = a_{i,t} + b_i \cdot f(y_{i,t-1}) + \xi_{i,t}$$

$$\xi_{i,t} \sim TPN(0, s^1_{i,t}, s^2_{i,t})$$

where: $f(y_t) = y_t$ or $ln(y_t)$, Δy_t, $\frac{\Delta y_t}{y_{t-1}}$.

Transformation $f(.)$ depends on the time series properties of the exogenous variable, i.e. its volatility and stationarity or non-stationarity. Shocks for each variable are correlated $(\text{E}(\xi_{i,t}, \xi_{j,t} \neq 0)$ and TPN stands for two-piece normal distribution (also called half-Gaussian distribution).

Therefore, exogenous variables in stochastic simulations are generated by AR(1) process with time-varying constant and shocks following asymmetric distribution with time-varying variance. Parameters describing autocorrelations for each variable (b_i) and values of cross-correlations between shocks for different variables are constant in time and are estimated.

Parameters $a_{i,t}, s_{i,t}^1$ and $s_{i,t}^2$ corresponding with equations for each exogenous variable are calculated so that DGPs generating these variables are consistent with the central path and confidence bands given by experts. As three parameters are calculated for each period and three characteristics of each period distribution are given by experts, calculation of the parameters is unambiguous.

5.3.2 DGP - Autocorrelations and cross-correlations

Historical time series of exogenous variables are described by the process:

$$f(y_t) = \alpha + \beta \cdot f(y_{t-1}) + \varepsilon_t$$

where $f(y)$ is a vector of variables after appropriate transformations. Parameters of this process estimated jointly with seemingly unrelated regression (SUR) method to allow for cross-correlations between residuals from equations entering the system. Estimator of β_i i.e. b_i , measuring the level of autocorrelation for the series, is used in DGP for the series. Estimators of the constants (α) are not used. Residuals of equations are used to calculate the correlation matrix $\Sigma = \{\rho_{ij}\}$, where ρ_{ij}- empirical Spearman rank correlation between $e_{i,t}$and $e_{j,t}$.

In order to retain those Spearman rank correlations for shocks for each variable, shocks are generated jointly by:

$$\xi_{i,t} = F_{i,t}^{-1}(\Phi(\varepsilon_{i,t}))$$

where:

$F_{i,t}$- cumulative distribution function (CDF) of TPN $(0, s_{i,t}^1, s_{i,t}^2)$,

Φ- CDF of N(0,1),

$e_t \sim$N(0, Σ).

The abovementioned transformation is monotonic and does not change Spearman rank correlations (The correlation between $\varepsilon_{i,t}$and $\varepsilon_{j,t}$ is the same as the one between $\xi_{i,t}$and $\xi_{j,t}$).

With the transformation $u_{i,t} = \Phi(\varepsilon_{i,t})$ variables from multivariate uniform distribution with retained Spearman rank cross-correlations are produced, and with the transformation $\xi_{i,t}=F_{i,t}^{-1}(u_{i,t})$ we obtain series from multivariate TPN distribution also with retained Spearman rank cross-correlations.

5.4 Illustrative results

Sample results, basing on the June 2009 forecast round, are shown below. First two figures show uncertainty of the past NBP forecast errors, which are the reference for estimating future uncertainty.

Table 11: Fan charts based on past forecast errors.*

CPI inflation   GDP growth
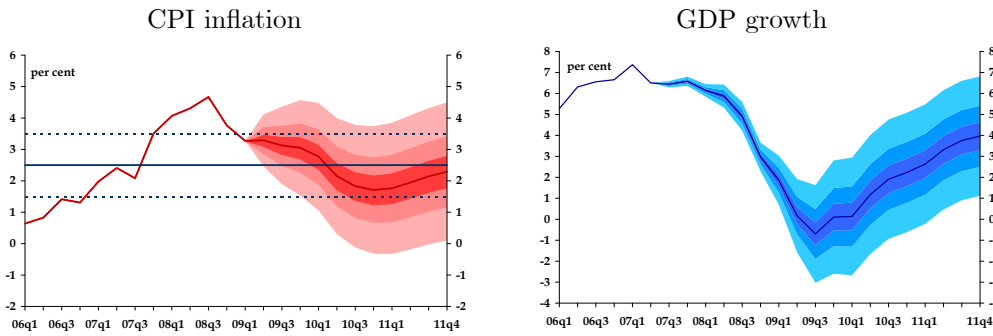
*Calculation up to February 2009 forecast.

Application of the NBP's procedure for future uncertainty evaluation resulted in considerable increase in anticipated uncertainty for CPI inflation projection in the long-term horizon. This should come as no surprise, taking into account that this uncertainty is estimated under the assumption of fixed reference interest rate, i.e. no reaction of monetary policy to inflationary developments. At the same time, anticipated uncertainty for GDP growth was slightly increased in the short term and slightly reduced in the medium term. The increase in the short term may be attributed to higher anticipated uncertainty of external assumptions (effects of the recent turmoil on the financial markets), while the decrease in the medium term is a result of workings of model mechanisms and fixed reference interest rate assumption. Namely, in the face of external shocks monetary policy (which in the model is aimed at stabilising inflation) may slightly destabilise GDP growth in the medium term. Final fan charts for CPI inflation and GDP growth in June 2009 forecasting round are shown below.

Table 12: Final fan charts.*

CPI inflation   GDP growth
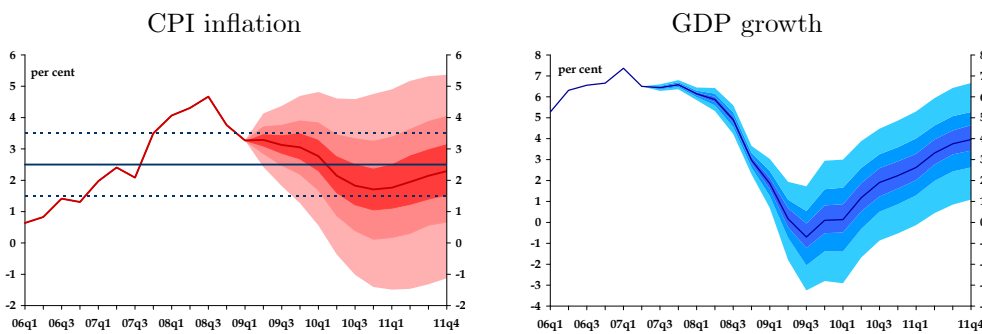
*June 2009 forecasting round.

6

Concluding remarks

The paper summarises the structure and properties of the model of Polish economy used for forecasting and simulation purposes at the NBP. The NECMOD model is regularly used as a basic tool for preparation of inflation and GDP projection and tested on being able to rightly reflect developments of underlying economy in sufficient detail. As new economic developments emerge or disappear from the surface of observable macroeconomic reality, the NECMOD model is challenged to incorporate these changes.

Major challenges tackled in the current version of the model originate in the gradual process of economic convergence and integration of Polish economy into European and global environment. Compared to the previous model version, closer look was given to coherency of specification of the trade block and the equilibrium exchange rate. The solutions implemented in NECMOD allow us to reinterpret convergence and integration processes as two phenomena tied closely together, which are driven and disturbed by similar set of factors. Explicit formulation of foreign assets accumulation and tagging the exchange rate volatility to deviations of the net foreign assets from the steady state steer medium run fluctuations of the exchange rate and introduce one more channel (next to labour market, capital and fiscal policy channels) of persistency and hysteresis in the modelled economy.

The clear-cut advantage of the model is its explicit treatment of policies tied to Polish participation in the European Union and their ties with fiscal and private sector in Poland. Inflow of structural funds and remittances interacts with other processes shaping exchange rate and capital accumulation dynamics.

The model as a simplification of the underlying economy should further evolve in line with changes in the economic environment and increasing experience of the team. The structure of the model may be extended in the coming years to account for some financial sector distortions. However, key area of consecutive works shall be preparation of forecasts on the basis of the traditional econometric model concurrently with projections on the DSGE model and extension of the risk assessment methodology.

References

Budnik K., Greszta M., Hulej M., Kolasa M., Murawski K., Rot M., Rybaczyk B., and Tarnicka M. (2009): "The new macroeconometric model of the Polish economy," *National Bank of Poland Working Papers No. 62.*

Estrada Á., Fernández J. L., Moral E., and Regil A. V. (2004): "A Quarterly Macroeconometric Model of the Spanish Economy," *Banco de España Working Papers.*

Fair R. C. (2001): "Optimal control and stochastic simulation of large nonlinear models with rational expectations," *Yale ICF Working Paper No. 00-41.*

Ploeg F. van der (1982): "Reliability and the Adjustment of Sequences of Large Economic Accounting Matrices," *Journal of the Royal Statistical Society. Series A (General)*, 145(2), 169–194.

Rubaszek M. (2008): "Economic convergence and the fundamental equilibrium exchange rate in Poland," *MPRA Paper 12910, University Library of Munich, Germany.*

Appendix: NECMOD variables

Symbols in the brackets following the variable name stand for: EX – exogenous, EN – endogenous.

- ALMP_N (EN) -expenditure on active labour market policy expenditure (sum of the general government (GG) expenditure on active labour market policy and structural funds from the European Union (EU) on human capital development)

- BS_TREND (EX) – trend in the core inflation equation, truncated from 2002Q3

- CAB (EN) – current account balance (including the capital account) in EUR

- CAB_GDP (EN) – current account balance (including the capital account) to GDP ratio

- CAB_INC_EUR_NOREM (EN) – current account income balance excluding remittances in EUR

- CAB_NT (EN) – trade balance of goods and services in EUR

- CAB_TRANS_EUR_NOREM (EN) – current account transfers balance excluding remittances in EUR

- CAB_TRANS_INC_GDP (EN) – ratio of current account income and transfer balances to GDP

- CONGOV (EN) – government consumption

- CONGOV_N (EN) – nominal government consumption

- CONP (EN) – individual consumption

- CONP_N (EN) – nominal individual consumption

- CORECPI (EN) – core CPI index (CPI net of food and energy prices)

- CPI (EN) – consumer price index

- DISC_H (EX) – discard rate of housing capital

- DISC_P (EX) – discard rate of private capital

- DxxQy (EX) – shift dummy variable where xx means year and y denotes quarter when the shift takes place

- EMP (EN) - employment in the economy

- EMP_A (EN) – employment in agriculture

- EMP_NA (EN) – non-agricultural employment

- ENERCPI (EN) – index of consumer energy prices

- FINACC (EN) – corporate disposable income share in GDP

- FOODCPI (EN) – index of consumer food prices

- G_BALANCE_GDP (EN) – GG balance to GDP ratio

- G_BALANCE_N (EN) – GG balance

- G_CORP_TR (EN) – effective tax burden levied on enterprises and farmers, taking into account the effective tax rate of corporate income tax, social security contributions of farmers, government subsidies to production and government capital transfers

- G_CORP_EU (EN) – ratio of EU structural funds directed to firms and farmers to corporate investments

- G_DEBT_DOM_N (EN) – GG debt in domestic currency

- G_DEBT_DOM_RES_N (EN) – GG debt in domestic currency held by residents

- G_DEBT_DOM_NRES_N (EN) – GG debt in domestic currency held by non-residents

- G_DEBT_FOR_N (EN) – GG debt in foreign currencies

- G_DEBT_FOR_RES_N (EN) – GG debt in foreign currencies held by residents

- G_DEBT_FOR_NRES_N (EN) – GG debt in foreign currencies held by non-residents

- G_DEBT_N (EN) – GG debt

- G_DEBT_RES_N (EN) – GG debt held by residents

- G_DEBT_NRES_N (EN) – GG debt held by non-residents

- G_REF (EX) – share of pensions covered by GG (variable accounts for changes following pension reform in 1999)

- GAP (EN) - output gap

- GDEBT_DOM_RES (EN) – share of GG debt denominated in domestic currency and held by residents

- GDEBT_DOM_NRES (EN) – share of GG debt denominated in domestic currency and held by non-residents

- GDEBT_EXCHANGE (EN) – the effective exchange rate relevant for changes in the value of GG debt denominated in foreign currencies

- GDEBT_EUR (EN) – share of GG debt in foreign currencies which is denominated in EUR

- GDEBT_FOR_RES (EN) – share of GG debt denominated in foreign currencies and held by residents

- GDEBT_FOR_NRES (EN) – share of GG debt denominated in foreign currencies and held by non-residents

- GDP (EN) – gross domestic product

- GDP_EXP (EN) – exports volume

- GDP_EXP_N (EN) – nominal exports

- GDP_EXT (EX) – foreign GDP (weighted average of the respective variables for euro area, the UK, and the USA)

- GDP_EXT_POT (EX) – foreign potential output (weighted average of the respective variables for euro area, the UK, and the USA)

- GDP_IMP (EN) – imports volume

- GDP_IMP_N (EN) – nominal imports

- GDP_N (EN) – nominal gross domestic product

- GDP_POT (EN) – domestic potential output

- GE_CAP_TRANS_N (EN) – GG capital transfers

- GE_CON_N (EN) – GG intermediate consumption

- GE_EU_N (EN) – GG contribution to EU budget

- GE_EU_EUR (EN) – GG contribution to EU budget (in EUR)

- GE_FAMILY_N (EN) –GG expenditure on family benefits

- GE_FIN_N (EN) – interest on the GG debt

- GE_GFCF (EN) – real GG investments

- GE_GFCF_N (EN) – nominal GG investments

- GE_INT_DOM_N (EN) – interest on the GG debt denominated in domestic currency

- GE_INT_FOR_N (EN) – interest on the GG debt in foreign currencies

- GE_INT_RES_N (EN) – interest on the GG debt held by residents

- GE_INT_NRES_N (EN) – interest on the GG debt held by non-residents

- GE_N (EN) – total GG expenditure

- GE_OTHER_TRANS_N (EN) – other GG transfers without EU budget contribution

- GE_PENSIONS_N (EN) – GG expenditure on pensions

- GE_PRERETIRE_N (EN) – GG expenditure on preretirement benefits

- GE_PRIV_N (EX) – GG revenues from privatisation

- GE_RELIEF_KIND_N (EN) – GG social transfers in kind

- GE_RELIEF_REST_N (EN) – other GG expenditure on social assistance

- GE_SOC_CASH_N (EN) – GG social benefits other than social transfers in kind

- GE_SOCSECURITY_N (EN) – GG expenditure on social benefits i.e. health, maternity benefits

- GE_SUB_FARM_N (EN) – GG subsidies to farmers

- GE_SUB_NOFARM_N (EN) – GG subsidies excluding subsidies to farmers

- GE_UNEMP_N (EN) – GG expenditure on unemployment benefits

- GE_WF_N (EN) – GG expenditure on compensation of employees

- GFCF_G (EN) – gross fixed public capital formation

- GFCF_H (EN) – gross fixed residential capital formation

- GFCF_N (EN) – nominal gross fixed capital formation

- GFCF_P (EN) – gross fixed corporate capital formation

- GFCF (EN) – gross fixed capital formation

- GR_CAP_TRANS_N (EN) – GG capital transfers revenues

- GR_CIT_N (EN) – taxes on income or profits of enterprises

- GR_CIT_TR (EN) – effective rate of taxes on the income or profits of enterprises

- GR_CORP_N (EN) – social security contributions paid by employers

- GR_CORP_TR (EN) – effective rate of social security contributions paid by employers

- GR_EMP_N (EN) – social security contributions paid by employees

- GR_EMP_TR (EN) – effective rate of social security contributions paid by employees

- GR_EXT_ENER_TR (EN) – effective tax rate of excise duties imposed on energy commodities (fuels and gas)

- GR_EXT_REST_TR (EN) – effective rate of excise duties on goods other than energy commodities (fuels and gas)

- GR_EXT_TR (EN) – effective tax rate of excise duties

- GR_FARM_N (EN) – social security contribution paid by farmers

- GR_FARM_TR (EN) – effective tax rate of social security contribution paid by farmers

- GR_GAM_TR (EN) – effective rate of gambling taxes

- GR_HC_N (EN) – GG revenues from compulsory health care contribution

- GR_HC_TR (EN) – effective rate of compulsory health care contribution

- GR_INC_TAX_N (EN) – GG revenues from income and wealth taxes

- GR_N (EN) – total GG revenues

- GR_OTAX_CORP_N (EN) – GG revenues from other taxes on production and products

- GR_OTAX_HH_N (EN) – GG revenues from other than indirect and income taxes levied on households

- GR_OTHER_CURT_N (EN) – GG revenues from other current transfers

- GR_OUTPUT_N (EN) – GG market output, output for own final use and payments for other non-market output

- GR_PIT_N (EN) – GG revenues from personal income tax

- GR_PIT_TR (EN) – effective rate of personal income tax

- GR_PIT_CIT_N (EN) – GG revenues from personal income tax levied on small entrepreneurs

- GR_PROD_TAX_N (EN) – GG revenues from taxes on production and imports

- GR_PROP_INC_N (EN) – GG property income

- GR_TAR_TR (EN) – effective rate of import duties

- GR_TCONTR_N (EN) – total social contributions

- GR_VAT_TR (EN) – effective rate of VAT

- HH_NET_WEALTH_RATIO (EN) – control variable for changes in the households' portfolio structure; ratio of a difference of financial assets and liabilities of households to nominal value of wealth

- I_3M (EN) – WIBOR 3M quarterly average

- I_3MR_CPI (EN) – real 3-month interest rate (deflated with CPI)

- I_3MR_EQ (EX) – equilibrium real interest rate

- I_3MR_EXT (EN) – real 3-month foreign interest rate deflated with foreign value-added deflator

- I_3MR_PVA (EN) – real 3-month interest rate deflated with the value-added deflator

- I_5Y (EN) – yield on 5-year government bonds

- $\overline{I\_5Y_t}$ (EN) – smoothed yield on 5-year government bonds (four-quarter moving average)

- I_5Y_EUR (EX) – yield on 5-year Bunds

- I_H (EN) – average interest on mortgage loans (weighted average of 5-year domestic and euro-area rates)

- INF (EN) – CPI inflation

- INF_TARGET (EX) – inflation target

- $\overline{INF\_TARGET}$ (EX) – smoothed inflation target (four-quarter moving average)

- INV (EN) – change in inventories

- INV_N (EN) – change in inventories in nominal terms

- IxxQy (EX) – one period dummy variable, where xx denotes year and y stands for quarter

- K_G (EN) – gross public capital

- K_H (EN) – gross residential capital of households

- K_P (EN) – gross corporate productive capital

- KN (EN) – net productive capital

- KN_G (EN) – net public capital

- KN_H (EN) – net housing capital

- KN_P (EN) – net corporate productive capital

- LF (EN) – labour force supply

- LF_EQ (EN) – the equilibrium participation rate

- LF_M (EN) – middle-aged labour force (25-44 years)

- LF_O (EN) – older labour force (45+ years)

- LF_Y (EN) – younger labour force (15-24 years)

- LIK_G (EX) – liquidation rate of public capital

- LIK_H (EX) – liquidation rate of housing capital

- LIK_P (EX) – liquidation rate of private enterprises capital

- M3 (EN) – money demand, M3 aggregate

- MINW (EN) – relation of minimum wage to average gross wage in the economy

- MPK (EN) – marginal product of corporate capital

- NAWRU (EN) – non-accelerating wage inflation rate of unemployment

- NFA (EN) – net foreign assets in PLN

- NFA_GDP (EN) - net foreign assets to GDP ratio

- OFE_N (EN) – general government transfers to open pension funds

- OPEN (EN) – measure of openness; ratio of imports and exports to GDP

- OPSURP_N (EN) – net operating surplus

- P_ENER (EX) – index of global energy prices

- P_FOOD (EX) – index of global food prices

- P_GAS (EX) – global gas prices (price of Russian gas per 1000 cubic meters)

- P_OIL (EX) – price of BRENT oil

- PCONGOV (EN) – government consumption deflator

- PEXP (EN) – deflator of exports

- PEXP^c (EN) – export prices corrected for equilibrium exchange rate fluctuations

- PGDP (EN) – deflator of GDP

- PGFCF_H (EN) – deflator of gross fixed residential capital formation

- PGFCF_G (EN) – deflator of gross fixed public capital formation

- PIMP (EN) – deflator of imports

- PIMP^c (EN) – imports prices corrected for equilibrium exchange rate fluctuations

- PIMP_CORE (EN) – deflator of imports excluding prices of oil and gas

- PIMP_CORE^c (EN) – imports prices excluding prices of oil and gas corrected for equilibrium exchange rate fluctuations

- POP (EX) – total population

- POP_M (EX) – middle-aged population (25-44 years)

- POP_O (EX) – older population (45+ years)

- POP_Y (EX) – younger population (15-24 years)

- PREMIUM (EN) – wedge on the mortgage credit tied to credit risk and shallowness of the market

- PVA (EN) – deflator of value-added

- PVA_EXT (EX) – deflator of foreign value added

- R_RATE (EN) – real interest rate (equal to the average of 3-month rate deflated with value-added deflator and 5-year rate deflated with inflation target)

- REM_BALANCE (EN) – remittances flow balance in EUR

- RETIRED (EX) – number of retired in the economy

- RR_NLF_M (EN) – replacement rate for middle-aged labour force (including disability benefits, retirement benefits and social relief)

- RR_NLF_O (EN) – replacement rate for older labour force (including disability benefits, retirement benefits and social relief)

- RR_RELIEF_KIND (EN) – ratio of the average value of social transfers in kind per eligible household to average gross wage

- RR_REM (EN) – ratio of the average value of remittances per Polish resident to average gross wage

- RR_UNEMP (EN) – replacement rate for unemployed (including unemployment benefits and social relief)

- RUCC (EN) – real user cost of capital

- RUCC_H (EN) – real user cost of residential capital

- S_EUR_PLN (EN) – EUR/PLN exchange rate

- S_NEER (EN) – nominal effective exchange rate

- S_REER (EN) – real effective exchange rate

- S_REER_EQ (EN) – real effective exchange rate

- S_USD_PLN (EN) – USD/PLN exchange rate

- SALES (EN) – level of sales; variable composed of the sum of private and government consumption, total investment and the volume of exports

- STOCK (EN) – level of inventories

- STUDENT (EX) – ratio of non-extramural students to total younger population

- TCAB (EN) – the equilibrium current account to GDP ratio

- TFP_TREND (EN) – trend total factor productivity

- TFP_EXT (EN) – total factor productivity abroad

- TRANS_CAP_N (EN) – Common Agricultural Policy transfers in PLN

- TRANS_EU_EUR (EN) – funds from the EU including structural funds and CAP transfers

- TRANS_GFCF_F_N (EN) – EU structural funds for rural development in PLN

- TRANS_GFCF_G_N (EN) – EU structural funds for public capital development in PLN

- TRANS_GFCF_P_N (EN) – other EU transfers mainly for enterprises in PLN

- ULCNA (EN) – unit labour costs in enterprises sector

- UNRATE (EN) – unemployment rate

- $\overline{UNRATE}$ (EN) – the average unemployment rate in the previous year

- W_CORE (EX) – weight of core inflation in CPI basket

- W_ENER (EX) – weight of energy prices in CPI basket

- W_FOOD (EX) – weight of food prices in CPI basket

- W_SHORT_DOM (EN) – variable controlling pass-through of short-term interest rate changes into servicing cost of public debt in domestic currency

- WAGE_N (EN) – nominal gross average wage

- WEALTH (EN) – households' wealth

- WORK_AGE (EX) – trend indicating the negative influence of gradual ageing of older population on its activity rate (the relation of population between 45+ and 65 years old to total 45+ population)

- YD (EN) – real disposable income of households

- YD_N (EN) – nominal disposable income of households

- YD_NOS_N (EN) – nominal disposable income of households from operating surplus

- YD_PRO_NOGINT_N (EN) – nominal disposable income of households from property excluding interests on GG debt

- YD_WF_N (EN) – nominal wage bill