MATERIAŁY I STUDIA

Paper No. 31

Structural Econometric Models in Forecasting Inflation at the National Bank of Poland

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Warsaw, January 2005

We would like to thank the participants of seminars held at the NBP, the ECB and Warsaw University, and in particular Wojciech Charemza, Wojciech Maciejewski, Krzysztof Marczewski, David Mayes, Lucjan Orłowski, Witold Orłowski and Krystyna Strzała for their comments and suggestions. Obviously, all remaining shortcomings of this text are the authors' sole responsibility.

Design:

Oliwka s.c.

Layout and print:

NBP Printshop

Published by:

National Bank of Poland
Department of Information and Public Relations
00-919 Warszawa, 11/21 Świętokrzyska Street
phone: (22) 653 23 35, fax (22) 653 13 21

http://www.nbp.pl

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Abstract

The paper presents the procedure and two structural macroeconometric models used at the National Bank of Poland for producing regular quarterly inflation projections. One of the models is a small macroeconomic model based on the New Keynesian Phillips curve, the IS curve and the exchange rate equation based on uncovered interest parity with risk factors. The other, more disaggregated model, explicitly focuses on the supply side and separates the steady state from short-term adjustments.

JEL: C5, E37, E58

Keywords: macroeconomic models, inflation forecasting.

I
Introduction

This paper presents the procedures and modelling tools used at the National Bank of Poland in the preparation of inflation projections for the Monetary Policy Council. The theoretical and methodological assumptions underlying the models used are rooted in the so-called New Neoclassical Synthesis, which dominates in the contemporary macroeconomics[1]. The first model used – the NSA – is a small macroeconomic model focused on the most important relationships recommended by contemporary macroeconomics: the New Keynesian Phillips curve, the IS curve, and the exchange rate equation based on uncovered interest parity extended with factor risk. The other model (the MSMI) is a much more disaggregated tool, explicitly focusing on the supply side and separating the steady state from the short-term adjustment process. Apart from the theoretical foundations of the models, diagrams of key relationships between them and equation specifications, the text also presents some detailed information concerning their dynamic properties.

The structure of this paper is as follows: the first part, which is an introduction of sorts, briefly restates the views prevailing in the central bank environment concerning the role of structural models in analytical activities, the most important recommendations formulated with regard to such models by academic economists, and the conclusions drawn from the use of the models by central banks. A short presentation of the current procedure of developing inflation projections used at the NBP since the last quarter of 2003 concludes the introduction. The next two sections contain detailed descriptions of the models used in the development of inflation projections. The New Analytical Scheme (Nowy Schemat Analityczny – NSA) model is presented first; although created somewhat later than the Small Structural Inflation Model (Mały Strukturalny Model Inflacji – MSMI), it was the primary model used for forecasts until 2003.

1. The role of structural models in monetary policy analysis

In the daily practice of central banks (in this paper identified with entities conducting the monetary policy) structural models are most often used for developing macroeconomic forecasts, designing monetary policy and analysing its alternative scenarios. Models have the advantage of providing an ordered framework for the monetary policy strategy development, and in particular of explicitly presenting how current monetary policy impacts long-term objectives (this area is usually referred to as the analysis of the monetary policy transmission mechanism)[2]. Counterfactual exercises are less often used in daily analytical activities, although they are often exploited as a tool for historical analyses. Moreover, larger structural models are used for integration of the work of expert teams dealing with particular sectors of the economy. The results of the experts' work complement or validate model studies, and thus an ordered discussion becomes possible on the basis of the system of balance conditions included in the model and also on the economic mechanisms represented in the model as well as those that have not been quantified and need to be supplemented or otherwise taken into account.

Economic forecasts may obviously be developed in various ways but all methods which ensure their transparency and repeatability require the use of models. Such models may be constructed in many different ways. In general, however, it may be stated that all methodological solutions used in this respect fit into an area delimited by purely statistical (empirical) models on

[1] Cf. Goodfriend (2004), Woodford (2003), Kokoszczyński (2004), p. 45.
[2] Similar concepts may be found e.g. in Bank of England (1999) and Meyer (1997).

the one hand, and models built upon strictly theoretical guidelines on the other[3]. Purely statistical models may be used and, indeed, are used in forecasting but the character of forecasts required by the central bank in order to make decisions naturally leads towards the use of models with clear theoretical foundations, which, however, combine theoretical assumptions with information gathered from data describing the modelled reality. The main reasons for that are, among others, the conditional character of forecasts developed by central banks, delays in the monetary policy transmission process, as well as strong interdependencies between forecasting and scenario analysis in the process of developing monetary policy decisions.

2. Structural models for forecasting inflation and monetary policy analyses – guidelines from theory and the practice of the European System of Central Banks

The approach to modelling used in monetary policy analyses currently prevailing in academic macroeconomics is usually called the New Neoclassical Synthesis or the New Keynesian Economics[4]. In models based on this paradigm, basic relationships are derived as the result of the optimising behaviour of rational microeconomic agents[5]. The most important relationships, which form a complete, albeit very synthetic, image of a closed economy in this approach, are the New Keynesian Phillips curve, the IS curve and the interest rate rule. When modelling an open economy, the above list of relationships must be supplemented by an exchange rate equation, which usually has the form of the uncovered interest parity, typically with additional factors representing a country's risk premium (these relationships are discussed in more detail in the section on the NSA model).

Such models may be used in order to look for the optimal monetary policy but also in order to forecast inflation – examples may be found in the already relatively abundant literature on the subject[6]. However, in the practice of central banks a much more detailed analyses are usually required. Firstly, central banks are normally concerned with inflation measures, which are determined not only by typical demand phenomena but also by supply shocks[7]. Secondly, inflation forecasts developed by central banks are usually based on the assumption that short-term interest rates remain constant, as this is the most transparent way of separating the process of forecasting from the process of decision-making[8]. In such circumstances it is useful to take the term structure of interest rates into account, which also requires the disaggregation of basic macroeconomic categories. Thus in practice central banks usually use a suite of models with varying levels of detail and importance of theoretical assumptions.

Even a skim through the models which prevail in the preparation of forecasts (or rather projections[9]) of inflation within the European System of Central Banks makes it clear that most of them include a block of steady state equations, which is in principle determined by neoclassical theoretical assumptions. Separate model components describing the short-term adjustment

3 The classification of models presented here is largely based on Kłos (2004), Pagan (2003), Turner (2001).
4 This current only crystallised in the late 1990s and therefore the relevant terminology has not fully stabilised yet, cf. Goodfriend (2004), Kokoszczyński (2004), pp. 44–50, Woodford (2003), pp. 6–10.
5 Cf. e.g. Minford and Peel (2001), part I; also see Wojtyna (2000), IV.1.
6 The first application has, as it seems, been discussed in most detail in Woodford (2003), cf. also King, Wolman (1999), McCallum, Nelson (1999), Rotemberg, Woodford (1999); for the second application, see Arratibel et al. (2002), Gali, Gertler (1999), Gali et al. (2001), Neiss, Nelson (2002), Sbordone (2001).
7 Cf. Kokoszczyński (2004), Chapter 5.
8 The conditional character of such central bank forecasts clearly distinguishes them from all other macroeconomic forecasts developed by market participants, government agencies or academics – cf. e.g. Meyer (1997). However, views have recently emerged in the literature which suggest that more emphasis must be put on forecasts developed under the assumption of changing interest rate path in the forecast period; such path is usually determined by financial market expectations, which are already known at the moment when the forecast is being developed, cf. Goodhart (2000), Honkapohja, Mitra (2004), Leitemo (2003) and Svensson (1999).
9 Some central banks distinguish between those two concepts: a forecast is the result yielded by the model, which is usually adjusted only in terms of the statistical and econometric properties of the model and the forecast, whereas a projection is the final product developed by a team of analysts, which is the result of interaction between model results and expert knowledge.

process are supposed to ensure that model fits the data (error correction modelling is often applied here). Due to the effort required to develop a disaggregated macroeconomic model, the foregoing recommendations of academic economics (forward-lookingness, complete microeconomic foundations, etc.) have only recently been taken into account in the models used in the daily practice of central banks and the process has been of an evolutionary nature, i.e. occurring through the gradual modification of individual model relationships[10]. Currently, a typical model used by a central bank, member of ESCB, may be described as follows[11]. In the long run the model is determined by the concept of the vertical aggregate supply curve formulated within the framework of the neoclassical synthesis; in the short term, however, demand-side effects are important. The supply side of the model is based on the Cobb-Douglas or CES production functions; there is usually one sector (one product) in the model. Among the factors which affect supply in the long term, there are variables describing labour supply, which usually take some form of equilibrium unemployment rate (NAIRU, NAWRU). Capital is either represented directly (capital stock), or indirectly, by including the cost of capital or the real interest rate. Variables related to the external sector (the real exchange rate, external demand, etc.) also play a significant role in the models used by individual countries. The ways in which expectations and monetary and fiscal policy rules are included in the models used by ESCB central banks are so diverse that no typical approach can be identified. In the majority of models, monetary aggregates have no direct influence on production and prices.

3. Model-based inflation forecasts at the National Bank of Poland

Within the framework of the previous NBP monetary policy strategy, which until the late 1990s was close to monetary targeting, the main analytical tools of the central bank based on the money demand function and the monetary model of inflation[12]. The strategic change introduced in 1998 was a snap decision made by the MPC, thus work on its model background started only after it had been implemented[13].

Thus although the MSMI model was constructed in the years 1999–2000, its primary applications were to be medium-term scenario analyses of inflationary processes and analyses of alternative economic policies. Due to the scope of interest of the Monetary Policy Council it soon turned out that a model was required that would be useful both for policy analyses and forecasting inflation. Moreover, the scale of possible choices and the sometimes huge number of decision variants considered induced the development of a small model with a simple and transparent construction[14]. Such a model, initially developed primarily in order to investigate the transmission mechanism in Poland, later became the fundamental tool for forecasting inflation, as well. It was the SA model (later called the NSA). However, both the degree of aggregation of the NSA model and the fact that it did not allow for separate modelling of the supply side of the economy pointed to the need of employing a more complex model as well. During the years 2000–2003, the NSA model was used routinely, first on a monthly, and then on a quarterly basis, in order to develop inflation projections for the Monetary Policy Council. The MSMI model was used two or three times a year for banks' internal analyses of scenarios related to such events as e.g. Poland's accession to the European Union.

10 In the last two years, several central banks (in Finland, Sweden, England and Canada) made an effort to base their routine forecast work on entirely new models in order to implement theoretical guidelines more easily and properly, but in most cases such models are still treated as experimental ones or they have been used for a very short time. Therefore it is not yet possible to formulate any synthetic assessments of the practical application of this approach.

11 The structural models used by central banks belonging to the euro zone will be described in a book to be published in 2005.

12 Cf. NBP (1994), NBP (1995), and Kokoszczyński (2004), section 9.4.

13 A long period was required for the Polish direct inflation targeting policy to take shape, cf. e.g. Kokoszczyński (2004), Szpunar (2000).

14 Obviously, research on the transmission mechanism in Poland, as well as elsewhere in the world, was conducted using structural vector autoregression models (SVAR), cf. e.g. Kłos, Wróbel (2001), Kokoszczyński et al. (2002).

I

In the final period of implementation of the monetary policy aimed at bringing inflation down to a low level, the stabilisation of inflation became the medium-term objective of the central bank. In such circumstances it was necessary to extend the horizon for regular forecasts, which undermined the further use of a model without the supply side explicitely included as the basic analytical tool. On the other hand, however, the NSA model had been validated in practice by several years of use, so it was not considered advisable to discontinue its use entirely. The necessary change in the methodology of forecasts developed at the NBP led – due to time and resource constraints – to inflation projections which took into account the results yielded by both the existing and working models, i.e. the NSA and MSMI. However, in order to preserve the transparency of the procedure, the combination of forecasts from both models had to be given formal foundations: thus the projection being developed since autumn 2003 is a linear combination of NSA and MSMI results with weights obtained from minimising the historical errors of the forecast:

$$\min_{\lambda\in(0,1)} \sum_{t=1}^{Maxt} \sum_{h=0}^{Maxh} \theta(t,h)\left[\pi_t - \left(\lambda^{\omega(h)}\pi_{th}^{A} + \left(1-\lambda^{\omega(h)}\right)\pi_{th}^{B}\right)\right]^2$$

where π_{th}^{A} (π_{th}^{B}) are forecast values from the NSA and MSMI models for period t with forecast horizon h, while $\theta(t,h)$ is a system of weights which ensures that the influence of each observation on the value of the minimised loss function is the same. The monotonic function $\omega(h)$ determines the rate of decrease of the contribution of the first model (i.e. NSA) to the optimal projection, which reflects the opinion held by the designers of the procedure that the weight of the NSA model should decrease as the forecast horizon is extended.

Model-based projections are subject to uncertainty due to the nature of the models themselves and because of the necessity of using forecasted values of exogenous variables. The so-called fan charts are the standard tool used by central banks in order to illustrate this uncertainty. The inflation projection yielded by the two models has been presented routinely, together with the uncertainty distribution in the form of a fan chart, which has been constructed according to the method developed by the Sweden`s Riksbank[15]. The fundamental advantage of this approach is the explicit inclusion of the uncertainty related to the fact that the central projection is a single value, as well as of the asymmetry of exogenous variable forecasts and of the inflation projection itself in the complete presentation of the projection (the characteristic feature of this approach is the assumption that the variables exhibit two-piece normal distribution, i.e. their distribution is the superposition of two normal distributions with different standard deviations for the pieces where the values of the variables are lower and higher than the mode). This second element enhances the procedure – particularly after low inflation had been achieved, it was desirable to account for the fact that the most probable single values of forecasted variables often do not lie in the centre of the forecast range.

To sum up, since the last quarter of 2003 the model-based projection of inflation at the National Bank of Poland has been constructed as a linear combination of forecasts yielded by two structural macroeconomic models and presented together on a fan chart illustrating the uncertainty distribution.

[15] The method of calculating the parameters needed to construct the distribution of uncertainty for the central projection of inflation and present it as the so-called fan chart is described in detail in Blix, Sellin (1998), (1999).

II
Selected information about the NSA model

1. Historical outline

The roots of the model currently called the NSA (Nowy Schemat Analityczny – New Analytical Scheme) lie in the Small Structural Model of Monetary Transmission Mechanism in Poland (Mały Strukturalny Model Mechanizmu Transmisji Monetarnej w Polsce – MSMTM) developed in the summer of 2000 within the framework of an international research project organised at the Bank of England (Mahadeva and Sinclair, eds. (2000)). The MSMTM model was developed in order to assess the basic properties of the monetary transmission mechanism in Poland. With time, i.e. in the years 2000–2002, the MSMTM model evolved and attempted to take account of specific features of the Polish economy insofar as it was possible with the unchanged, theory-based, highly aggregated model structure (descriptions of the model and the results of its applications can be found e.g. in: Mahadeva and Sinclair, eds. (2000), Łyziak (2001), Łyziak (2002), Kokoszczyński, Łyziak, Wróbel (2002)). In 2001, the Analytical Scheme (Schemat Analityczny – SA) was developed at the National Bank of Poland. It was a tool similar in size and structure to the MSMTM but designed as a basis for inflation forecasts. The small size of the SA and its transparent structure had been well suited to the requirements of the Board of the NBP and the Monetary Policy Council concerning frequent scenario-based inflation forecasts. The most important feature of the Analytical Scheme, which was reflected in its very name, was the capability to include both quantitative analysis results and expert opinions in the forecast development process in a rigorous (ordered) way (Hornok, Jakab, eds. (2002)). The model evolved until 2002 when it reached the form presented in this paper and was named the NSA in order to distinguish it from its earlier versions.

2. Theoretical foundations

The NSA is an aggregate structural model describing the transmission mechanism in the spirit of the New Keynesian School. The underlying theoretical model combines the methodologies of models typical for the Real Business Cycle School (microfoundations) with the sticky price and wage assumption (Kokoszczyński (2004)). The reference points for the construction and development of the MSMTM/SA/NSA models were the British Batini and Haldane model (1999) as well as other small structural models, such as those presented in Svensson (1998), McCallum and Nelson (1999), Vlaar (2002) and Vincent (2002). Basic macroeconomic relationships analysed in those models were the aggregate demand curve, uncovered interest parity (UIP) and the Phillips curve. These relationships are considered crucial for the description of the mechanism of transmission of monetary policy impulses (Woodford (2003)).

Specific solutions, which have adjusted the general design of small structural models of this type to Polish conditions, include e.g.: using the aggregate demand curve in its open economy version, introducing the term structure of interest rates and specific risk factors into the UIP equation (Przystupa (2002)), modelling net inflation, i.e. inflation net of food and fuel prices, and removing the assumption concerning the rationality of inflation expectations by introducing quantified measures of households' inflation expectations into the Phillips curve and the endogenisation of these expectations within the model.

3. Data and methodology of modelling

The relationships of the NSA model are re-estimated three to four times a year on the basis of quarterly data dating back to 1997. Model variables are not subject to seasonal adjustment – the exception is the GDP series, which is used to determine the output gap. Due to the size of the model and its area of application (short-term analyses), which justifies the absence of explicit modelling of the supply side, the model uses a statistical measure of the output gap (Hodrick-Prescott filter).

II

4. Basic relationships in the model

As mentioned above, the NSA model focuses on three relationships rooted in the theory of economy, i.e. the aggregate demand curve, the uncovered interest parity (with risk factors), and the Phillips curve. However, the list of behavioural relationships is not limited to those. Additional modules have been developed around the model, such as the food price module (used for simulations) and the fuel price module, which form an integral part of the NSA price block, as well as inflation expectation and interest rate term structure modules. Apart from that, for simulation purposes the NSA model is supplemented by a monetary policy rule, which can be alternatively specified as the standard Taylor rule or the Taylor rule with interest rate smoothing. Its modularity and the alternative specifications of certain equations (e.g. forward--looking or adaptive rules for exchange rate, assuming a complete or incomplete pass-through of oil prices on international markets and the exchange rate to fuel prices in domestic currency) make the model flexible and suitable for various experiments (simulations, counterfactual simulations, forecasts).

The equations of the NSA model are as follows:

$$\hat{y}_t = c_{\hat{y}} + \alpha_1 \hat{y}_{t-1} + \alpha_2 i^r_{t-1} + \alpha_3 e^r_{t-2} + \alpha_4 \Delta\left(\Delta_4 y^{EU}_t\right), \text{ where: } \alpha_2, \alpha_3 < 0 \quad (1)$$

$$\pi_t = w^C_t \pi^C_t + w^F_t \pi^F_t + w^P_t \pi^P_t \quad (2)$$

$$\pi^C_t = c_{\pi^C} + \beta_1 \pi^e_t + \beta_2 \hat{y}_{t-3} + \beta_3 e^r_{t-1}, \text{ where: } \beta_3 < 0 \quad (3)$$

$$\pi^F_t = c_{\pi^F} + \gamma_1 \pi_t + \gamma_2 \pi^F_{t-1} + \gamma_3 \left(p^F_{t-1} - p_{t-1}\right), \text{ where: } \gamma_3 < 0 \quad (4)$$

$$\pi^P_t = \pi^O_t \text{ lub: } \pi^P_t = \lambda_1 \pi^O_t + \lambda_2 \pi_{t-1} + \lambda_3 \Delta \hat{y}_t \quad (5)$$

$$\text{where: } \pi^O_t = \Delta b^{USD}_t - \Delta e^{USD/PLN}_t$$

$$\pi^e_t = \theta_1 \pi_{t-1} + (1-\theta_1)\pi_{t+1} \quad (6)$$

$$e^{USD/PLN}_t = c_{e^{USD/PLN}} + \varphi_1 e^{USD/PLN}_{t-1} + \left(i_t - i^f_t\right) + \phi_2 \left(i_t - i^{WIBOR1M}_t\right) - \varphi_3 g_{t-1} - e^{EUR/USD}_t \text{ or:} \quad (7)$$

$$e^{USD/PLN}_t = e^{USD/PLN}_{t+1} + \left(i_t - i^f_t\right)$$

$$e^n_t = e^{USD/PLN}_t + w^{EUR}_t \cdot e^{EUR/USD}_t \quad (8)$$

$$i_t = 0{,}5\,\hat{y}_t + 1{,}5\left(\pi_t - \pi^*_t\right) \text{ lub: } i_t = \pi^e_t + 0{,}8 i_{t-1} + 0{,}2\left[0{,}5\left(\pi_{t+1} - \pi^*_{t+1}\right) + 0{,}5\,\hat{y}_t\right] \quad (9)$$

The following symbols have been used:

$\hat{y}$ – output gap;

Δy^{EU} – real GDP growth rate in the euro zone;

i – WIBOR 3M interbank market rate in nominal terms;

$i^{WIBOR1M}$ – WIBOR 1M interbank market rate in nominal terms;

y^r – WIBOR 3M interbank market rate in real terms;

y^f – LIBOR 3M foreign interbank market rate in nominal terms;

e^n – nominal effective exchange rate (in logs);

e^r – real effective exchange rate (in logs);

$e^{USD/PLN}$ – USD/PLN exchange rate (in logs);

$e^{EUR/USD}$ – EUR/USD exchange rate (in logs);

w^{EUR} – euro weight used for the determination of the nominal effective exchange rate (55%);

π^C – rate of growth of consumer price index net of food and fuel prices (net inflation), quarter on quarter;

π^F – rate of growth of food prices, quarter on quarter;

π^P – rate of growth of fuel prices, quarter on quarter;

w^C – weight of consumer goods and services net of food and fuels in the CPI basket;

w^F – weight of food in the CPI basket;

w^P – weight of fuels in the CPI basket;

b^{USD} – oil price per barrel on world markets (USD, in logs);

g – budget deficit related to the GDP;

π – inflation, quarter on quarter;

π^* – central bank inflation target;

p^F – food price index;

p – consumer price index (goods and services);

π^e – households' inflation expectations (for the next quarter);

Equation (1) is the aggregate demand curve in an open economy. The output gap in this equation depends on its lagged value, the ex-ante real interest rate, the real effective exchange rate and the variable representing external demand.

The growth of prices of the listed components of the consumer basket – i.e. food, fuels and the remaining consumer goods and services – are modelled by separate equations. According to identity (2), inflation as measured by the rate of growth in consumer price index (CPI) is the weighted average of price increases of the listed components of the consumer basket. In the Phillips curve (equation (3)), the explained variable is net inflation. Output gap, the real effective exchange rate and households' inflation expectations (quantified direct measure based on survey data) are the explanatory variables. These expectations have been endogenised. They are mostly adaptive, and to a limited extent forward--looking. The specification of equation (4) makes a reference to the error correction mechanism models. The transformed version of this equation[16], which is used for simulation purposes only[17], makes the quarterly increase in food prices dependent on its lagged value, net inflation, the increase in fuel prices and the relative food price in the earlier period. The increase in oil prices is described by equation (5). The first version of this equation assumes that the changes in oil prices in world markets and movements of the USD/PLN exchange rate are fully transmitted to fuel prices on the domestic market. The second (empirical) version of this relationship, which makes fuel price changes dependent on the price of a barrel of oil in domestic currency, the lagged inflation and changes in the output gap, removes this assumption of the complete transmission.

16 Using identity (2), the general form of equation (4):

[a] $$\pi_t^F = \alpha_0 + \alpha_1 \cdot \pi_t + \alpha_2 \cdot \pi_{t-1}^F + \alpha_3 \cdot \left\{ \log\left(p_{t-1}^F\right) - \log\left(p_{t-1}\right) \right\}$$

may be transformed into:

[b] $$\pi_t^F = \frac{\alpha_0}{1-\alpha_1 \cdot w_t^F} + \frac{\alpha_1 \cdot w_t^O}{1-\alpha_1 \cdot w_t^F} \cdot \pi_t^O + \frac{\alpha_1 \cdot w_t^C}{1-\alpha_1 \cdot w_t^F} \cdot \pi_t^C + \frac{\alpha_2}{1-\alpha_1 \cdot w_t^F} \cdot \pi_{t-1}^F + \frac{\alpha_3}{1-\alpha_1 \cdot w_t^F} \cdot \left(\log\left(p_{t-1}^F\right) - \log\left(p_{t-1}\right) \right)$$

17 In forecasts based on the NSA model, the increase in food prices is subject to expert assumptions.

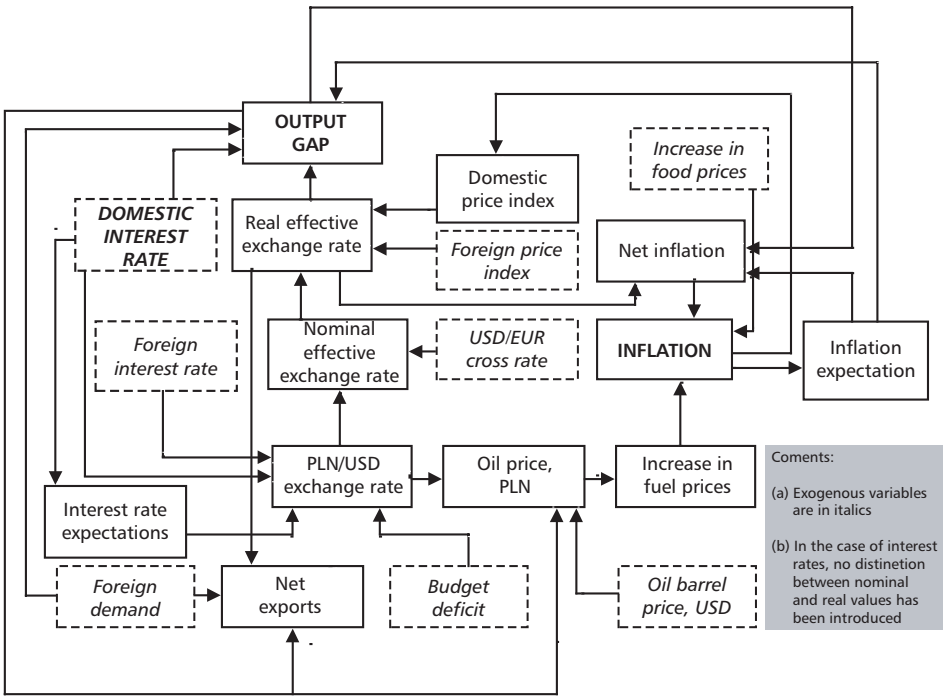
II

Tabela 1. Specification of New Analytical Scheme equations (02/2004 version)*

Explained equation variable	Variable or equation type, comments	Depends on	Has direct impact on
output gap	behavioural equation	• real WIBOR 3M interest rate • real effective exchange rate • external demand	• increase in fuel prices • net inflation
USD/PLN exchange rate	behavioural equation	• interest rate disparity • term structure of interest rates • EUR/USD cross rate • risk factors (proportion of budget deficit to GDP, proportion of current account balance to GDP)	• increase in fuel prices • nominal effective exchange rate
nominal effective exchange rate	identity	• USD/PLN exchange rate • USD/EUR cross rate	• real effective exchange rate • EUR/PLN exchange rate
real effective exchange rate	identity	• nominal effective exchange rate • domestic price index • foreign price index	• output gap • net inflation
WIBOR 1M interest rate	behavioural equation	• WIBOR 3M interest rate	• USD/PLN exchange rate adjusted for USD/EUR exchange rate fluctuations
net inflation (quarter on quarter)	behavioural equation	• inflation expectations • output gap • real effective exchange rate	• inflation
increase in food prices (quarter on quarter)	behavioural equation (used for simulations)	• inflation • relative food price index	• inflation
theoretical oil barrel price in PLN	identity	• oil barrel price in USD • USD/PLN exchange rate	• increase in fuel prices
increase in fuel prices (quarter on quarter)	behavioural equation	• theoretical oil barrel price in PLN • inflation • output gap	• inflation
inflation expectations	behavioural equation	• lagged inflation • next period inflation	• net inflation • real WIBOR 3M interest rate
CPI inflation (quarter on quarter)	identity	• net inflation • increase in food prices • increase in fuel prices • weight of food in the CPI basket • weight of fuels in the CPI basket	• WIBOR 3M interest rate (monetary policy rule used for simulations)
WIBOR 3M interest rate	behavioural equation (used for simulations)	• inflation • inflation target • output gap	• real WIBOR 3M interest rate • WIBOR 1M interest rate • USD/PLN exchange rate adjusted for USD/EUR exchange rate fluctuations
real WIBOR 3M interest rate	identity	• nominal WIBOR 3M interest rate • inflation expectations	• output gap
CPI inflation (quarter on the same quarter of previous year)	identity	• CPI inflation (quarter on quarter)	

* With regard to explanatory variables in individual equations, lagged explained variables and deterministic variables have been omitted.

Diagram 1. Basic building-blocks of the NSA (02/2004 version)



The USD/PLN exchange rate in the NSA is modelled within the concept of the uncovered interest parity (UIP), in line with equation (7). The first (empirical) version of the exchange rate rule is adaptive one (the so-called UIP+). The explanatory variables of the USD/PLN exchange rate are the lagged value of this variable, the interest rate disparity, the term structure of interest rates, the EUR/USD cross rate and risk factors[18]. The list of risk factors includes budget deficit, net exports, foreign direct investment, etc. Another version of this equation, used for simulation purposes, is a forward-looking one (consistent with the theory). The nominal effective exchange rate is determined – in line with the arbitrage condition – as a function of the USD/PLN exchange rate and the EUR/USD cross rate (exogenous variable) – equation (8).

The monetary policy rule is used for simulations. The first version of the rule is derived from the traditional Taylor rule: the nominal interest rate responds to the deviation of inflation from the inflation target and the deviation of the GDP from its potential value. In the second version of the rule, monetary authorities use interest rate smoothing and react in an anticipatory manner to expected (not observed) deviations of inflation from the inflation target.

A detailed specification of NSA model equations is presented in Table 1, whereas Fig. 1 shows the building-blocks and feedbacks of the model.

5. Simulations of selected impulses

Simulations of various types of impulses, including the interest rate, external demand, food prices, oil prices and the USD/PLN cross rate were conducted to assess the dynamic properties of the NSA model. Table 2 presents the response of inflation (quarter on the same quarter of previous year) to shocks, which has been derived from the two versions of the NSA model, assuming the complete or incomplete pass-through of oil prices on international markets and the USD/PLN exchange rate to domestic fuel prices. Table 3, on the other hand, includes figures presenting the responses of various macroeconomic variables (nominal and effective exchange rates, output gap, and inflation) to the interest rate impulse.

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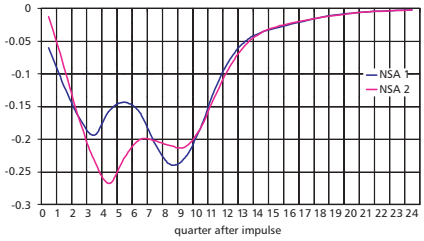
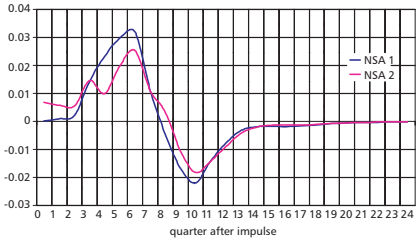
Table 2. Response of annual inflation to selected impulses in NSA1 and NSA2 – deviations from the baseline (in percentage points)

NSA1 – 02/2004 version (forward-looking exchange rate – UIP+, complete pass-through of oil prices and the USD/PLN exchange rate to fuel prices)
NSA2 – 02/2004 version (forward-looking exchange rate – UIP+, incomplete pass-through of oil prices and the USD/PLN exchange rate to fuel prices)

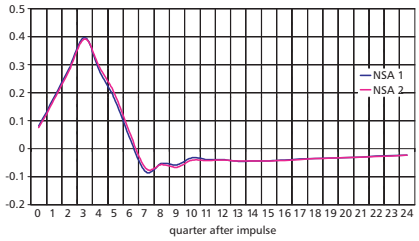
Interest rate impulse[a]



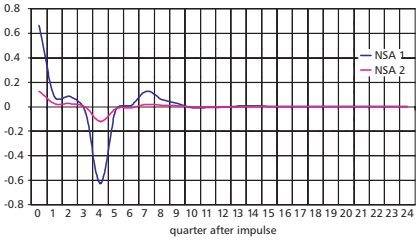
External demand impulse[b]



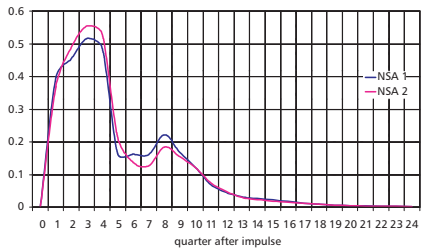
Food price impulse[c]



Oil price impulse[d]



USD/EUR cross rate impulse[e]

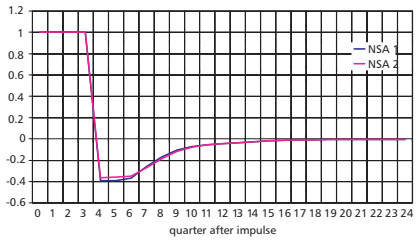


[a] a four-quarter increase in the nominal short-term interest rate by 1 pp from the baseline
[b] an increase four quarters in the annual GDP growth rate in the euro zone by 0.1 pp from the baseline
[c] an increase in the annual food price growth rate by 1 pp from the baseline, evenly distributed over four subsequent quarters
[d] a one-quarter increase in the oil barrel price by 10% form the baseline
[e] a one-quarter increase in the USD/EUR cross rate (depreciation of the US dollar against the euro) by 10%

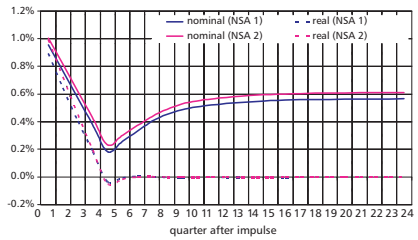
Table 3. Response of selected variables to the interest rate impulse[a)] in NSA1 and NSA2 – deviations from the baseline (in percentage points)

NSA1 – 02/2004 version (forward-looking exchange rate – UIP+, complete transmission of oil prices and the USD/PLN exchange rate to fuel prices)
NSA2 – 02/2004 version (forward-looking exchange rate – UIP+, incomplete transmission of oil prices and the USD/PLN exchange rate to fuel prices)

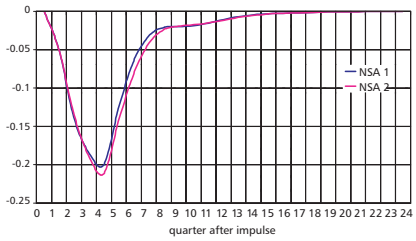
WIBOR 3M interest rate



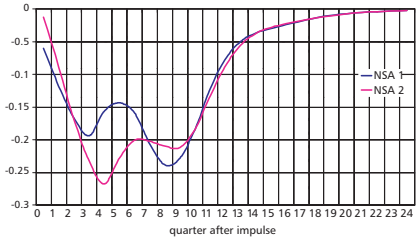
Effective exchange rate (percentage deviations, appreciation ↑, depreciation ↓)



Output gap



Annual inflation



a) a four-quarter increase in the nominal short-term interest rate by 1 pp from the baseline.

II

6. Summary

The New Analytical Scheme is a small structural model describing the inflationary processes in Poland in a highly aggregated way. In our opinion, the theoretical foundations of the model as well as its origins and the evolution it has undergone make it a useful tool for analysing the transmission of monetary policy and external shocks. Due to the short-term character of the model (reflected by the fact that the supply side of the economy has not been endogenised) the forecasts yielded by the NSA are only one of the factors determining inflation projections, and the significance of this factor – in line with the rigorously determined system of weights, which minimise forecast errors – diminishes, as the projection horizon is extended.

III
Selected information about the Small Structural Inflation Model

1. Historical outline

The Small Structural Inflation Model (*Mały Strukturalny Model Inflacji* – MSMI) is a quarterly model of the Polish economy, which was designed in 1999. Its primary applications were to be medium-term (2–4 years) scenario analyses of inflationary processes in Poland and policy analyses within a 3–4 year horizon. The formal characteristics of the model (size, type of utilised data, etc.) were adjusted to the technical and organisational conditions present at the NBP at that time (information available, cooperation with the Central Statistical Office (GUS), human resources available, work organisation and procedures, timely accomplishment of subsequent work stages, etc.). In the years 2000–2002, several scenarios and analyses of policy changes were developed. Since the end of 2003, the model has been used exclusively as one of the tools for current (conditional) inflation forecasting, supplementing the NSA model – the basic forecasting tool used at the Bureau of Macroeconomic Research.

Since the summer of 2000 (when first analyses based on the MSMI model were developed), the model has been modified several times[19]. Version 4.02, presented in this paper, was used in the development of the latest inflation projection (May 2004). However, continuous work on such models, sometimes beyond routine updates, is necessary. Routine model revisions – typically conducted 2 or 3 times a year[20] – were necessitated by new data inflow (re-estimation/re--calibration of parameters). Certain discrepancies between data of various model elements also came to light, resulting from the evolution of the institutional economic framework. The redefinition of model objectives and the evolution of the ways of understanding and interpreting various phenomena present in the Polish economy as well as the changing methods of empirical modelling of economic processes in EU countries (including the need to adjust forecast and analysis methods to ECB standards) were also among important reasons for the introduced changes.

From the technical and organisational point of view, the current version of the model may be considered as ultimate, i.e. any development consisting in increasing the disaggregation of the model, making the description more detailed, adding new variables or behavioural equations, etc., will make the model inoperative because the time period required to update the model is longer than the delay in the new (revised) statistical data inflow. In such circumstances, grounds for subsequent updates emerge before a new version is developed. However, the quickly changing institutional economic framework, process dynamics and transformation conditions (including the EU accession) call for introducing model updates as frequently as possible.

2. Modelling methodology

From the point of view of modelling methodology, the MSMI may be classified as an empirical hybrid model[21], e.g. this is an attempt to combine a significant amount of a priori assumptions (not

19 Earlier versions of the model were presented e.g. in Kłos (2000); Kłos, Wróbel (2001) and Kłos (2002).
20 Due to this schedule, practically every scenario was based on a slightly different version of the model.
21 For more detailed information concerning the proposed classification of empirical models, see Kłos (2004), *Niepewność modelu w polityce makroekonomicznej. Zasada odporności* (to be printed in "Bank and Credit"). The term *hybrid models* is also used by A. Pagan but in his interpretation, no such emphasis is put on the role of a priori assumptions and the rigorous use of statistical techniques, and therefore Pagan's classification and the one proposed above should be considered different.

formally validated) with information derived from a sample – in this case, a short and heterogeneous one (in terms of statistical measurement methodology as well as changes in the nature of processes described by the data). In such a model the values of some parameters are imposed (motivated by theory or practice – e.g. other models) and the rest are fitted using econometric techniques (i.e. estimated conditionally) with a routinely performed diagnostic tests. From a purely formal point of view it cannot be said that the procedure provides a complete rationale for parameter (and more generally model) assessments, and using the authority of mathematical statistics (econometrics) in order to support model characteristics is not fully justified[22]. In general, if the statement that a model is an "objective" description of a given fragment of reality and its objectivity results from rigorous statistical analysis methods applied to data samples collected according to accepted principles (e.g. preselection has been avoided) can ever be justified, then hybrid models are considerably less "objective" in this respect.

Since the author is aware of this issue, the MSMI – just like the majority of empirical models – is subject to an additional validation test. The model validation stage is based on possibly thorough testing of the model's dynamic properties and the economic interpretation of results. The primary exercise here is the examination of the impact of disturbances related to exogenous variables and their verification and interpretation from the point of view of the model's declared theoretical foundations but also from the point of view of stylised facts identified during earlier research or even the expected "correctness standards". If discrepancies are found, attempts are made to locate the source of the anomaly and to eliminate it by a re-specification of equations, adjustment of parameter values, etc. Testing the model's ability to reproduce specific sample characteristics (in-sample fit) is an additional test – this exercise has no great value for "pure" empirical (estimated) models but is sometimes destructive for the calibrated ones; in the case of the MSMI, this test is conducted primarily on request of potential forecast recipients. Attention to sufficient in-sample fit limits the freedom of shaping the dynamic properties of the model. Obviously, it was the limitations and specific features of the Polish economy (transformation and accession processes, small sample size, frequent structural changes, very frequent changes in statistical measurement methodology, low data quality) and not the conviction that this was the optimal solution that provided the reason for using the methodology described above.

It should be noted that a considerable proportion of the macromodels used by central banks and international institutions (e.g. AWM at the ECB, NiGEM at the NIESR and the Interlink model used by the OECD) can be classified as hybrid models, although only the euro zone model (AWM) exhibits at least some of the limitations encountered while modelling the Polish economy, i.e. short and heterogeneous time series[23]. This is because hybrid models allow the two features which are desirable from the policymakers' point of view – the consistency with historical data, which is considered (not always correctly) to be the precondition for good predictive properties, and structural interpretation, which is a prerequisite for decision transparency – to be combined to a larger degree than other empirical model types ("pure" and "applied" empirical models). Many researchers express critical views concerning such models (and, more generally, models used by central banks), but it should be noted, as Sims (2002) and Heckman (2001) do, that the quality (type) of models used in practice is not only the result of looking for "easier" solutions but also of the fact that academic econometrics and macroeconomics ignore practical needs.

3. Formal structure and theoretical foundations

The MSMI model describes the impact of short-term adjustment and the steady (stationary) state separately. Therefore behavioural equations in this model conform to the textbook error

[22] In order to maintain a proper perspective it should be noted that in practice conditional estimation is actually present in every model because the decision regarding the exclusion of certain variables also constitutes an unverifiable constraint.
[23] However, the issue of perception of steady state on the part of producers and consumers within the institutional framework of market economy, which presumably has not changed fundamentally after the introduction of the euro, is not a questionable one and therefore the challenges faced by the authors of macromodels of Central European economies and those of the euro zone models (AWM) are not entirely comparable.

correction model (ECM). Most of the aforementioned unverifiable constraints are actually imposed on the parameters inside ECM blocks (i.e. the description of the steady state), while equation dynamics and the rate of achieving the steady state are left to (conditional) estimation.

The question concerning the steady state in economies undergoing transformation has a more fundamental character. In all hitherto existing versions of the MSMI model it has been assumed that the current stage of transformation processes, the number of institutional changes, etc. do not allow economic agents to identify (perceive) the desired (steady) state. Therefore empirical research concerning this aspect – even if insufficient data, their limited information content and the asymptotic motivation of estimation techniques and statistical tests are disregarded – may yield random results. Thus the search for steady-state type/character was conducted among stabilised market economy models (mainly the EU), with the assumption that both integration processes and the market experience of domestic producers and consumers will cause steady-state types to converge. In practice this meant looking for common features among the specifications of blocks describing the stationary solution for stabilised market economy models[24]. From this point of view, the current version of the MSMI is based on a concept of the supply-side steady state which has been largely derived from the MANAGE model of the French economy[25] (and from the domestic modules of the NiGEM model as well as, to a smaller extent, on the Interlink, AWM and MM – an older model developed by the Bank of England), while the demand side is based on the domestic modules of the NiGEM model (also the AWM, the ES-MCM model used at the ECB and the Central Bank of Spain, MM, the JADE model used by the Netherlands Bureau for Economic Policy Analysis, the Multimod used by the IMF, etc.), and more generally – on the older generation of market economy macromodels[26]. This assumption means that the current degree of consistency with the data of the block describing the steady state may not be satisfactory[27] because steady-state types will converge only after institutional changes are completed (or their rate declines), and certain progress in the correct anticipation of producers' and consumers' responses to market incentives is achieved.

As most older-generation models mentioned here, the MSMI (i.e. its consecutive versions) is not based on a single, coherent theoretical concept (theoretical model). The Keynesian concept of the demand side is supplemented with a description of the supply side (which is focused on costs). The steady-state concept, similar to the neoclassical one, is accompanied by the impact of incomplete and delayed adjustments (nominal rigidities) as well as of imperfect competition. It appears, however, that the eclecticism of the utilised concepts does not exceed the outlines of the so-called New Keynesian School.

In such a theoretical framework, inflationary processes – the most important issue explained by the model – has a multidimensional character. Both the supply/cost effects (autonomous or induced impulses originating in the labour market, fiscal and monetary policies as well as the economic environment, which are shrunk or amplified by the fluctuations in the endogenous exchange rate) and short-term demand pressure are sources of inflation. The smooth short-term absorption of shocks (price and quantity adjustment) is limited by the existing rigidities and

24 We are aware that models of stabilised and mature market economies are also designed in a way which does not ensure their compatibility with the "objectively existing economic conditions." Thus the argument that the search conducted in the comparative studies of the models of EU country economies resulted in identifying the "current fashion" and not the characteristics of the prevalent type of steady state cannot be refuted.

25 Carnot (2001), Carnot (2002).

26 A more recent generation of models includes the models of the Bank of Canada, Sweden, New Zealand, Finland, the Bank of England (the new BEQM model) and also the Smets-Wouters model tested at the ECB. The older and more recent generations of models are distinguished on the basis of the nature of the models' microfoundations as well as their general steady-state character, the way in which model dynamics is derived, the way of forming expectations, the character of exogenous variables, etc., as Pagan (2003) and Kim and Pagan (1995) suggest. In view of the method of combining the information derived from the sample with theoretical assumptions, it may be claimed that the new generation of models also belongs to the hybrid class.

27 It should also be stressed that the existing sample – not only/as much due to its size as to its heterogeneity – does not provide grounds for attaching too much importance to estimation and formal test results. Most tests exhibit acceptable properties only with regard to large samples and one of the conditions for their correct application is that the object (the process generating the data) must remain unchanged as the sample size approaches infinity.

persistence. Attempts have also been made at taking the role of inflationary expectations into account but due to the current primary application of the model (conditional forecasting[28]) and also on the basis of the other research (e.g. Brzoza-Brzezina, Kłos, Kot, Łyziak (2002)) it is assumed that such expectations are not forward-looking.

The current version of the model exhibits the following features:

- There is one aggregate (homogeneous) product and two homogeneous production factors: labour and capital. There are also two basic types of domestic optimising agents: homogeneous (in the sense of their behaviour in the goods market) consumers and homogeneous producers. Additionally, the bodies responsible for the implementation of fiscal, social and monetary policy are distinguished.
- The general government sector is limited to the central budget, for which only expenditure is calculated, while budget revenue, balance (deficit) and debt are excluded from the model.
- In the basic version of the model, all fiscal (tax rates, social security rates, budget expenditure and social benefits) and monetary policy instruments (short-term interest rate) are exogenous. No monetary or fiscal policy rules are used[29].
- The goods and labour markets are implicitly distinguished, while the financial sector is only represented by the foreign exchange market.
- Consumers are divided into two groups: employees and benefit recipients. The number of employees and their wages are endogenous within the MSMI. Total nominal benefits remain exogenous (they are an instrument of fiscal and social policy). With regard to producers, no primary revenue (or cash flow) is calculated, i.e. the revenue account (generation and flows of revenue) of the economy is incomplete within the MSMI.
- Labour is not internationally mobile. It is assumed though, that goods are fully mobile – product price arbitrage is one of its consequences. However, the law of one price holds only partially.
- The conditions of imperfect competition prevail on the domestic market, resulting in mark-up formulas for labour and product prices.
- There is a single external market (no distinction exists between the EU and other markets), which is fully competitive.

3.1 Long term

3.1.1 Supply block

As Carnot (2001) argues, the equations presented below describing the demand for capital (10), demand for labour (11) and producer prices (14) may be considered a logarithmic approximation of the producer equilibrium yielded by the solution to the profit maximisation problem. In this problem, n goods are produced using the CES technology with neutral, as understood by Harrod, technological progress; the elasticity of production factor substitution is the same for each type of goods. Assuming condition of imperfect competition, the classical profit function is maximised, with two constraints: that of the technology and of the demand for products (a typical, negatively sloped demand function derived from the problem of the dynamic maximisation of consumer utility under a classical budget constraint). The derived equations describing product prices (cost plus constant mark-up) and the demand for factors – after

28 Forecasting in the presence of model consistent forward looking expectations requires terminal conditions to be defined and/or the forecast horizon to be extended so that the terminal conditions have no impact on the forecasts with the shortest horizon. The situation is made more complex by the principle stating that forecasts should be built with a constant nominal interest rate – this exacerbates the difficulty of finding a solution to the model, especially at the presence of forward looking exchange rate expectations, which are compatible with the model.

29 The modular nature of the model enables it to be supplemented by additional equations. In earlier versions of the model, experiments were conducted concerning partial endogenisation of the monetary policy through the introduction of the (unoptimised) interest rate rule.

aggregation, taking logs and leaving out the constants – are relatively legible in their analytical form and constitute the basic part of the long-term supply block. The block is supplemented by equations describing factor prices and import prices[30]. The details may be described as follows:

- Producers take the prices (cost) of capital and labour as given. Input prices are minimised through adjusting the demand for factors to market conditions (defined by aggregate demand and costs). The equality of the marginal productivity of production factors and factors' costs is the condition that determines the long-term demand for factors (lowercase letters denote variables in logs except for interest rates and tax rates, which are given as fractions; Greek letters denote parameters and the c stands for constants):

$$ik = y - \sigma\,(kk - p) + c_{inv} \tag{10}$$

$$zz = (y - yyzz) - \sigma(ww + txl - yyzz - p) + c_{zz} \tag{11}$$

where: σ – elasticity of substitution, kk – nominal cost of capital, ww – nominal gross wages, txl – rate of non-wages labour costs, p – producer prices, zz – employment, ik – fixed asset index, y – gross domestic product, $yyzz$ – labour productivity (technological progress) trend, czz, $cinv$ – constants.

In this version of the MSMI model, the demand for labour equation utilises a condition equating the marginal rate of substitution and relative factor prices, i.e.:

$$(zz + yyzz - ik) = c_{zz} + \sigma\,(kk - (ww + txl) + yyzz) \tag{12}$$

As a result, the long-term demand for labour also depends directly on the factors which determine the demand for capital (investment outlays), including the real price of capital. Although the production function is explicitly included in the MSMI, its transformed version is not used for determining the demand for labour.

- The prices of labour and products on the domestic market (also in the long term) are determined by the mark-up formula. In the equation describing the cost of labour, the mark-up (margin) depends on conditions prevailing on the labour market, while in the long-run price equation the mark-up is constant (c_{pp}), i.e.:

$$(ww - (p + txo)) = c_{ww} + yyzz - \lambda u \qquad \lambda > 0, \tag{13}$$

$$p = c_{pp} + \gamma\, kk + (1 - \gamma)(ww + txl - yyzz) \qquad 0 < \gamma < 1, \tag{14}$$

where: u – unemployment rate, txo – effective indirect tax rate, c_{ww}, c_{pp} – constants.

- If prices and wages are determined by the foregoing equations, one may derive natural unemployment rate:

$$u^* = c_u + \frac{1}{\lambda}\left(\frac{\gamma}{1-\gamma}(kk - p) + txl + txo\right) \tag{15}$$

The deviations of the current unemployment rate from the u^* rate enable the determination of available workforce reserves, and also – based on the CES production function – of the potential output.

- As with most macromodels, the price (cost) of capital is an arbitrarily defined variable. The MSMI assumes that the cost of capital depends on the fixed base index of import prices adjusted for the domestic interest rate, the depreciation rate and the effective corporate income tax rate[31], i.e.:

$$kk \overset{def}{=} pm + depr + \frac{rs}{4} + txp \tag{16}$$

where: pm – import price index, $depr$ – depreciation rate, rs – nominal (annual) interest rate, txp – corporate income tax rate.

30 Apart from the already cited works by N. Carnot, additional references are: Turner, Richardson, Rauffet (1996), Wallis (2000), Juselius (2002), Hall, Nixon (2000), Greenslade, Henry, Jackman (1998), Dixon, Rankin (1994), Blanchard, Kiyotaki (1987), Barrell, Dury, Holland (2001) and other works. These works present most of the theoretical motives proposed below and most of the practical solutions implemented within the MSMI.

31 A similar definition of the cost of capital has been used in the Spanish model (a module of the ECB MCM model). The cost of capital is usually a variable including the interest rate, depreciation and a price index (e.g. the investment deflator).

- The supply block is supplemented by a homogeneous import price equation:

$$pm = c_{pm} + \beta_1(er + pn) + \beta_2(eer + pw) + (1 - \beta_1 - \beta_2)(pc - txo), \ \beta_i > 0, \ \beta_1 + \beta_2 < 1 \quad (17)$$

where: pn – oil prices, pw – world prices, er – PLN/USD exchange rate, eer – nominal effective exchange rate, pc – consumer prices.

- There is no explicitly defined long-term level of consumer prices – the variable used for determining inflation. Both the price level and the price growth result from the features of the entire model[32]. The one price rule, which is included in the model and causes the exchange rate to move in line with the relationship between consumer prices and external prices in the long term, is an important element of the consumer price determination mechanism (although the exact proportion postulated by the PPP hypothesis is not achieved). Because of that, no direct relationship between the long-term level of domestic prices and the price level of imported goods is assumed. In the case of producer prices, however, this relationship is maintained due to the way in which the cost of capital is defined. As the first approximation, when trying to analyse the types of steady state presented below, it may be assumed that consumer prices converge to producer prices plus indirect taxes and a fixed margin, i.e.:

$$pc \approx p + txo + c_{pc} \quad (18)$$

3.1.2 Demand block

Due to the fact that a large group of entities has been left out of the revenue account, the GDP cannot be determined on the basis of primary factor revenues and thus it is determined using the classical method, i.e. by summing the consumption demand, the investment demand and net exports. The equilibrium conditions for individual aggregate demand components are fairly typical:

- The stylised real (disposable) consumer income equation (after applying the logarithm) may be expressed as follows:

$$pinc = c_{pinc} + zz + ww - pc - txzus - txd - txkch \quad (19)$$

where: $txzus$ – social security contribution rate paid by the employee, txd – effective personal income tax rate, $txkch$ – health insurance contribution rate, $cpinc$ – constant describing non-wage income after tax (in the MSMI model this is social benefit income).

- The equation (10) describing the desired amount of fixed assets presented at the discussion of the supply side does not directly determine the amount of fixed assets but implicitly determines the amount of investment outlays. Fixed capital is formed in a standard way – through capitalising investment, but an approximation can be made:

$$INV = \Delta IK + depr \cdot IK_{-1},$$

which, however, means that in the long term:

$$inv = ik + depr. \quad (20)$$

- Consumers who derive their current income from wages and (exogenous) benefits maximise their lifetime utility, also taking into account their wealth. The macroeconomic function of private consumption is based on the concept of permanent income (life cycle) modified by the wealth effect, as proposed in the NiGEM model[33]. In the MSMI model, wealth is represented by the amount of real broad money, i.e.:

$$cs = c_{cs} + \beta_{cs} pinc + (1 - \beta_{cs})(m2 - pc), \qquad 0 < \beta_{cs} < 1 \quad (21)$$

32 In earlier model versions, there were several competing equations describing the consumer prices growth. Those equations differed with regard to the type of expectations (adaptive vs. forward looking) and the presence or absence of an explicit steady state.

33 Cf. e.g. Barrell, Dury, Holland (2001). The additional inclusion of the interest rate in order to take into account the effect of intertemporal substitution is a frequent solution (cf. e.g. Willman, Estrada (2002)); in this case the relationship between broad money and the interest rate justifies the claim that this effect is also represented within the MSMI. Obviously, intertemporal substitution effects may be represented not within the part which defines the steady state but in the one describing adjustment dynamics – this solution has been adopted in the current version of the MSMI.

where: cs – real consumption from wage income and social benefits, $m2$ – amount of nominal M2, c_{cs} – constant.

- The money demand equation employed within the MSMI is as follows:

$$(m2 - pc) = c_{m2} + \alpha_1 y - \alpha_2 rs + \alpha_3 \Delta pc = c_{m2} + \alpha_1 y - \alpha_2 (rs - \Delta pc) - (\alpha_2 - \alpha_3)\Delta pc \text{ , } 0 < \alpha_3 < \alpha_2 \quad (22)$$

- The remaining two equations within the block describe long-term import and export levels with imposed unit elasticities with regard to domestic and external demand.

$$m = c_m + y - \psi_m (pm - pc) \quad (23)$$

$$x = c_x + yw + \psi_x (pw + eer - p) \quad (24)$$

where: m – imports, x – exports, yw – external demand, c_m, c_x – constants.

III

3.2. Steady state

The form of the equations presented above makes the analytical determination of the interpreted equation describing long-term aggregate demand a cumbersome task. It appears, however, that the aggregate supply equation itself is fundamental for the character of the steady state, but additional simplifying assumptions are required here as well, in order to obtain clear results. For example, if differences between the bilateral and effective exchange rates are disregarded ($er \approx eer$), and if an additional exogenous variable lf is included, which enables the workforce balance to be calculated ($u = lf - zz$), and finally if changes in the exchange rate er are forced to be exactly in line with the strong version of the purchasing power parity ($er = pc - pw$)[34], the following equations describing real factor prices can be obtained from (11), (13), (16), (17) and (18) (constants have been omitted):

$$ww - p = \frac{1}{1+\lambda\sigma}\left[\lambda(y - lf - yyzz) + (1+\lambda\sigma)yyzz - \lambda\sigma \cdot txl + txo\right] \quad (25)$$

$$kk - p = \beta_1 (pn - pw) + (1 + \beta_1 + \beta_2)txo + depr + \frac{rs}{4} \quad (26)$$

which, taking into account the producer price equation (14), makes it possible to determine the equation describing the long-term supply (y) whose elasticity with respect to domestic prices equals zero. Ultimately, supply depends on workforce resources, the labour productivity trend (technological progress) and on the relative external prices ($pn - pw$), non-wage cost of labour rate (txl), indirect tax rate (txo) and the domestic interest rate (rs). It should be noted that in the long term, with full capital mobility (and the absence of risk), the domestic interest rate cannot permanently deviate from the world interest rate (rsf) and thus the following standard factors will be fundamental in determining the GDP: the labour productivity trend and workforce resources, technology (factor substitution elasticity), institutional factors and macroeconomic policy (taxes, social security contributions, depreciation rate) as well as external factors such as world prices, oil prices and the interest rate. In such circumstances the long-term demand equation would only determine the level of domestic prices.

The exchange rate mechanism assumption is fundamental for the reasoning presented above. During experiments conducted with regard to both a single exchange rate equation and the entire model it was found that maintaining a satisfactory fit with the data was impossible if the strong version of the purchasing power parity had been imposed. The results of empirical research conducted for several countries also suggest that PPP does not manifest itself in its strong form but only describes a certain trend (cf. e.g. Jacobson, Lyhagen, Larsson, Nessén (2002), Patel (1990)). In

34 In practice, price growth measures (fixed base price indices) are used instead of absolute price level measures, which suggests the relative rather than the absolute version of the purchasing power parity hypothesis. It should, however, be noted that after applying the logarithm, the absolute and relative versions of PPP only differ by a constant. Since constants are consistently omitted in all further estimates (although they are not deemed to be equal to zero), the difference between the absolute and relative versions of PPP becomes less important. Since the logic of the relationship suggests the absolute version, this PPP version will be consistently discussed.

such circumstances, when we look at the long-term logarithmic approximation of the supply equation and the estimates of long-term relationship parameters, we find that the estimates of the price elasticity of supply do not equal zero, and the inverse relationship between domestic prices and production (level of economic activity) exists, but to a very limited extent[35]. However, the very existence of such a relationship means that a description of the demand side is also necessary in order to determine the steady-state point; with regard to the demand side, the most important factors are disposable income (determined by wages and employment) and investment outlays (determined by supply-side equations). The fact that the price elasticity of supply does not equal zero makes the analysis of the steady state more difficult but its relatively low value allows classical steady-state characteristics to be used as the first approximation.

The u^* natural unemployment rate defined by equation (15) is an element of the mechanism that pushes the model towards the steady state. This rate is used for determining the level of workforce reserves, which can be used in production processes without pushing prices. Thus the CES production function and the natural unemployment rate enable the determination of potential output and subsequently the output gap. The gap itself – treated, among other things, as the measure of short-term tensions in the goods market – influences price growth and accelerates the achievement of a steady state corresponding to the concept described above.

The analysis of individual equations leads to the conclusion that in the long term, the level of domestic prices is determined by factor prices on the one hand (unit labour costs and the cost of capital related to external prices and the external interest rate) and on the other hand, under the conditions of open economy and assumed full mobility of goods, a tendency should emerge towards the convergence of domestic and world prices. Within the MSMI model, this process is based on the form of the exchange rate equation (purchasing power parity is partially realised in the case of price levels), the homogeneity of the import price equation as well as the relationship between capital prices and import prices. This list suggests that in the long term – even given the lack of labour mobility – wages will also be subject to the influence of external factors.

4. Data, representation of variables within the model, parameter estimation techniques

The model is based on quarterly data officially published by the Central Statistical Office (GUS) and the NBP; the missing values (including exports and imports in the GDP account as well as producer prices) are estimated by the author of the model.

The use of raw, not seasonally adjusted data, is a fundamental but also very controversial choice. The removal of seasonal fluctuations has certain advantages – it eliminates regular oscillations but also some of the irregular noise; in general, it reduces the variance of explained variables, automatically ensuring better equation fit. The simplification of equation specifications is also an important advantage – there is no need to model the fluctuations. However, several disadvantages of seasonal adjustments emerge, particularly with short samples. It is not possible to capture the seasonal pattern in a sufficiently precise way (assuming that this can be done with a long sample), and the series become still more sensitive to the inclusion of even a single additional observation, which translates into fundamental changes in parameter estimates whenever the equation is reestimated; neither the variables explained by the model can be compared to officially published data. There are additional arguments related to econometrics: the stochastic structure of the series is distorted and characteristics not exhibited by the original series may be introduced. However, due to the manner in which econometric techniques are used, such arguments are slightly less important. Having considered all the

[35] If, as before, exchange rate differences are disregarded ($er \approx eer$), the workforce balance equation is introduced ($u = lf - zz$), and it is assumed that the domestic interest rate converges to the worldwide level ($rs = rsf$) and the purchasing power parity is realised as: $er = 0.8\ (pc - pw)$, we obtain approximately:
$y = yyzz + lf - 0.46\ (rsf/4 + depr + txp) - 0.90\ txo + 0.037\ (pc - pw) + 0.052\ (pc - pn) + \text{const.}$
The long-term supply equation within the MSMI will additionally include the EUR/USD cross rate.

arguments, it was decided that the series would not be seasonally adjusted and seasonal effects would be modelled directly. As a consequence, the model is based on the annualised variable growth (a given quarter against the same quarter of the previous year)[36], which, however, is not sufficient to fully describe and/or remove seasonality, and therefore some explanatory variables appear in the model as (usually uncentred) moving averages (in order to remove certain side effects – e.g. the seasonality drifting between quarters), also seasonal deterministic variables are used.

Another controversial solution adopted within the MSMI has been the decision not to include certain macroeconomic identities and balance equations which function as budget constraints or equilibrium conditions in economic models. In particular, as signalled before, there is no complete primary revenue account in the model (or consumers' personal income – the income of the self-employed, including farmers, is not included), (current) trade or capital flows are not accounted for, budget expenditure is not calculated (it is only possible to determine the primary deficit); the same is true for public finances, public debt, workforce, etc. The reasons for such decisions are pragmatic and simple – the required quarterly statistics either do not exist or become available with such a long delay that the model would not be able to serve forecasting purposes. In many cases a considerable disaggregation of the model would also be required in order to obtain clear balance data, which would clash with the technical and organisational constraints present at the NBP. There are also constraints resulting from the considerable volatility of the institutional framework (e.g. the budget account). Thus, in such a situation the aforementioned balance data cannot be obtained on the basis of available information, even by incurring very high costs, which means that a large number of artificial variables of fairly random values would have to be defined to obtain identities, with such equations having a very large impact on the responses of the entire model. Despite a considerable increase in model operating expenses, it would be difficult to avoid a radical deterioration in the forecasting properties of the model and the emergence of multiplier responses, much more difficult to interpret. The fact that several important balances are missing is an obvious defect of the MSMI model but the author's influence on correcting this shortcoming is very limited.

The sample used to estimate the parameters of the discussed model version (and in order to assess the ability of the model to reproduce historical data) includes the period from the first quarter of 1995 to the third quarter of 2003. Although the number of observations is still insufficient to ensure satisfactory test power with regard to both long-term relationships and dynamic properties, the removal of the oldest observations, especially those from the period before 1999, appears increasingly justified due to the number of structural changes which occurred in recent years. Observations from the period from the first quarter of 1995 to the fourth quarter of 1998, which are becoming decreasingly representative for the logic of economic processes observed currently, have a strong impact on the obtained parameter estimates. Due to this fact, it cannot be assumed that in the coming quarters the size of the sample will enable a successive verification of model assumptions in line with accepted principles.

Nevertheless, attempts are made to assess the steady-state parameters for each equation (linearised ADL equation, nonlinear LS method, Johansen's method variants, etc.) but such results are considered reliable in very few cases. The parameters related to short-term dynamic properties are estimated using the GMM (and less frequently – the LS) method[37]. In line with the earlier declaration, although (conditional) estimation results are routinely analysed and treated as guidelines when constructing equations, they are not used in order to rationalize the model.

All the behavioural equations describe fourth differences of variable logarithms, i.e. the estimated parameters are annual variable growth elasticities[38].

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[36] This is equivalent to the assumption that a seasonal unit root is present.

[37] In the first (earliest) version of the MSMI model, only calibrated parameters were used. The parameter calibration technique used simultaneously for all equations was a formal one, based on the conditional minimisation of the objective function, similarly to the GMM concept. Side conditions referred to the minimum and maximum values of all model parameters and – less often – to relationships between the parameters.

[38] One of the side effects of basing the annual variable growth rate on data which has not been seasonally adjusted is the increased delay in the model's convergence to the long-term solution. This phenomenon can be observed through the analysis of multiplier results.

5. Basic relationships of the model

As it has already been mentioned, MSMI behavioural equations include error correction blocks. Those blocks are based on the equations presented and any differences are the result of specific data features – mainly seasonal adjustments. The dynamic properties of equations are motivated on the one hand by the form of long-term equations and on the other hand by the necessity of ensuring sufficient fit to the data so that the model can be treated as a forecasting tool by its recipients.

Diagram 2. Basic relationships in the aggregate demand block of MSMI model

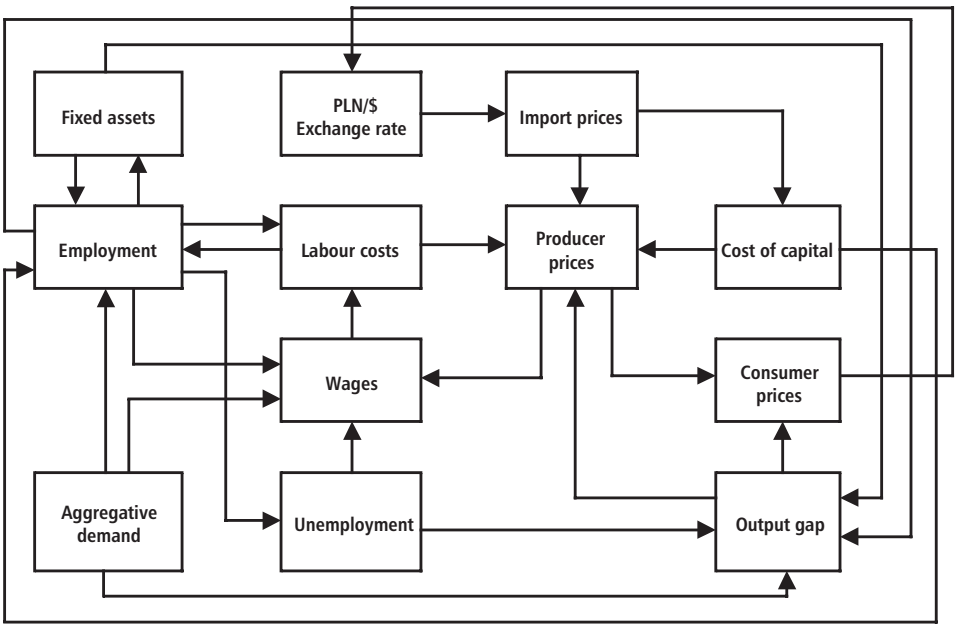
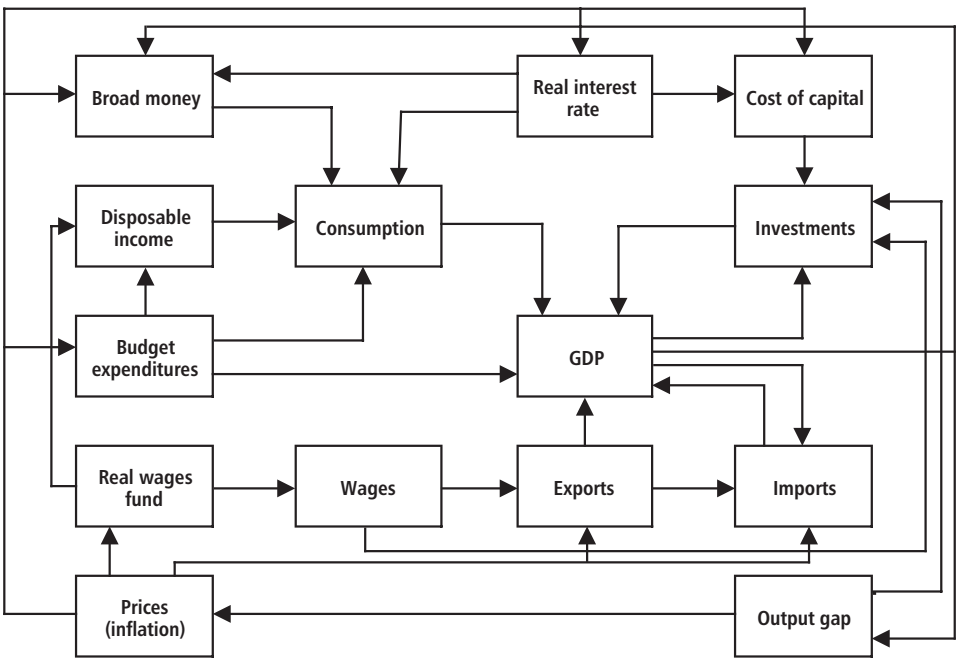


Diagram 3. Basic relationships in the supply block of MSMI model



Stochastic demand-side equations include following equations:

- private consumption;
- gross fixed capital formation;
- imports and exports;
- money demand – money resources represent wealth effects in the consumption equation.

The above equations – after an additional adjustment for the remaining aggregate demand components – determine the economy's GDP. Diagram 2 presents main relationships of the demand block. Certainly, the diagram does not distinguish between the relationships defining the steady-state level and the dynamic properties of the category; most exogenous variables have also been left out. The relationships presented here define the negative relationship between the price level and the aggregate demand level.

Stochastic supply-side equations are as follows:

- total employment;
- average wages in the economy;
- producer prices (input prices);
- consumer prices;
- import prices;
- exchange rate (PLN/USD).

Using the above equations one can determine real consumer incomes, employment and the price system. The latter affects aggregate demand components (real budget expenditure, social benefits, wages and incomes) as well as the supply side variables (nominal wages, which are directly indexed by inflation expectations and demand for labour, which is influenced indirectly). Diagram 3 presents relationships between supply block variables, showing a positive relationship between aggregate demand and prices.

In earlier versions of the model, exchange rate equation was imposed rather then estimated. It was usually postulated that the exchange rate of domestic currency against the US dollar would change in line with the UIP hypothesis adjusted by risk indicators. Two versions of the interest rate parity hypothesis were used: the forward looking version when analysing policy changes and the adaptive one when conducting scenario analyses. In both cases the underlying assumption is that – under full mobility of capital – interest rate deviations from parity are of a short-term nature, i.e. parity is the normal and currently existing state. This assumption is definitely wrong with regard to economies undergoing transformation, where privatisation processes and the opening of the economy or, more generally, incorporating the economy into global economic structures, involving the arbitrage of prices of goods (and later also of factor prices), cause a relatively permanent trend towards exchange rate appreciation; such processes are accompanied by a thorough verification of the economy's reliability. This resulted in significant differences between the exchange rate trends that were observed and those that were suggested by UIP variants[39]. Taking the above into account – especially in the context of changing MSMI applications (focus on inflation projections) – a decision was made to replace the theoretical foundations of the exchange rate mechanism with an heterogeneous one, which ensured better data congruency. Currently the endogenous PLN/USD exchange rate changes together with movements in nominal interest rate disparity, changes in the EUR/USD cross rate and disproportions between the domestic and foreign price levels calculated using the bilateral exchange rate. As it has already been pointed out, the PPP hypothesis treated as a long-term relationship is not fully realised. The PLN/USD exchange rate is used for constructing the

[39] Apart from the arguments presented above, institutional changes regarding the foreign exchange market in Poland also had a significant impact.

effective exchange rate. The role of the exchange rate in the entire model is limited to shaping import prices, but the presence of the dynamic feedback: domestic prices → exchange rate (interest rate) → domestic prices, does not allow to treat this part of the model as an unnecessary complication[40].

The output gap, which is derived from the CES production function (defining potential output), is an important factor within the MSMI model. Formally, the gap represents the short-term effects of demand changes as well as those supply-side effects which change more slowly, including the amount of fixed assets, labour resources which can be utilised under steady-state conditions and technological progress (autonomous labour productivity trend). However, the fact that the supply-side effects only emerge after a certain delay[41] suggests that changes in the gap result primarily from shocks on the demand-side (a symptom of imbalance in the goods market caused by changes in aggregate demand). The level of the gap influences the growth of several variables – it stimulates short-term adjustments, both with regard to prices (producer and consumer prices) and quantities (output gap directly increases the growth of investment outlays[42]). The unemployment rate, which directly influences the growth (and also the long-term level) of wages, conveys similar information[43].

The fact that the output gap simultaneously stimulates price and quantity adjustments decreases the impact of the gap itself (a demand-side shock) on the inflation growth. In the current version of the model (with the impact of the gap on import and export growth left out), the short--term quantity adjustment increases the gap (*ceteris paribus*, it stimulates inflation by fuelling the investment demand) but in the medium and long run the inflationary pressure wanes due to the increased potential output. A similar effect should be expected in the case of the impact of inflation (which is dependent on the gap) on the real interest rate, which (with other conditions remaining the same) decreases, thus stimulating investment (a reduction in the real cost of capital), and facilitates the absorption of the shock, but also stimulates consumption at the same time[44]. According to Diagram 1, the aggregate demand block includes a classical stabilisation mechanism, since an increase in prices, with a certain lag, leads to decreased budget and social expenditure (exogenous values) in real terms reducing aggregate demand and multiplier effects.

Within the model, inflation also appears as a result of the supply-side (cost) shocks. However, the emergence of cost-related sources of inflationary processes is conditioned by the current state of the business cycle, because the primary component of costs – wages, which are indexed according to inflation expectations (in line with the mechanism of imperfect competition on the labour market) – depends not only on labour productivity but also on the economic activity level (which is measured by the unemployment rate, a variable strongly correlated with the output gap). A new feature in comparison to earlier model versions is the explicit inclusion of cost of capital, which influences both the current dynamic properties of the model and the steady state, in the producer price equation. As a standard in all versions of the model, the increase in producer prices (the fundamental price category within the MSMI) depends on the increase in wage-related payroll expenses and the increase in the price of imported goods.

As in the solutions employed in the Multimod (IMF) and MM (Bank of England) models, inflation expectations are heterogeneous in their structure. The expected inflation is the weighted average of the MPC inflation target, the adaptive expectations (past inflation) and the rational expectations (not future-oriented). The weights have been determined experimentally. Expected inflation directly influences wage indexation, import prices and current inflation[45].

40 Earlier versions of the model assumed that the exchange rate played a direct part in determining wages.
41 The delay mentioned here is amplified by the methodology of calculating the gap – within the MSMI, the gap (which is formally the difference between the logarithms of the current and potential GDP) is an uncentred four-quarter moving average.
42 In earlier versions of the model, the impact of the gap on imports and exports was tested.
43 Due to the definition of the output gap, the presence of such a variable in the equation can be considered to constitute an additional ECM module, i.e. a figure which influences the character of the steady state.
44 This argument highlights the controversial character of projections which assume constant interest rates.
45 Although it is possible to obtain a formally acceptable consumer price equation, where inflation expectations would be anticipatory, the conditional estimation results for the equation describing wages indexed by such expectations are unsatisfactory.

6. Specification of equations

The MSMI model consists of 11 behavioural equations (consumption, investment, imports, exports, money demand, import prices, consumer prices, producer prices, employment, wages, USD/PLN exchange rate) and three auxiliary or approximating equations (potential output/CES production function, unemployment rate, and fixed capital formation). The remaining equations (ca. 45–50) are identities or they approximate identities.

The list of exogenous variables of the MSMI model includes:

- external prices, oil prices, external demand, external interest rate, EUR/USD exchange rate;
- nominal budget expenditure, average number of social benefit recipients, average social benefit;
- effective indirect tax rate, effective corporate income tax rate, effective personal income tax rate, health insurance contribution rate, rate of non-wage labour costs borne by the employer;
- depreciation rate;
- domestic short-term interest rate.

Table 4. Specification of equations – MSMI 4.02 model

Explained variable (equation)	Equation type	Depends on	Has impact on
GDP	identity	consumption, investment outlays, imports, exports, public consumption	Share of imports in GDP, investment outlays, imports, employment, output gap, money demand
Consumption	behavioural equation	real budget expenditure, real money demand, real interest rate, real disposable income	GDP
Investment outlays	behavioural equation	GDP, cost of capital, nominal wages, non-wage cost of labour rate, output gap, fixed asset index	GDP, fixed asset index
Fixed asset index	identity	investment outlays	investment outlays, employment
Imports	behavioural equation	GDP, exports, import prices, producer prices, indirect tax rate	GDP, share of imports in GDP
Exports	behavioural equation	external prices, nominal effective exchange rate, producer prices, real external demand, real payroll fund, total employment	GDP, imports
Money demand	behavioural equation	GDP, inflation, real interest rate	consumption
Public consumption	approximation	real budget expenditure	GDP
Import prices	behavioural equation	nominal effective exchange rate, PLN/USD exchange rate, world prices, oil prices, consumer prices, indirect tax rate, expected inflation	producer prices, consumer prices, imports

Table 4. cont. Specification of equations – MSMI 4.02 model

Capital prices	definition	import price index, interest rate, depreciation rate, corporate income tax rate	investment outlays, producer prices, employment
Consumer prices	behavioural equation	expected inflation, producer prices, import prices, share of imports in the GDP, expected inflation	real budget expenditures, real payroll fund, real social benefit fund, disposable income, nominal wages, import prices, inflation, expected inflation, PLN/USD exchange rate, real interest rate
Inflation	identity	consumer prices	nominal wages, real money demand
Expected inflation	definition	inflation, MPC inflation target	inflation, import prices, nominal wages
Producer prices	behavioural equation	import prices, costs of capital, nominal wages, non-wage cost of labour rate, output gap, labour productivity trend	consumer prices, employment, nominal wages
Nominal wages	behavioural equation	expected inflation, inflation, labour productivity trend, unemployment rate, producer prices, indirect tax rate	real payroll fund, producer prices, exports
Employment	behavioural equation	GDP, fixed asset index, nominal wages, non-wage cost of labour rate, cost of capital, number of working days per quarter	output gap, unemployment rate, nominal payroll fund
Unemployment rate	approximation	employment	nominal wages, output gap
Natural unemployment rate	definition	cost of capital, producer prices, indirect tax rate, non-wage cost of labour rate	output gap
Real payroll fund	identity	employment, nominal wages, consumer prices	
Real benefit fund	identity	number of benefit recipients, average benefit, consumer prices	disposable income
Disposable income	identity	real payroll fund, real social benefit fund, personal income tax rate, insurance contribution rate, health insurance contribution rate	consumption
PLN/USD exchange rate	behavioural equation	external interest rate, interest rate, EUR/USD exchange rate, world prices, consumer prices	import prices, nominal effective exchange rate
Nominal effective exchange rate	identity	PLN/USD exchange rate, USD/EUR exchange rate	import prices, imports, exports
Output gap	approximation	employment, natural unemployment rate, number of working days per quarter, fixed asset index, GDP	investment outlays, producer prices, consumer prices
Real interest rate	identity	interest rate, inflation	consumption, money demand

7. Responses of the MSMI model variables to standard shocks

The responses of selected endogenous model variables to shocks related to the interest rate (Figs. 1–5), nominal budget expenditures (Figs. 6–10), oil prices (Figs. 11–15), external demand (Figs. 16–20), EUR/USD cross rate (Figs. 21–25) and world prices (Figs. 26–30) have been presented below. All experiments have been conducted under the assumption of the exogenous interest rate and the endogenous PLN/USD exchange rate. The figures show percentage deviations of variables from the baseline path (in the case of inflation and output gap the deviations are absolute) in subsequent years[46].

The first quarter of 2004 is the starting quarter for the simulation; since the model is non-linear, the results of experiments presented here do not fully reflect its dynamic properties – multiplier values depend on the values of baseline variables (the condition of the economy). The current condition of the economy should be taken into account in particular when analysing the responses of the variables which describe the labour market, since the observed deviations from baseline may not be responses to simulated shocks but rather attempts to correct an already existing imbalance[47].

7.1. Eight-quarter increase in nominal interest rate by 1 percentage point

The expected result of an increase in nominal interest rate is a reduction in the level of economic activity (a decrease in investment outlays due to increased costs of capital and a decrease in consumption caused by e.g. reduced liquidity – subsequently a reduction in employment and disposable income amplified by a decrease in wage pressure), which is illustrated by Figs. 1–2 and 4. The reduction in activity level causes a surplus of capacity over aggregate demand and thus an increase in the output gap, which also translates into decreased inflation (Fig. 5). However, the interest rate increase also gives rise to several additional effects, which overlap with the mechanism presented above. The strongest effect is related to the impact of the rate on the effective exchange rate and import prices, as well as on domestic prices later in the course. It leads directly to a decrease in the producer and consumer price indices (Fig. 3). At the same time, however, several effects which absorb the shock emerge: the decrease in imports limits the decrease in the aggregate demand, and the decrease in price levels limits the decrease in the real wage level (which is the result of reduction in employment and the indexation of nominal wages), real benefits and budget expenditure (public consumption). The decrease in import prices limits the growth of capital costs, which – together with the reduction of wage-related payroll expenses – makes it possible to reduce input prices. It is the decrease in those prices that allows a relatively rapid revival in investment demand to occur after 5–6 years (Fig. 1). Exports should also have a stabilising effect (the decrease in domestic prices should make exports more competitive), but – as shown in Fig. 1 – this effect is not observed during the first two years after the shock. It results from the fact that the zloty appreciates faster than domestic prices decrease, but in subsequent years the response of exports agrees with the intuition.

The scale, proportion and delay of variable responses are another issue related to the interpretation of the above results. A comparison between Figs. 1, 2 and 5 suggests that real variables are more sensitive to interest rate changes than inflation. The relationship *exchange rate* → *domestic prices* and then *labour costs* → *domestic prices* appears to be the primary channel through which monetary policy influences prices. In the latter case, labour costs decrease due to a reduction in the aggregate demand, particularly in the investment demand, and this effect is amplified by a decrease in wage pressure (caused by increased unemployment). The return to the baseline path, however, is particularly unfavourable in the case of employment (cf. Fig. 4). The scale of response of the GDP to the interest rate change is currently much smaller than in earlier versions of the model.

[46] The multiplier analyses results presented here cannot be directly compared to those presented earlier (cf. K_os (2002)) due to the change in the type of shock. Previously all shocks related to exogenous variables were permanent, while currently the patterns proposed in experiments with country models conducted at the ECB have been used, i.e. the variable changes its value for a precisely defined time period and subsequently returns to the baseline value. Such experiments consist in testing two responses: to an increase in the exogenous variable and to its decrease.

[47] This phenomenon was very much pronounced during the experiments with the Taylor rule conducted on earlier versions of the model – the relatively large negative gap (i.e. the actual condition of the economy) determined the responses of the interest rate regardless of the type of shock introduced.

Figure 1. Responses of investment outlays (*inv*), consumption (*cs*), imports (*m*) and exports (*x*)

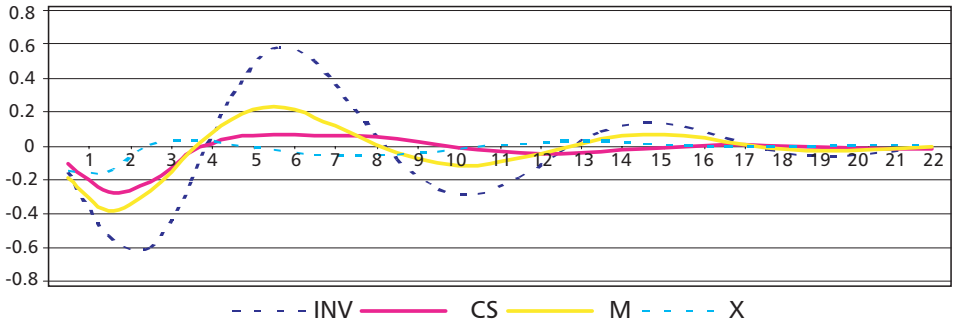


Figure 2. Responses of GDP (*y*), domestic demand (*yd*) and employment (*zz*)

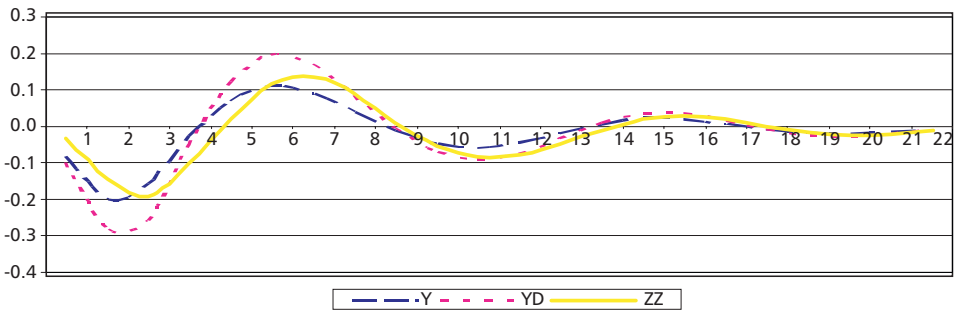


Figure 3 Responses of consumer prices (*pc*), producer prices (*p*), nominal wages (*ww*), import prices (*pm*) and exchange rate (*er*)

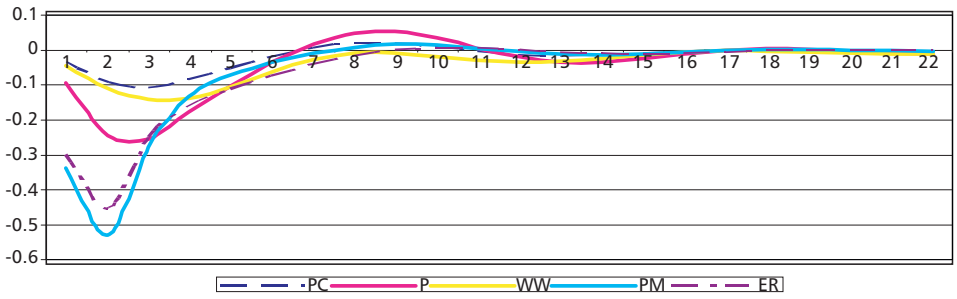
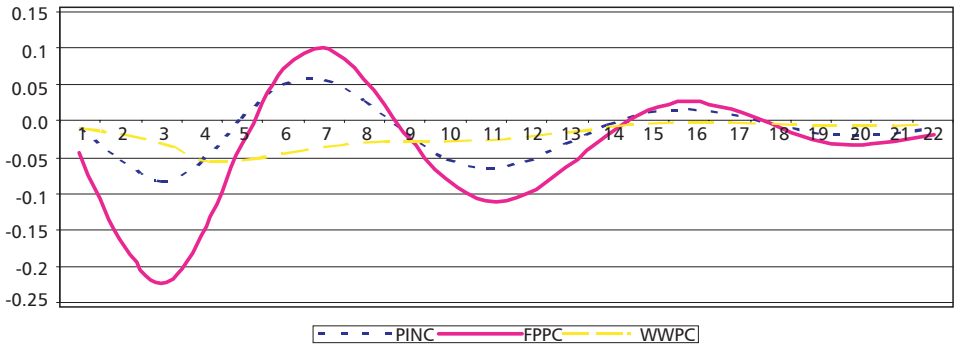
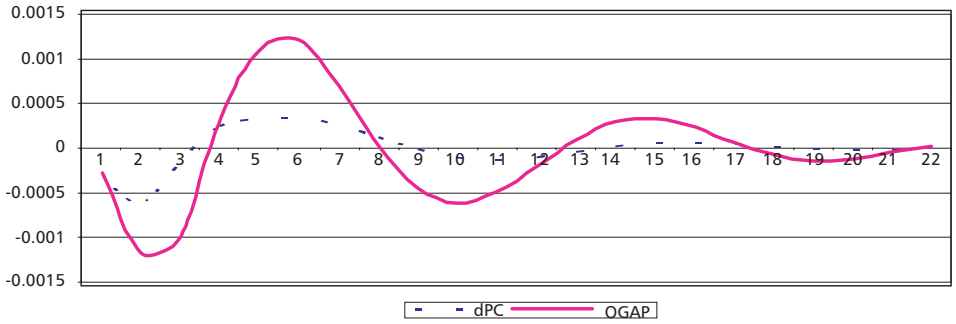


Figure 4. Responses of disposable income (*pinc*), real payroll fund (*fppc*) and real wages (*wwpc*)



III

Figure 5. Responses of inflation (*dpc*) and output gap (*ogap*)



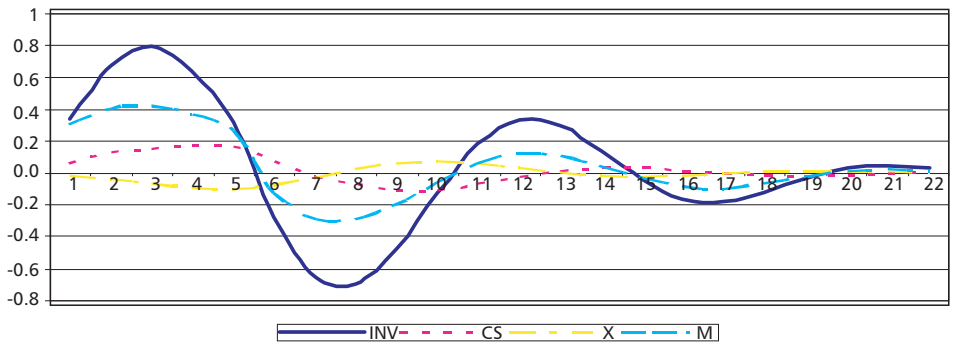
III

7.2. Five-year (20-quarter) increase in budget expenditures by 1 percent of the baseline value

While interpreting the results of the increase in budget expenditure it should be remembered that the MSMI model does not include expenditure balancing (or deficit financing); there is no fiscal policy rule that would ensure long-term maintenance of public finance stability, either. Thus an increase in budget expenditures is equivalent to acquiring external subsidies and does not entail any current or future budget liabilities. The expected effect of such a shock is therefore a "pure" increase in demand activated through the public consumption and consumption channels[48] – thus Figs. 6–10 present the results of an autonomous increase in domestic demand and not the results of an increase in budget expenditure financed by raised taxes or increased deficit.

Figs. 6–7 show a moderating influence of foreign trade; as a result of an increase in imports[49] and a decrease in exports (reduced competitiveness), GDP grows much slower than domestic demand. Since the increases in employment and fixed assets are delayed, an imbalance (output gap) emerges in the goods market, which stimulates inflation. The increase in wages and employment (including the effect of wage pressure) causes an increase in the payroll fund. It again leads to rise of input prices and price levels, while the depreciation of the zloty induces an additional rise in import prices and capital cost, which limits the scale of expansion. Due to the superposition of all those effects, the 5-year (this is the period during which the primary impulse lasts) increase in demand does not have long-term consequences, since – as it has been pointed out earlier – the long-term GDP level is primarily conditioned by fundamental factors. This result – although expected (desirable) – cannot be considered typical, since such effects are achieved where an active budget constraint is present.

Figure 6. Responses of investment outlays (*inv*), consumption (*cs*), imports (*m*) and exports (*x*)



48 The MSMI model does not take into account investment outlays financed from the budget.
49 Short-term elasticity of imports relative to GDP has been one of more stable parameters in subsequent versions of the model and has oscillated around 2. The long-term value is imposed and equals 1.

Figure 7. Responses of GDP (*y*), domestic demand (*yd*) and employment (*zz*)

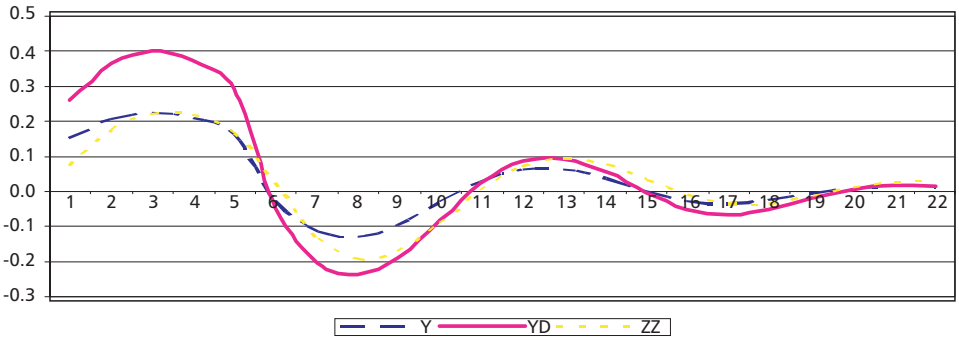


Figure 8. Responses of consumer prices (*pc*), producer prices (*p*), nominal wages (*ww*), import prices (*pm*) and exchange rate (*er*)

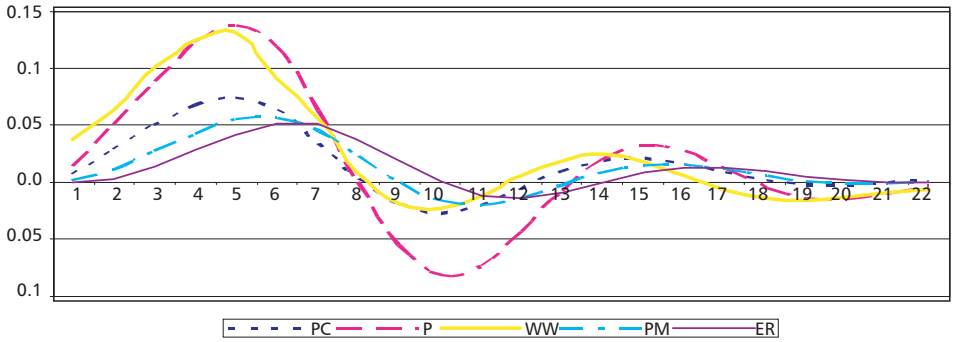


Figure 9. Responses of disposable income (*pinc*), real payroll fund (*fppc*) and real wages (*wwpc*)

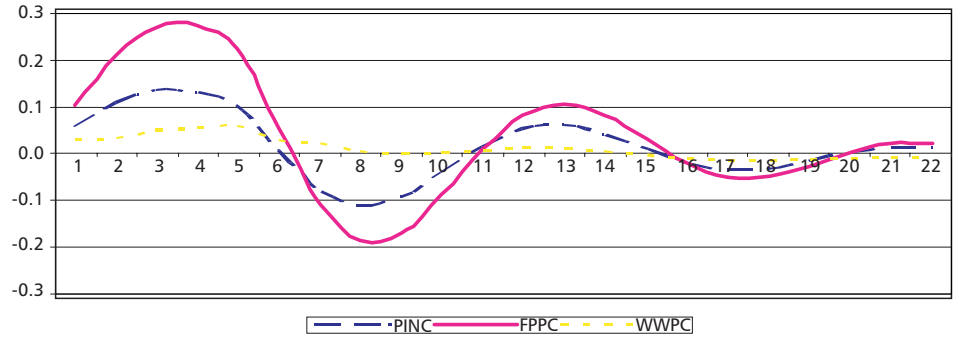
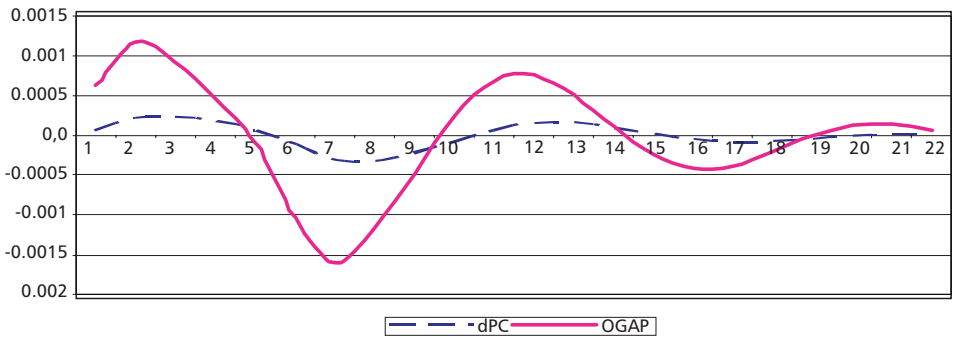


Figure 10. Responses of inflation (*dpc*) and output gap (*ogap*)



7.3. Five-year (20-quarter) increase in oil prices by 10 percent of the baseline value

An increase in oil prices is a classical supply-side shock for an economy which does not have oil resources and thus the expected result is a decrease in GDP growth and an increase in prices (inflation)[50]. Fig. 15 suggests that the nature of the analysed shock conforms to such expectations but not all variables respond immediately according to this scheme. In the short and medium term all aggregate demand components decrease. The exception here is a temporary increase in investment outlays caused by a temporary reduction in the real cost of capital, the increasing output gap, a more pronounced increase in the price of labour (an effect of factor substitution) and (most probably) the statistical base effect. It is this coincidence which retains employment practically unchanged during the first years. In subsequent years, however, the scale of the supply--side shock becomes apparent – import prices, cost of capital and labour as well as prices (inflation) rise whilst real variables decrease.

In the long term – when the price impulse itself disappears – prices return very slowly to their baseline values (cf. Fig. 13). A similar phenomenon is much less pronounced in the case of real variables, e.g. aggregate demand components (cf. Fig. 11), but as long as price relationships do not return to their baseline level, factor proportions will be distorted as well. The distorted factor structure will also cause changes in product structure. The delay and extent of investment's response to the shock are also reasons here. The maximum effect is apparent six years after the initiation of the experiment; it translates into shocks in the labour market, which takes the longest time to reach the baseline path. The very low (estimated) value of the parameter determining the rate at which imbalances in the employment equation are corrected is the reason here.

Figure 11. Responses of investment outlays (*inv*), consumption (*cs*), imports (*m*) and exports (*x*)

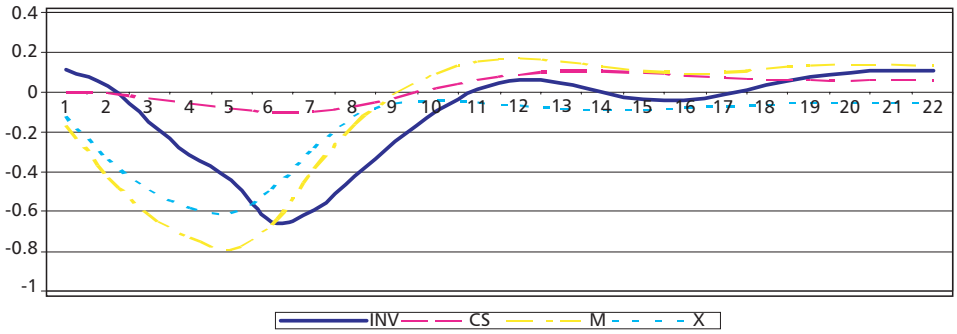
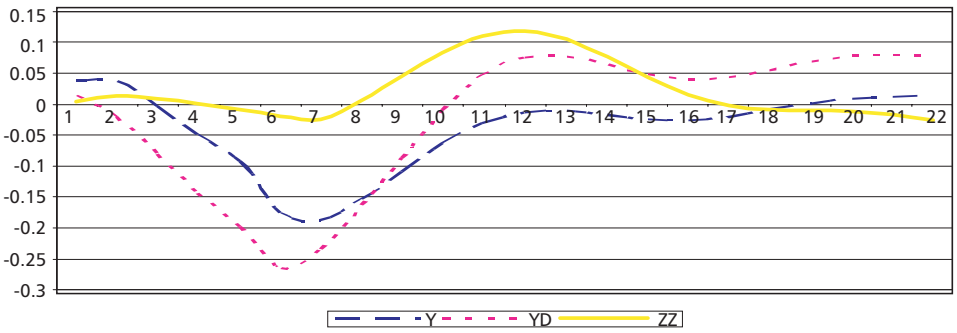


Figure 12. Responses of GDP (*y*), domestic demand (*yd*) and employment (*zz*)



[50] It should be noted that an increase in oil prices should be accompanied by an overall increase in world prices. Since with exogenous world prices and exogenous oil prices this relationship is severed, the results of the experiment do not realistically reflect the nature of the external cost shock.

Figure 13. Responses of consumer prices (*pc*), producer prices (*p*), nominal wages (*ww*), import prices (*pm*) and exchange rate (*er*)

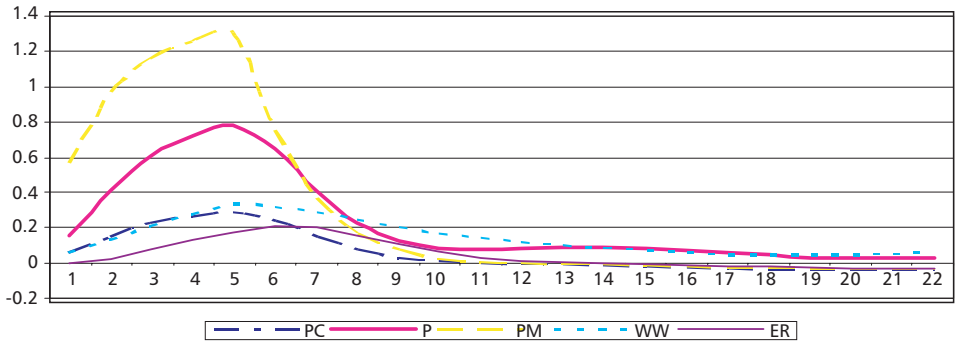


Figure 14. Responses of disposable income (*pinc*), real payroll fund (*fppc*) and real wages (*wwpc*)

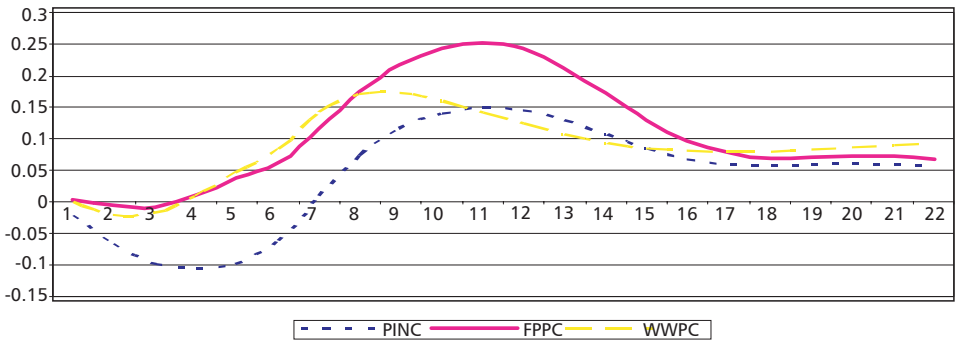
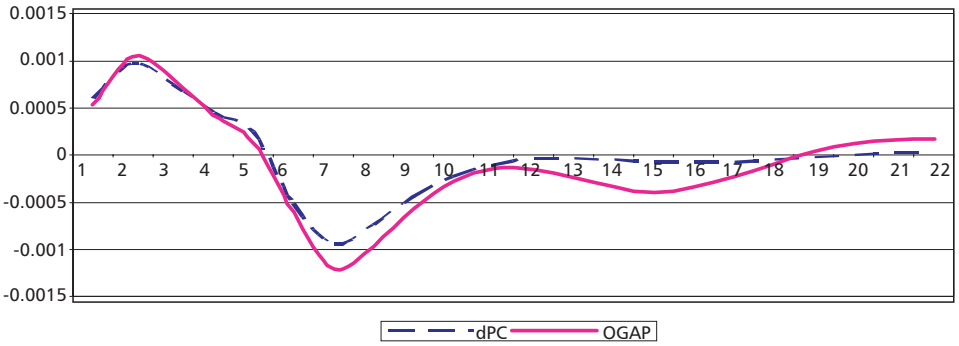


Figure 15. Responses of inflation (*dpc*) and output gap (*ogap*)



7.4. Five-year (20-quarter) increase in external demand by 1 percent of the baseline value

The experiment examining the impact of an increase in external demand supplements the analysis of purely demand-side shocks. As in the case of an increase in budget expenditure, the demand impulse is also autonomous and not related to any expenses. However, the scale of this shock and the considerable delays with which the external demand impulse induces responses of the real sector of the economy and of prices make the multipliers dissimilar to those shown in Figs. 6–10.

Obviously, external demand influences GDP via an increase in exports but this effect is considerably dampened by an increase in imports, which is induced almost simultaneously.

However, all these phenomena are significantly delayed[51] and therefore classical responses in the remaining part of the economy (increased output gap, higher employment, rises in prices and wages, etc.) become apparent only after many years and the scale of response is small – it may even be suspected that non-zero values here are the result of numerical issues.

Figure 16. Responses of investment outlays (*inv*), consumption (*cs*), imports (*m*) and exports (*x*)

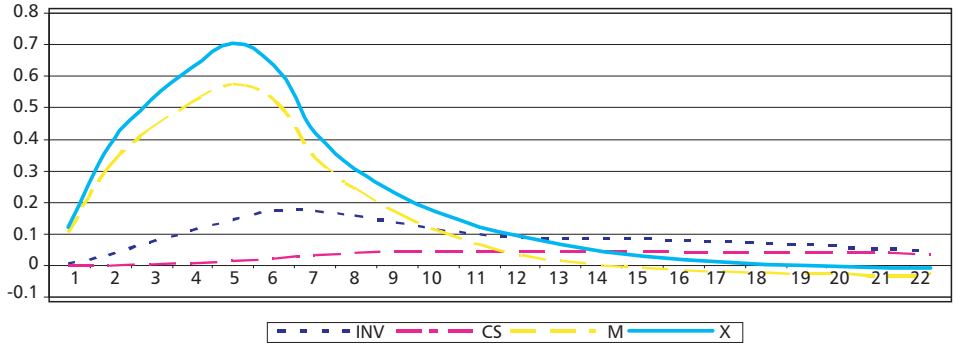


Figure 17. Responses of GDP (*y*), domestic demand (*yd*) and employment (*zz*)

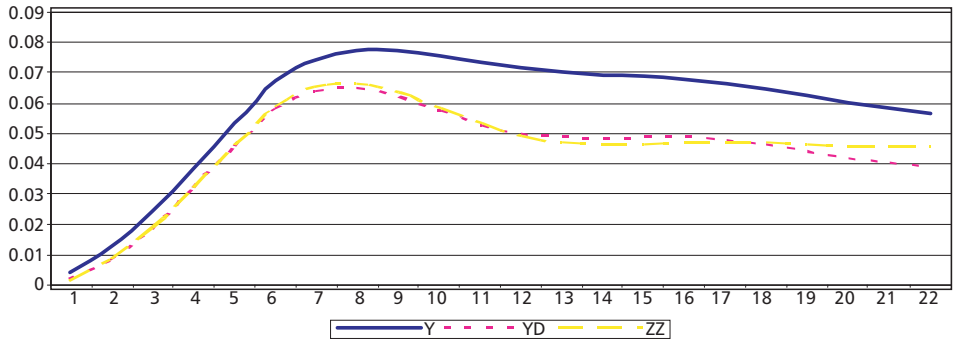
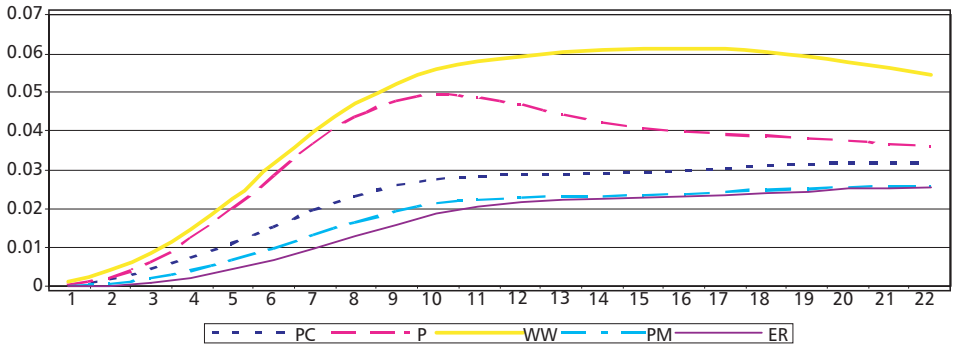


Figure 18. Responses of consumer prices (*pc*), producer prices (*p*), nominal wages (*ww*), import prices (*pm*) and exchange rate (*er*)



[51] Comparing the results of several experiments in which exports and imports respond to internal and external impulses (also analysing the specification of equations), asymmetries in the delays foreign trade responses to price- and revenue-related shocks can be observed – responses of trade to price changes appear more rapid.

Figure 19. Responses of disposable income (*pinc*), real payroll fund (*fppc*) and real wages (*wwpc*)

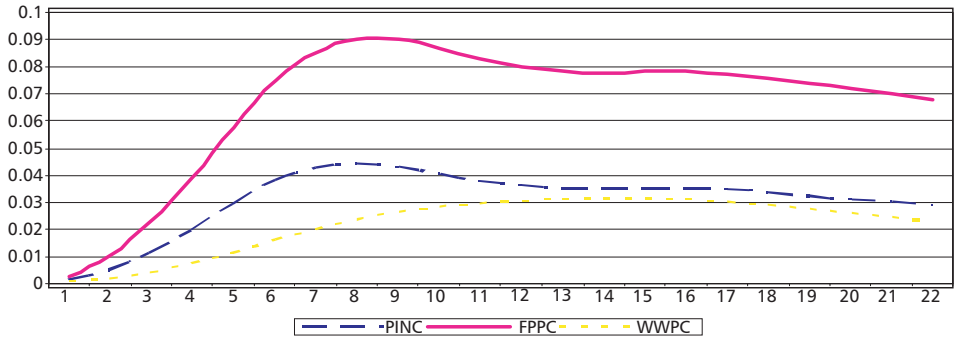
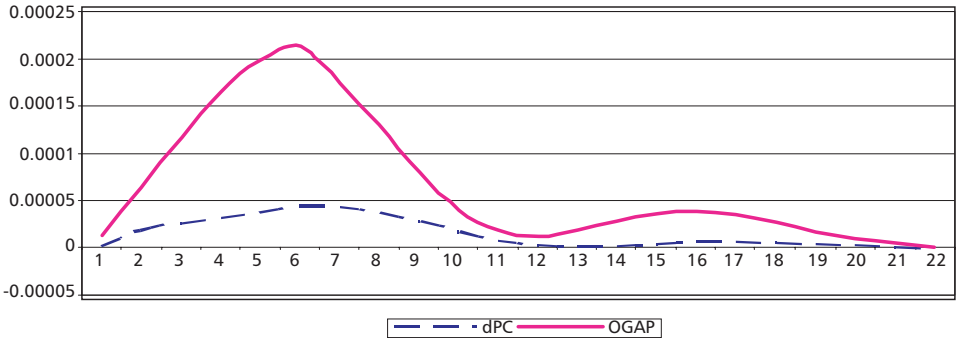


Figure 20. Responses of inflation (*dpc*) and output gap (*ogap*)



7.5. Five-year (20-quarter) appreciation of the euro against the US dollar by 1 percent of the baseline value

The exchange rate shock is the most complex one among the types of shocks analysed. As it has already been pointed out, the exchange rate of the euro against the dollar is a component of the effective exchange rate (and thus, with other conditions remaining the same, appreciation of the euro causes a depreciation of the nominal effective exchange rate[52]), but at the same time it is also an explanatory variable in the equation describing the exchange rate of the zloty against the dollar (and causes an appreciation of the zloty against the dollar). Due to the respective weights of currencies in the nominal effective exchange rate and the parameters of the equation describing the exchange rate of the zloty against the dollar, the expected direct consequence of the cross rate appreciation would be a depreciation of the zloty. Figs. 21–25 directly illustrate some of the effects described above.

In general, responses of variables correspond to the expected consequences of domestic currency depreciation. Exports rise whilst the contraction in imports is relatively small, and the responses of consumption and investment outlays indicate that income effects are insufficient to neutralise the price effects which accumulate in subsequent periods – an increase in import prices means increased cost of capital, nominal wages and consumer prices. Thus, a decrease in disposable income becomes apparent together with an increase in the overall cost of labour.

An interesting phenomenon emerges on the labour market. Employment remains above the baseline path practically throughout the period. In the first stage of the experiment, higher

[52] The effective exchange rate is the weighted average of the exchange rates of the zloty against the dollar and the zloty against the euro, cf. Table 1.

employment directly results from the increase in GDP but also from the relationship between factor prices, which favours labour (cost of capital rise more significantly than the cost of labour in relation to producer prices, which also contributes to the fluctuations in investment outlays, as visible in Fig. 21); in subsequent stages, employment does not decrease despite the fact that aggregate demand dips below the baseline path and the relationship between factor prices is reversed. This is again a result of the slow adjustment of the labour market – it adjusts so slowly that when employment shows a downward trend, an increase in aggregate demand (which oscillates during the adjustment process) changes the trend. This feature is also illustrated by Figs. 4 and 12.

Figure 21. Responses of investment outlays (*inv*), consumption (*cs*), imports (*m*) and exports (*x*)

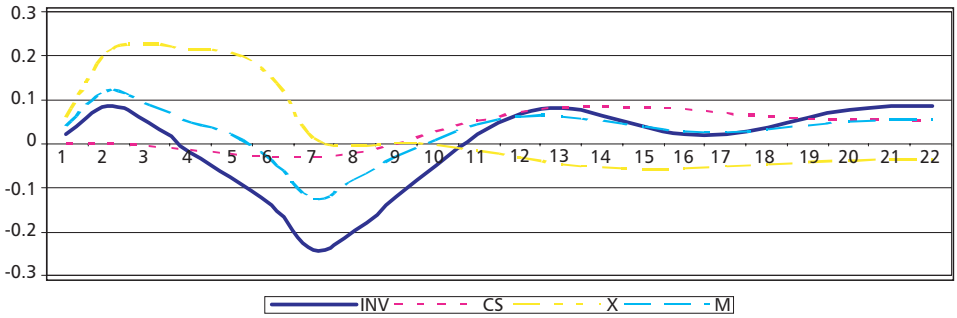


Figure 22. Responses of GDP (*y*), domestic demand (*yd*) and employment (*zz*)

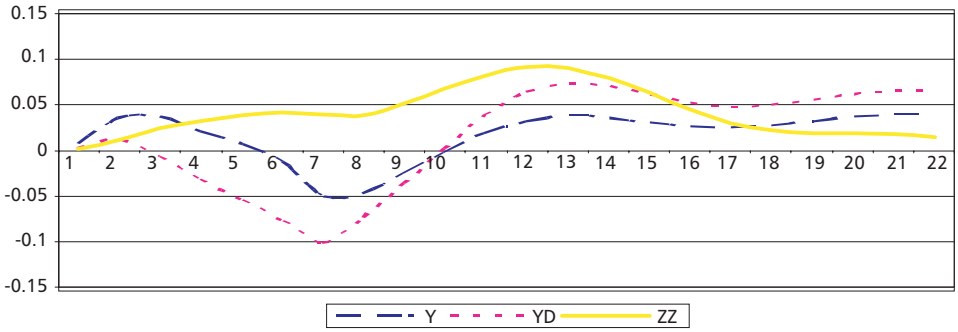


Figure 23. Responses of consumer prices (*pc*), producer prices (*p*), nominal wages (*ww*), import prices (*pm*) and exchange rate (*er*)

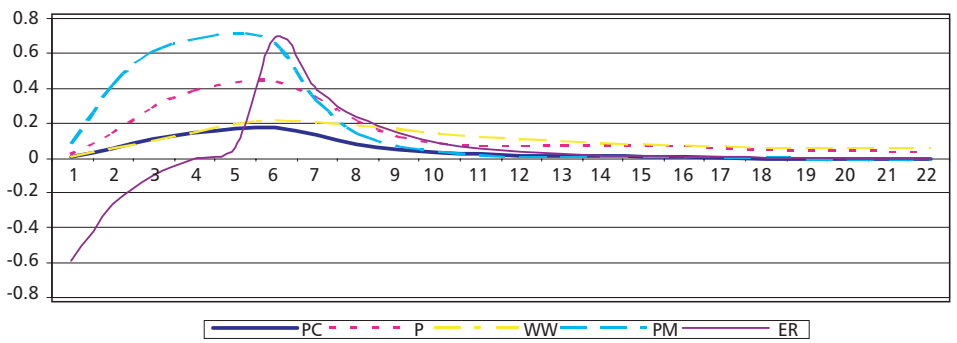


Figure 24. Responses of disposable income (*pinc*), real payroll fund (*fppc*) and real wages (*wwpc*)

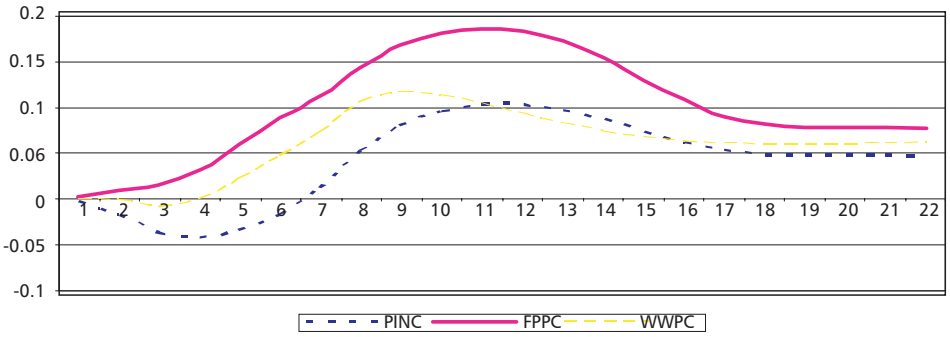
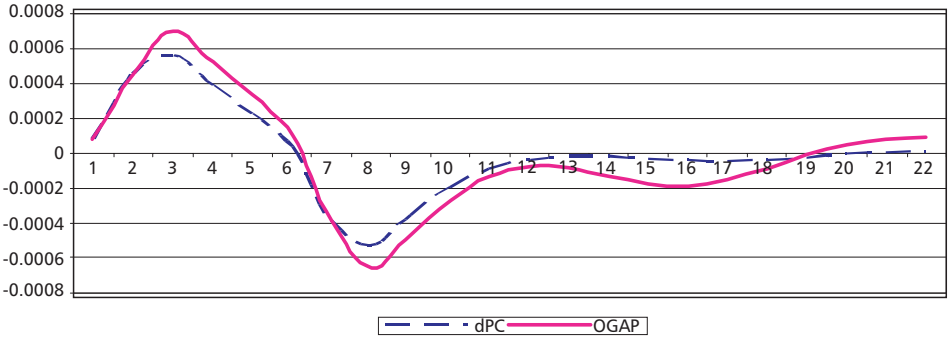


Figure 25. Responses of inflation (*dpc*) and output gap (*ogap*)



7.6 Five-year (20-quarter) increase in world prices by 1 percent of the baseline value

Formally, an increase in world prices should be treated as a shock similar to an increase in oil prices, i.e. a supply-side shock, as suggested by Fig. 30. However, world prices have a simultaneous impact on imports (via import prices), exports (after an exchange rate conversion they determine its competitiveness) and the exchange rate of the zloty against the dollar (due to the tendency towards the realisation of the one price rule, which is model-inherent), and thus the shock is heterogeneous. This is confirmed by the variable trajectories presented in Figs. 26–29. Due to the distribution and strength of the impact of world prices on foreign trade, exports are the first to respond and the relative scale of the response is the largest here – there is an increase in exports, which causes an increase in imports (thus limiting GDP growth) and in investment outlays. However, the increases in imports and investment induced by the rise in exports may be regarded controversial. The elasticity of imports with regards to exports is larger than the elasticity of imports with regard to the overall GDP within the MSMI model, but an increase in world prices almost immediately results in an increase in import prices and there is a significant "overshoot" effect[53]. However, the delay with which imports respond to prices is longer, and thus imports grow and stabilise the GDP. An increase in import prices should also result in an increase in the cost of capital and a reduction in investment demand. In this case, delays are again the decisive factor – investment outlays only respond to the cost of capital with a two-quarter lag, which allows investment to grow despite the increase in world prices during the first year of the shock.

Employment is stimulated by the growth in investment and exports, thus destabilising the condition of the labour market, which receives conflicting impulses: demand and consumer prices rise (as if a purely demand-side shock occurred), but the real cost of capital also increase (causing,

[53] This is confirmed by an error correction response, which comes with a 4–5 year delay, cf. Fig. 28.

among other things, first an increase, and then a decrease in the natural unemployment rate). Despite the fact that the supply-side character of the shock is more pronounced in subsequent years, the labour market exhibits imbalances until the end of the examined period, although the scale of this phenomenon does not appear to be significant. In general, it may be observed that fairly rapid changes in aggregate demand components (apart from consumption) are accompanied by relatively negligible changes in the GDP trajectory.

The responses of the domestic price level seem to conform to expectations – prices rise during the shock (despite an appreciation in the exchange rate, which decreases the scale of the impulse) and this response is delayed with regard to the impulse, which causes a somewhat counterintuitive response of exports; later – after an error correction regarding import prices – prices slowly converge to the baseline path. However, price movements in time justify the fluctuations in real categories (e.g. a strong decrease in investment outlays and exports emerging 5–7 years after the beginning of the experiment).

Figure 26. Responses of investment outlays (*inv*), consumption (*cs*), imports (*m*) and exports (*x*)

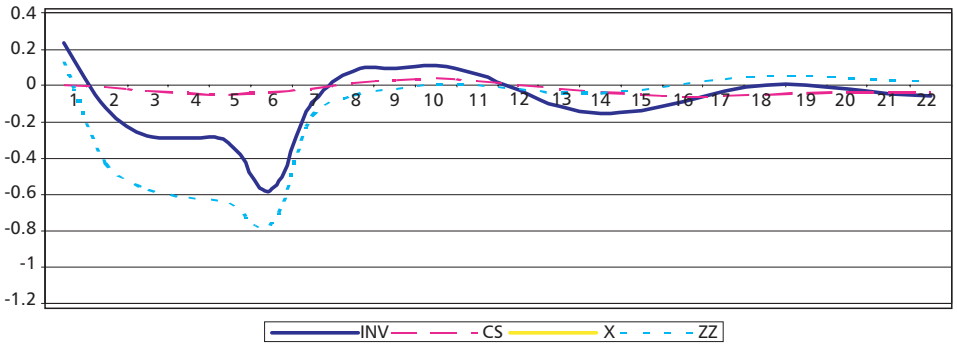


Figure 27. Responses of GDP (*y*), domestic demand (*yd*) and employment (*zz*)

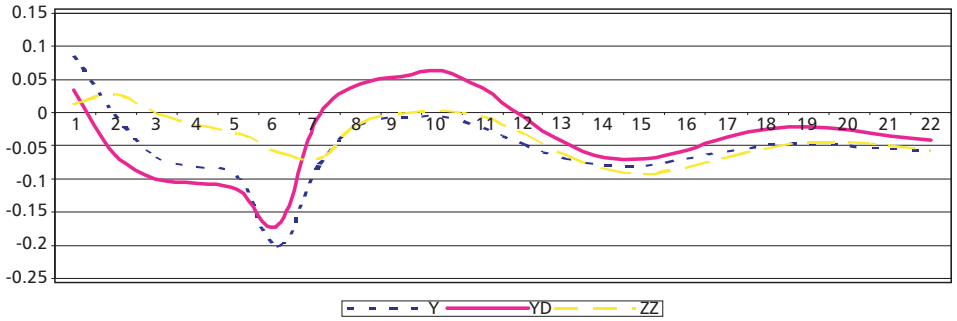


Figure 28. Responses of consumer prices (*pc*), producer prices (*p*), nominal wages (*ww*), import prices (*pm*) and exchange rate (*er*)

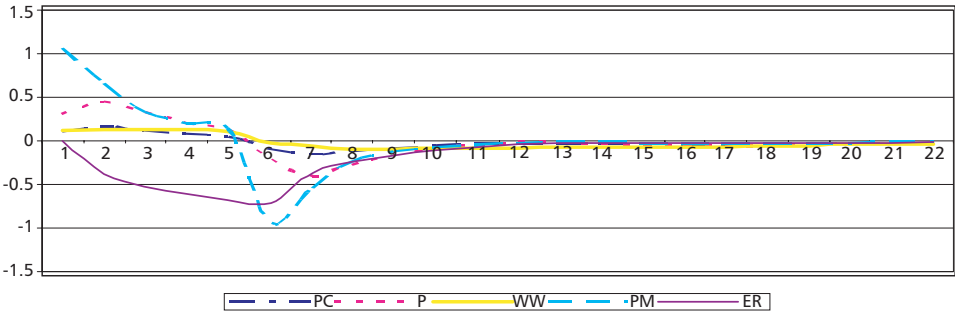


Figure 29. Responses of disposable income (*pinc*), real payroll fund (*fppc*) and real wages (*wwpc*)

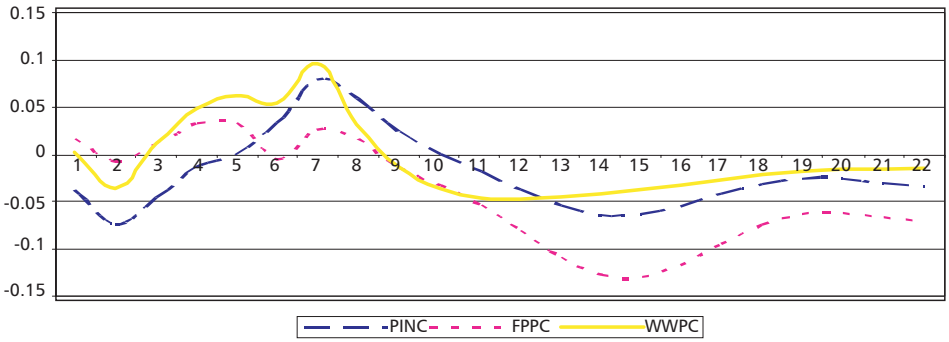
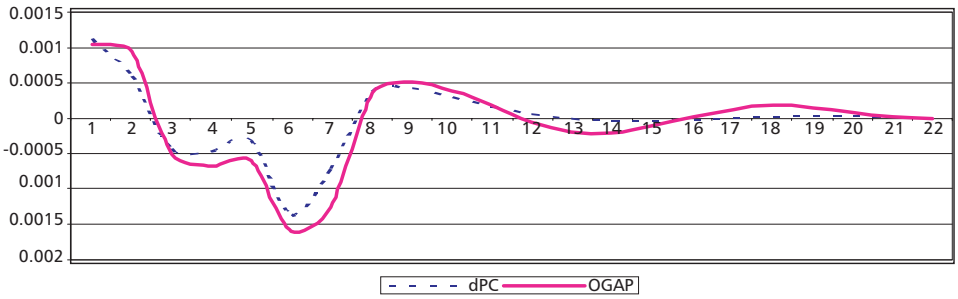


Figure 30. Responses of inflation (*dpc*) and output gap (*ogap*)



IV
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