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The Hungarian Monetary Policy Model

MNB WORKING PAPERS 1
2013

MAGYAR NEMZETI BANK

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The Hungarian Monetary Policy Model*

(A magyar monetáris politikai modell)

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**International Monetary Fund

Contents

Abstract

March 2011 marked the introduction of the Magyar Nemzeti Bank's Monetary Policy Model (MPM), representing a paradigm shift in both macroeconomic projection and monetary policy decision support. In contrast to previous conditional projections, the MPM provides an endogenous definition of both the projected policy rate and the projected exchange rate. Given the forward-looking nature of the model, expectations of economic agents play a key role in the monetary transmission process; therefore, the future achievement of the inflation target is guaranteed by the projected path of the interest rate over the forecast horizon. In this paper, we discuss the underlying structure and logic behind the MPM, describe the key behavioural equations and examine how the channels of monetary transmission appear in the model. In addition, we present the empirical validation process in detail from calibration, through Bayesian estimation and discussion of the economic properties of the model to the historical projection exercise. Finally, we discuss the main challenges we faced during the first year of application.

JEL: C51, E17, E52, E58.

Keywords: Model Projection, Simulation, Central Banking, Monetary Policy.

Összefoglalás

A Magyar Nemzeti Bank 2011. márciusában a Monetáris Politikai Modell (MPM) bevezetésével új fejezetet nyitott mind a makrogazdasági előrejelzés, mind a monetáris politikai döntéselőkészítés területén. A korábbi feltételes előrejelzési gyakorlattal szemben az MPM endogén módon határozza meg az irányadó kamat és az árfolyam pályáját. A modellben a változók előretekintő módon viselkednek, vagyis a gazdasági szereplők várakozásai döntő szerepet játszanak a monetáris politika transzmissziós mechanizmusában. Ezért az infláció célra kerülését egy egyszeri monetáris politikai döntés nem tudja biztosítani, a cél teljesüléséhez a horizonton várt kamatlépések sorozata szükséges. A tanulmányban ismertetjük az MPM felépítését és a modell mögött meghúzódó összefüggéseket, bemutatjuk a legfontosabb viselkedési egyenleteket, valamint megvizsgáljuk, hogy a transzmissziós mechanizmus csatornái hogyan jelennek meg a modellben. Emellett részletesen tárgyaljuk az empirikus validálás folyamatát. Ez magába foglalja a modell kalibrálását és bayesi becslését, valamint a modell tulajdonságainak elemzését és historikus előrejelzési gyakorlatokat. Végül röviden összefoglaljuk, hogy milyen kihívásokkal szembesültünk a modell alkalmazásának első évében.

1 Introduction

Until March 2011, the Magyar Nemzeti Bank (MNB) used separate models for its forecasting and monetary policy decision-support processes. Projections were based on macroeconometric models while policy simulations were carried out using DSGE models to capture the effect of endogenous monetary policy reaction.

In 2011, the MNB introduced the Monetary Policy Model (MPM), a carefully designed systematic tool, which is able to support both the forecasting and the decision-making processes at the same time.[1] The MPM is a relatively small, semi-structural model. Nevertheless, its concise description of the economy and focus on the monetary transmission mechanism makes it a good organisational device allowing a common language between staff and management. In addition,the MPM also extends the toolkit of the MNB by allowing an endogenous determination of the interest rate and the exchange rate, a feature that earlier projection models did not have.

The MPM was constructed to strictly comply with the modern paradigm of monetary policy. While it is a consistent framework describing the evolution of key macroeconomic variables relevant for policy making, the new model also gives an explicit role to monetary policy in providing a nominal anchor for the economy in the medium to long run. Accordingly,the MPM incorporates the most important characteristics of the Hungarian economy as well. Some of these features are typical of other emerging countries, such as the trend appreciation of the real exchange rate and the large proportion of administered prices in the CPI basket. By contrast, the high external indebtedness of the country[2], the large share of foreign currency-denominated private-sector liabilities[3] and the high reliance of the banking system on funding from foreign parent companies make the Hungarian economy highly vulnerable to exchange rate depreciation. Consequently, a sudden depreciation not only has a direct impact on inflation, but also immediately raises financial stability concerns. Therefore, financial stability concerns may give rise to responses of the policy rate to nominal exchange rate developments over and above those designed to fight pure inflationary consequences. As we will see, these considerations make both the analysis of the monetary transmission mechanism and the conduct of monetary policy difficult in the case of Hungary.

In the following, we will place emphasis on the motivation behind modelling choices and focus on policy experiments highlighting the role of monetary policy as a stabilisation tool for the economy.[4] Instead of analysing impulse responses to unexpected shocks alone, we also aim to present thought experiments demonstrating the main mechanisms of the model as well as the drivers and consequences of the monetary policy reaction function. The role of monetary policy in providing a nominal anchor to the economy is best presented by comparing systematic inflation targeting behaviour (represented by a Taylor-rule), with monetary policy being passive (represented by constant nominal rates, or delayed policy reactions). Also, we compare the transmission mechanism following a shock to the risk premium in the baseline model and in an identical model characterised by no foreign exchange (FX) liabilities' problem, and analyse the consequences of the non-standard balance sheet channel. We also present how experience gained during the first forecast rounds affected the structure and parameters of the model. In particular we explain the motivation behind modifying the original policy rule to capture financial stability concerns of the decision makers.

[1] The development of the MPM was supported by the Technical Assistance Program of the IMF during 2010-2011.

[2] Gross external debt decreased from a peak of 157% in 2010Q2 to 128% of GDP in 2012Q3. The source of data is the Statistical Data Warehouse of the European Central Bank.

[3] Foreign currency-denominated private-sector liabilities were around 60% of GDP both for households and corporations in 2012 Q3. Source: MNB.

[4] This paper is a follow-up to Horváth et al. (2011), which succinctly presented the equations and the main mechanisms of the model.

In the parametrisation of the model, we followed a stepwise approach. First, we identified the main parameters of the model that govern the most important channels of the monetary transmission mechanism, and calibrated their values to match existing empirical evidence from other structural tools (i.e. SVAR and DSGE models). This way, we had a relatively solid view about how monetary policy affects the most important macro variables in the model. However, the success criteria of our parametrisation excercise was not exclusively empirical. In parametrising the monetary policy reaction function we definitely had some normative concerns in mind. As a model designed for policy advice, we aimed to have a policy rule that has reasonable stabilisation properties, providing a favourable trade-off between inflation and output stabilization. After having extensively used the calibrated version of the model in simulation and forecast excercises, we estimated the model in a Bayesian way.

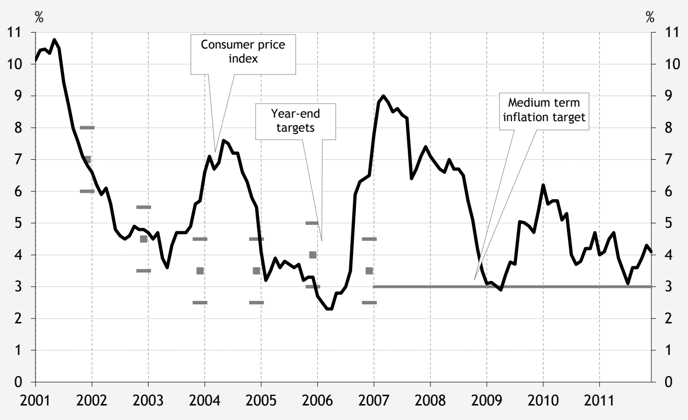
The structure of the paper is as follows. In the next section we present the historical background, experiences with inflation targeting in Hungary and the motivation for introducing the MPM. In Section 3 we describe the model equations in detail. Section 4 covers parametrisation, discussing the calibration excercise, the normative properties of the policy rule and the main results of the Bayesian estimation and presents the historical performance exercise. Section 5 presents the economic properties of the model. Section 6 discusses the successes and challenges during the forecast rounds in the first year of application. Section 7 concludes.

2 Historical background and motivation

June 2001 marks the introduction of inflation targeting (IT) in Hungary. This move was a response to various unsuccessful attempts to use other nominal anchors as a way of controlling inflation in an environment characterised by large shocks and strong exchange rate pass-through to domestic prices. The shift to IT came as no surprise: by 2001 best-practice central banks all over the world adopted IT policies. The academic literature and policy papers all agreed that the benefits of a successful forward-looking inflation targeting regime are numerous (see, e.g., Laxton et al. (2009)). First, reduced uncertainty about future inflation brings about a more efficient allocation of resources and better price signals. Second, a successful forward-looking IT is associated with lower real interest rates, and consequently, higher levels of investment. More investment leads to increased permanent income, and implies lower levels of unemployment and higher levels of productive economic activity. On the policy front, IT leads to improved transparency and higher policy credibility. Nevertheless, the new regime could not be regarded as a fully-fledged IT system from the onset, as the exchange rate band was not abolished in parallel.[5] The hybrid monetary policy regime was abandoned in 2008, when the MNB adopted a floating exchange rate system.

As for practical implementation in Hungary, against an annual rate of inflation of 10% in early 2001, the inflation target was set at 7% for the end of 2001. In subsequent years, the target was lowered gradually and was ultimately fixed at 3% in 2007 (see Figure 1). Experiences with anchoring inflation around the target are rather mixed. On the one hand, inflation declined substantially, especially in the first couple of years following the introduction of the new regime. On the other hand, inflation has been stuck well above the target since 2006, reflecting an unfortunate combination of bad luck and policy mistakes.

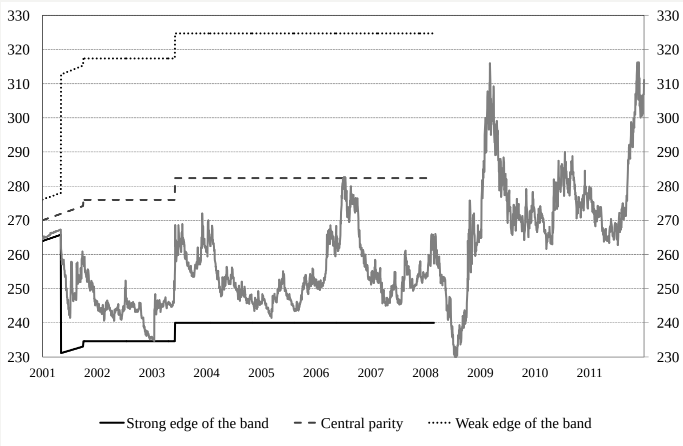
Figure 1
The evolution of CPI inflation and the target



[5] For a concise history of Hungarian monetary policy, see for example, MNB (2002, 2006, 2012).

An obvious culprit was the exchange rate band, which remained effective until 2008. During the period from the 2001 to 2007, the EUR/HUF exchange rate was typically close to the upper bound of the official exchange rate band, which limited the room for manoeuvre of the decision makers when tightening monetary conditions became necessary from an inflation perspective (see Figure 2).

Figure 2
Development of the HUF/EUR exchange rate



Also, with the benefit of hindsight, the consensus view within the MNB staff is that the mismeasurement of the real-time cyclical position of the economy[6], inaccurate judgment about the persistence of disinflationary forces following EU accession as well as a sequence of supply shocks (oil and food price shocks in particular) played a crucial role in inflation continuously missing the target.

The success of the IT enterprise depends on various factors, one of which is the availability of a consistent analytical framework. Prior to the arrival of the MPM, the MNB produced forecasts based on different macroeconometric models. In particular, the models NEM (see Benk et al. (2006)) and DELPHI (see Horvath et al. (2010)) proved useful for computing conditional projections. These exercises primarily aimed at answering the question of whether the central bank would achieve its inflation target while maintaining monetary conditions (i.e. interest rates and exchange rates) unchanged. While such devices may provide useful information at short horizons where conditions do not change markedly, they may suffer at longer horizons where the consistency of a general equilibrium system is required. Moreover, those models could not further assist the MNB in its decision-making process. More explicitly, they could not give guidance on how to develop a path for the interest rate that would help achieve the desired target for inflation. This exercise requires an endogenous interest rate and a forward-looking general equilibrium model.

The necessity of an endogenous interest rate paved the way for developing an advanced Dynamic Stochastic General Equilibrium (DSGE) model named PUSKAS (see Jakab-Világi (2008)). PUSKAS was used in monetary policy decision support to produce historical shock decompositions, enabled the carrying out of welfare analysis and was able to perform counterfactuals without exceedingly abusing the Lucas critique. While micro-founded and allowing for endogenous interest rates and exchange rates, PUSKAS did not prove very useful in the regular projection exercise. In particular, the tight cross-equation restrictions of PUSKAS resulted in poorer external validity, i.e. unsatisfactory empirical fit and hence forecast performance relative to the more flexible, empirically-motivated macroeconometric models. Moreover, the Hungarian economy, as is the case with many emerging countries, has been undergoing major changes in its structure and organisation, and such changes do not easily lend themselves to empirical regularities that a model with strict structural restrictions can capture.

[6] See Section 4 for details.

In 2010, the MNB decided to develop a model that can be used both for projection and policy simulations and – with the support of the Technical Assistance Programme of the IMF – opted for a stepwise approach. This approach consists of starting with a calibrated core model, and, only later on, based on the experience gained, building a more ambitious DSGE model. Current theoretical and empirical knowledge on monetary policy affirms that central banks can influence the cyclical position of macro variables but have no long-term effect on real economy developments. Therefore, the MPM is a so-called gap model, i.e. behavioural equations were applied to the cyclical position of real economic variables. These models attempt to explain how real economy 'gaps' – defined as percent deviations from equilibrium trends – arise and how they are dissipated over the medium-to-long term. Although MPM equilibrium trends differ from the flexible-price equilibrium trend concept of a structural model, in practice the gap-trend decomposition is derived from Kalman filters to capture the degree of inflationary pressure coming from the real economy.

To summarise, in comparison with earlier macroeconometric models, the MPM operates with a less disaggregated economic structure, while it still manages to integrate all variables relevant for monetary policy. Issues concerning the supply side or long-term trend developments are exogenous and are kept outside the model. While this approach assumes away many practically relevant questions, its simplicity makes it a good organisational device allowing a common language between staff and management. Moreover, model-based forecasts tell a consistent, forward-looking story making policy necessarily forward-looking as well. As a story-telling device, the MPM was a clear success and gained popularity among policy makers. Consequently, the MPM has been a key input to the interest setting decisions of the MNB over the recent forecast rounds (see Quarterly Reports on Inflation from 2011 on).[7]

[7] It is important to emphasise that the model is just one key input into interest rate setting decisions. Judgement of staff and policy makers is another important element and is a way of taking on broad information that is not captured by the model.

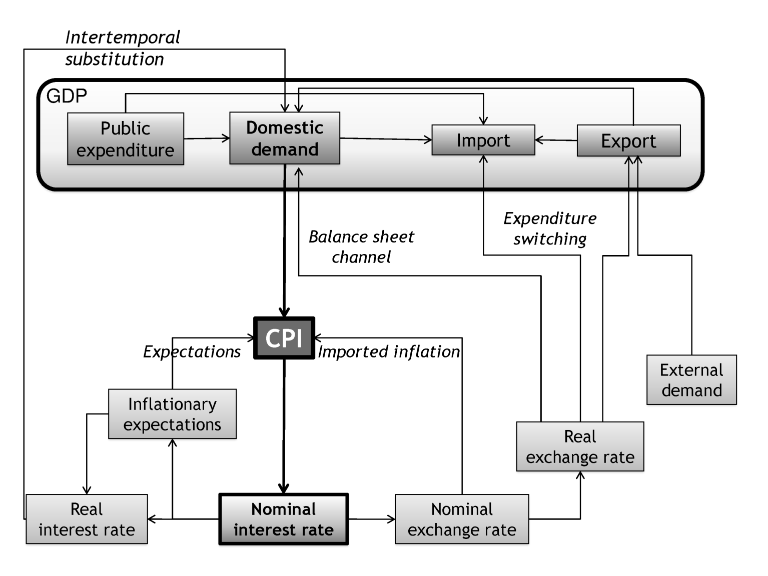
3 The Model

At its core, the MPM is a new-Keynesian model of a small open economy. One common feature shared by all members of this model family is that their underlying mechanisms can be defined with the following four basic relationships.

1. In the short run, excess demand leads to higher inflation (new-Keynesian Phillips curve).
2. Aggregate demand depends negatively on the real interest rate (IS curve).
3. The central bank sets the path of the policy rate in order to stabilise inflation around the target (Taylor rule).
4. The exchange rate is determined by current and future interest rate differentials and the risk premium (uncovered interest rate parity).

These basic building blocks of the model are extended further to capture the specifics of the Hungarian economy. The structure of the model and the most important channels of monetary transmission are presented in Figure 3.

Figure 3
The flowchart of the model



The monetary transmission mechanism refers to a complex, multi-level process through which central banks can exert influence on output and inflation. We can distinguish between various monetary transmission channels, all of which represent a unique mechanism: monetary policy measures have an impact on the real economy's demand and – in terms of changing production costs – supply as well, thereby influencing the consumer price index. In the following, we explore in detail how the main transmission channels appear in the MPM.

- *The interest rate channel* (i.e. intertemporal substitution in Figure 3). In the short term and under sticky prices, a nominal interest rate increase results in higher real interest rates, thereby influencing key demand decisions by the private sector. First, the rising real interest rate encourages households to save more, which in turn translates into lower consumption. Second, it also makes postponement more of an option for corporate investment, as fewer projects are able to generate an output that can still ensure profitability. These two factors seem to reinforce one another, thereby lowering domestic demand and mitigating demand-side inflationary pressures.
- *The expectations channel*. Given the forward-looking nature of the model, monetary policy also influences economic agents' expectations. A good example of this mechanism is that, in view of the central bank's policy rule, agents of the model are aware what measures the central bank is likely to take in the future should the level of expected inflation deviate from the target already announced. In the event that, for instance, inflation is above the target, the private sector would anticipate tighter monetary conditions and will immediately lowers its expectations concerning future inflation. That, in turn, will have an effect on current pricing decisions. This is how expectations become the central and decisive element of a given forecast. It must be noted that forward-looking behaviour also implies that agents do not react to temporary inflation shocks which have no second-round effects. They ignore these because of their understanding that in this case, over the medium term, inflation will return to its target level even without central bank intervention.
- *The exchange rate channel*. The higher the central bank's policy interest rate (assuming that all other factors remain unchanged), the more attractive forint-denominated instruments become, thus demand for the forint grows, resulting in an appreciation of the Hungarian currency. Through a reduction in import prices, a stronger nominal exchange rate can also have a direct downward effect on inflation. The exchange rate does not leave the real economy unaffected either; it has two opposing effects on inflation. Appreciation, on the one hand, damages the competitiveness of domestic companies, thereby acting as a drag on economic activity and, ceteris paribus, mitigating price increases. On the other hand, given the considerable foreign currency-denominated debt held by domestic agents, appreciation also increases available income (as the amount of foreign currency-denominated debt is reduced and loan instalments are revaluated), thereby boosting domestic demand which, ceteris paribus, leads to higher inflation.

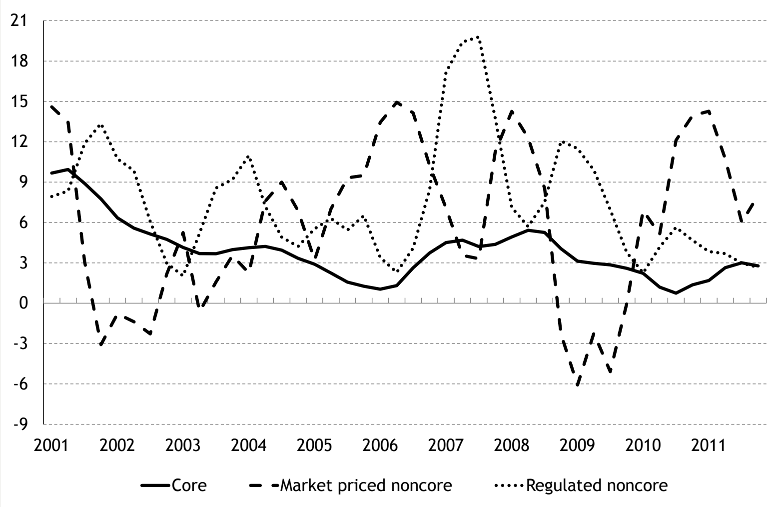
3.1 COUNTRY-SPECIFIC FEATURES OF MPM

Given the mission of inflation targeting, the key variable in this model is the consumer price index (CPI) or, more precisely, its fluctuations and dynamics over time. In contrast to most small gap models, where there is usually one variable for inflation, the MPM splits indirect tax-adjusted headline CPI into three subcategories: (1) core, (2) market-priced non-core (i.e., unprocessed food and market energy) and (3) regulated non-core (see Figure 4).

The reason for modelling the CPI components separately is as follows. Being a small, open economy, inflation in Hungary is heavily affected by movements in the exchange rate. However, the exchange rate passes through to consumer prices in many ways. In non-core items, the effect of the exchange rate appears directly and without delay, but without any second-round effects on expectations. This can be attributed to the fact that a large proportion of the non-core item is characterised by very high import content (such as fuel and raw food) and are priced flexibly. Movements in the exchange rate have only indirect[8], but relatively more persistent consequences for core inflation causing higher expected inflation. In addition, the effect of demand on core and non-core inflation : the former is far more dependent on cyclical movements in domestic demand. Moreover, because of their relatively large share (around 16%) in the CPI basket and purely exogenous evolution over the forecast horizon, administered prices are treated separately. Finally, indirect tax effects are not modelled explicitly as forward-looking and credible monetary policy looks through one-off changes in the price level.

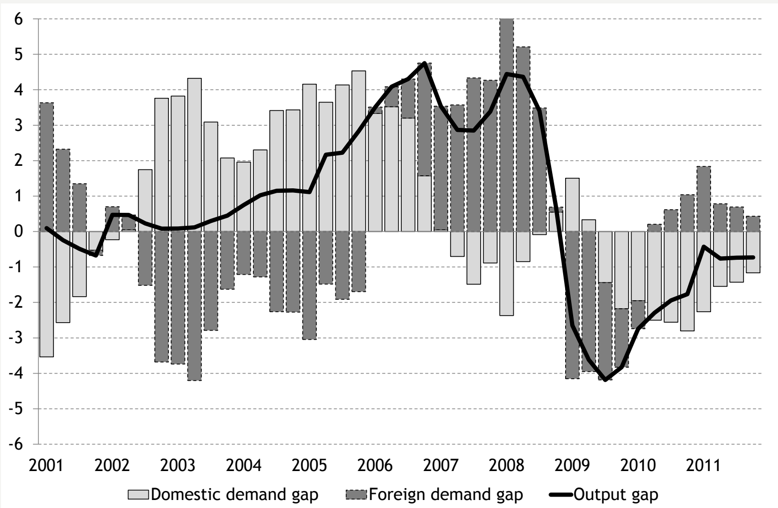
[8] Core items typically have a relatively lower import content, therefore exchange rate movements have a smaller direct effect. Moreover, empirical evidence shows that a large proportion of core items are sticky price products (for a more detailed analysis see Reiff-Várhegyi (2012)).

Figure 4
The components of CPI (% YoY)



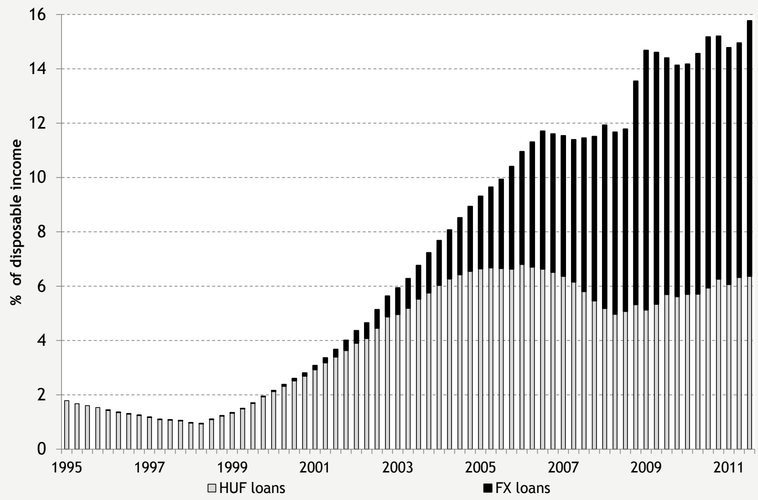
Theoretical knowledge on the long-run neutrality of monetary policy prompted central banks to develop models with a firm grasp on the cyclical position of real economic variables. Being a so-called gap model,the MPM also belongs to this tradition. That is, it assumes away all issues about the long run and the supply side, and keeps equilibrium trends outside the model. In its simplest form, a gap model could include just one real economy variable: the output gap. However, in the Hungarian case, the split of GDP into domestic and foreign demand components is crucial. The main reason is that cycles in domestic and foreign demand can be seriously disconnected (see Figure 5).

Figure 5
The contribution of the domestic demand gap and the net exports gap to the output gap



As the financial crisis demonstrated, foreign demand (defined as the export gap minus its import content) can recover faster than slack domestic demand (sum of private and government consumption and investment, inventories minus their import content). Moreover, the effects on CPI inflation of foreign and domestic demand components are markedly different. While domestic demand cycles, in particular the household sector consumption gap, are strongly linked to movements in consumer price inflation, foreign cyclical position has a far smaller, indirect effect on domestic inflation. Finally, fluctuations in the real exchange rate have opposing effects on domestic demand and net exports. While a temporary real depreciation boosts net exports via the usual 'expenditure switching' effect, it restrains domestic spending through the 'balance sheet' channel. The latter is the consequence of the heavy FX indebtedness of the private sector, which increases the value of such debt obligations when the domestic currency weakens.

Figure 6
Debt service of households (as % of disposable income)



The large share of foreign currency liabilities in households' balance sheets is a crucial feature of the Hungarian economy (see Figure 6). It affects the economy in two important ways. First, it introduces a balance sheet channel to monetary transmission, which lessens the magnitude of the effect of an interest rate change on real domestic demand. For example, a higher policy rate holds back demand via the usual intertemporal substitution channel. On the other hand, the associated appreciation of the currency lowers the value of the foreign currency debt and decreases the debt service of households in domestic currency terms. Second, because of the currency mismatches in both household and corporate balance sheets, depreciations of the domestic currency increase the risk of widespread solvency problems and thus pose a threat to the banking system. Therefore, the central bank has a strong distaste for excessive currency depreciation not only because of the inflationary consequences but also because of the potential problems in the banking sector.

3.2 MODEL EQUATIONS

The MPM is a so-called gap model, where gap variables represent deviations from equilibrium trends. The modelling strategy is to construct a trend-cycle decomposition for the real variables in the system, and level variables are thus defined as the sum of the gap and trend variables (i.e. for any real variable $x = \widehat{x} + \overline{x}$, where $\widehat{x}$ denotes the gap and $\overline{x}$ denotes the trend part). It is important to note that all variables are in logarithmic terms. Cyclical components are thus assumed to be multiplicative and expressed as a percentage of the trend. In practice gap-trend decompositions are derived from Kalman filters in order to capture the degree of inflationary pressure coming from the real economy.[9]

[9] For an overview of MNB's output gap estimation see Tóth (2013).

It should be noted that behavioural equations of the model are expressed in terms of the real gap variables, while trend variables purely serve to calculate levels and growth rates. In other words, the core model abstracts from supply-side issues, long-term developments and issues about the equilibrium level of the real exchange rate and interest rates. In the following, we concentrate on the gap model and disregard the equations describing trend developments as well as the identities linking gap and trend variables.

More on the notation: t will denote time, which is taken to be quarters; Δ denotes annualised quarter-on-quarter changes; $\Delta 4$ denotes year-on-year changes; $\mathbb{E}$ is the expectation operator at time t; variables starting with ε denote IID exogenous shocks. Variables marked by a tilde ($\sim$) are defined as a deviation from their equilibrium values (targets). Exact parameter values are listed in the appendix.

3.2.1 Monetary policy

Monetary policy is represented by a Taylor-type rule with various targets and a smoothing motive. In particular, equation (1) determines the short-run nominal interest rate as a function of its lagged value, the natural (trend) rate of interest ($\overline{R}_t$), the expected deviation of year-on-year CPI inflation from its target (net of indirect taxes) four periods ahead ($\mathbb{E}(\widetilde{\Delta 4P_{t+4}})$) and the output gap ($\widehat{Y}_t$). The natural rate of interest ($\overline{R}_t$) is defined as the sum of the trend real interest rate ($\overline{RR}_t$) and the inflation target ($TARG$).[10] The reason for including a forward-looking inflation term into the rule is to avoid excess output volatility by ignoring short-term, transitory inflationary shocks. Through the output gap, the central bank's policy also directly keeps track of developments in economic activity (known as flexible inflation targeting). In addition, monetary policy also reacts to the cyclical component of the risk premium in the model. Both the private and the public sectors have accumulated a large share of foreign currency-denominated debt in Hungary. For this reason, nominal exchange rate changes have a direct and significant effect not only on inflation but also on the real economy. Financial stability concerns have come to the fore as risk premium movements become volatile during the crisis. Consequently, the currency mismatch in the economy justifies a policy rule described below (see also Section 6 on the modification of the monetary policy reaction function).

$$R_t = \delta_1 R_{t-1} + (1-\delta_1)[\overline{R}_t + \delta_2 \mathbb{E}\left(\widetilde{\Delta 4P_{t+4}}\right) + \delta_3 \widehat{Y}_t + \delta_4 1_{\widehat{PREM}_t>0}\widehat{PREM}_t] + \varepsilon_{R,t} \tag{1}$$

The term $\widehat{PREM}_t$ is the cyclical component of the risk premium on Hungarian assets. Similarly to the real interest rate and the real exchange rate, the risk premium is also decomposed into trend and gap components. The trend part of the risk premium reflects the slowly decreasing but highly persistent extra riskiness associated with Hungarian assets relative to their euro area counterparts, the cyclical or gap component is designed to capture short-run transitory shifts in investor preferences. Transitory shifts in the perceived riskiness of the country may have direct and abrupt consequences for nominal exchange rate movements. Particularly, if there is a transitory upward movement in the risk premium on Hungarian assets, and hence a flight out of the Hungarian currency, the central bank can attenuate the impact on the currency by raising the interest rate. The indicator function $1_{\widehat{PREM}_t>0}$ introduces some nonlinearity in the sense that the nominal interest rate only reacts to positive premium gaps (i.e. sudden currency depreciations) and not to negative ones. For an illustration of how the rule functioned in practice during the turbulent 2011 period see Section 4.

3.2.2 Domestic prices and inflation

Given the objective of inflation targeting, the key variable in the model is the consumer price index (CPI) or, more precisely, its fluctuations and dynamics over time. Formally, headline inflation (ΔP_t) is divided into core (ΔPC_t) and non-core (ΔPNC_t), while the latter is further decomposed into market-priced and regulated items (as shown below). Both the core and non-core measures of inflation are calculated net of indirect taxes, so the effect of changes in indirect taxes (ΔPT_t) appears as an exogenous additive term in equation (2):

$$\Delta P_t = \lambda_1 \Delta PC_t + (1-\lambda_1)\Delta PNC_t + \Delta PT_t \tag{2}$$

In the equation λ_1 is the weight of core items in the overall CPI basket.

[10] The trend real interest rate is equal to the world natural interest rate adjusted by the trend real appreciation and the permanent component of the risk premium.

Core inflation

The evolution of core prices is determined by a hybrid new-Keynesian Phillips curve (equation 3) in which the lagged term ($\beta_1 \Delta PC_{t-1}$) could be interpreted as capturing the effects of frictions in price setting, direct and indirect indexation to past inflation or the proportion of price setters who base their expectations of future inflation on past actual inflation. The lead term, on the other hand, reflects the fact that today's pricing decisions are also influenced by agents' expectations of future inflation. Analogously to the lagged term, the lead term relates to the proportion of price setters who base their expectations on model-consistent estimates of future inflation.

$$\widetilde{\Delta PC_t} = \beta_1 \widetilde{\Delta PC_{t-1}} + (1-\beta_1)\mathbb{E}\widetilde{\Delta PC_{t+1}} + \beta_2 \left(\widehat{\beta_3 C_t} + \beta_4 \widehat{Z}_{t-1} + \beta_5 \widehat{G}_t\right) + \beta_6 \widetilde{\Delta PMNC_{t-1}} + \varepsilon_{\Delta PC,t} \quad (3)$$

Additionally, the core inflation process includes demand pressure terms (cyclical components of private consumption) and the real exchange rate gap ($\widehat{Z}_t$) (the cyclical component of the CPI-based real exchange rate Z_t) to link core inflation to the real side of the economy. Hungarian experience with regular fiscal adjustments justifies the inclusion of the cyclical component of government expenditure. Core inflation also responds to cyclical increases in market-priced non-core inflation ($\widetilde{\Delta PMNC_{t-1}}$). This term reflects the fact that cost-push shocks (i.e., cyclical increases in commodity prices) have an impact on core inflation as well.

Non-core inflation

As formulated in equation (4), non-core inflation itself is a convex combination of market-priced items, such as unprocessed food and market energy ($PMNC_t$), and regulated prices ($PRNC_t$). In this equation, λ_2 denotes the share of market-based items in non-core inflation.

$$\Delta PNC_t = \lambda_2 \Delta PMNC_t + (1-\lambda_2)\Delta PRNC_t \quad (4)$$

Regulated prices are set exogenously by the government, and, as such, are unrelated to economic fundamentals (i.e. demand and cost factors), and are treated as exogenous in the model. Equation (5) shows that the evolution of the market-priced components of non-core inflation (i.e. unprocessed food and market energy, $\Delta PMNC_t$) is purely backward-looking, but also varies with several factors, such as core inflation, the euro denominated price of oil ($\Delta POWEUR_t$) and the rate of nominal depreciation (ΔS_t). As usual in the literature, cost-push factors matter only as far as they differ from their trend. To put it differently, it is only the cyclical component of real marginal costs that appears in the new-Keynesian Phillips curve.

$$\widetilde{\Delta PMNC_t} = \omega_1 \widetilde{\Delta PMNC_{t-1}} + \omega_2 \widetilde{\Delta PC_{t-1}} + \omega_3(\widetilde{\Delta POWEUR_t} + \widetilde{\Delta S_t}) + \varepsilon_{\Delta PME,t} \quad (5)$$

It is important to note that nominal exchange rate movements affect CPI inflation in two different ways. The nominal depreciation term (ΔS_t) in equation (5) captures the direct and immediate pass-through of the exchange rate into imported non-core items with highly flexible prices (i.e. fuel and unprocessed food). The real exchange rate gap term ($\widehat{Z}_t$) in the core Phillips curve, in turn, reflects the indirect pass-through which affects core price movements through the costs of imported production inputs. While the former is designed to capture the bulk of the pass-through occurring in the first two quarters following an exchange rate shock, correcting itself relatively quickly, the latter works through a more slowly-moving variable and captures the long-lasting effects of exchange rate movements.

3.2.3 Real economy

According to the underlying logic of the model, gross domestic product (GDP) is comprised of two parts: potential (trend) output and the cyclical GDP (output gap). The output gap is defined within the model, while potential GDP is exogenous as far as the model is concerned. This is in line with mainstream economics, where monetary policy cannot exert a lasting impact on real economic variables beyond the time horizon of business cycles. Among others, this also implies that price stability and fast-paced economic growth can go hand-in-hand only in a period characterised by vivid potential growth and not when the output gap is predominantly positive.

In the MPM, the output gap is the weighted sum of the cyclical positions of the demand components.

$$\widehat{Y}_t = \zeta_1 \widehat{C}_t + \zeta_2 \widehat{I}_t + \zeta_3 \widehat{X}_t - \zeta_4 \widehat{M}_t + (1 - \zeta_1 - \zeta_2 - \zeta_3 + \zeta_4)\widehat{G}_t \tag{6}$$

where $\widehat{Y}$ is the output gap, $\widehat{C}, \widehat{I}, \widehat{X}, \widehat{M}, \widehat{G}$ are the gap components of private consumption, investment, exports, imports and government spending, respectively. Parameters $\zeta_1, \zeta_2, \zeta_3, \zeta_4$ represent nominal expenditure shares. Thus, equation (6) above represents the GDP identity in terms of gap components. In the following, we will elaborate on the components of the output gap and demonstrate equations describing the behaviour of cyclical positions of final household consumption, private investment, export demand and total imports. The extent to which government spending deviates from trends ($\widehat{G}_t$) is defined as the weighted aggregate of cyclical components in final government consumption and government investment. The cyclical component of government spending is exogenous to the model and is set for the forecast horizon on the basis of expert knowledge. It should be noted that in the current setup we ignore issues of fiscal solvency or long-term fiscal sustainability. These issues, while highly important in the Hungarian case, are treated judgmentally at this stage.

Private consumption

Equation (7) is the consumption Euler equation, which governs the intertemporal substitution between consumption today and consumption in the future. According to this equation, the consumption gap ($\widehat{C}_t$) is determined by various factors. The first one is past consumption and reflects habit formation. The second one is the expectation of the future consumption gap ($\mathbb{E}\widehat{C}_{t+1}$). The third one is the real interest rate gap ($\widehat{RR}_t$), which is negatively related to the consumption gap. However, the effective interest rate level determining economic agents' savings decision can be quite different from that defined by monetary policy due to supply side effects (see also section 4.1.1). Credit conditions for households (CCH_t) are defined here as a simple spread (i.e. the difference between the interest rate on household loans and the policy rate) which is exogenous.[11] Consequently, in the absence of stochastic shocks, the cyclical component of household credit conditions returns to zero. It should be noted that non-price information on the supply side of the credit market have to be treated judgmentally. $\widehat{Y}$ represents the income position of households. In addition, households' income is also directly affected by movements in the real exchange rate gap ($\widehat{Z}_t$) because of the significant foreign currency-denominated debts (i.e. balance sheet effects). A temporary real exchange rate depreciation will drive up nominal debt service in domestic currency and thus decrease current disposable income. The last factor affecting the consumption gap is the stochastic shock $\varepsilon_{C,t}$, which summarises exogenous disturbances such as preference shifts.

$$\widehat{C}_t = \alpha_1 \widehat{C}_{t-1} + (1 - \alpha_1)\mathbb{E}\widehat{C}_{t+1} - \alpha_2 \widehat{RR}_t - \alpha_3 CCH_t + \alpha_4 \widehat{Y}_{t-1} - \alpha_5 \widehat{C}_t - \alpha_6 \widehat{Z}_t + \varepsilon_{C,t} \tag{7}$$

The first part of equation (7) above is a kind of Euler equation. The second half extends the equation with an 'adjustment cost' motive. It reflects the fact that absent real rigidities (adjustment costs) consumption would jump to an 'optimal level' which is assumed to be proportional to real disposable income. It is important to note that all behavioural equations describing the real economy are analogous, and thus the general functional form (the so-called Phillips curve type specification) reflects adjustment costs in all demand components.

[11] Currently we are working on endogenising the behaviour of credit conditions by creating a bank lending tightness indicator based on bank lending survey's information.

Private investment

The evolution of the investment gap ($\widehat{I}_t$) is described by an Euler equation (equation 8). Amounting to one-third of domestic demand, this category represents the weighted aggregate level of cyclical positions of retail and corporate investments. The backward-looking element in this equation implies that prospective adaptation is not possible immediately due to adjustment costs. From both an empirical and theoretical perspective, expectations and forward-looking behaviours play a particularly important role when investment decisions are made. Moreover, changes in the cyclical position of private investment are defined by the cyclical position of aggregate demand ($\widehat{Y}_t$) reflecting the liquidity constraints faced by corporate agents of the economy and the alternative cost of capital (Q), the latter being a kind of Tobin's Q measure.

$$\widehat{I}_t = \psi_1 \widehat{I}_{t-1} + (1-\psi_1)\mathbb{E}\widehat{I}_{t+1} + \psi_2 Q_t + \psi_3\left(\widehat{Y}_t - \widehat{I}_t\right) + \varepsilon_{I,t} \tag{8}$$

The real value of capital (Q_t in equation 9) is a forward-looking variable as it is an increasing function of expected future demand ($\mathbb{E}\widehat{C}_{t+1}$). In addition, an increase (decrease) in the real interest rate makes postponement (advance implementation) of an investment project more attractive to companies. The tightness of the loan market is indicated by the conditions on corporate lending (CCC_t) as a type of credit spread. Finally, we also accounted for the crowding-out effect of government investment.

$$Q_t = \xi_1 Q_{t+1} + \xi_2 \mathbb{E}\widehat{C}_{t+1} - \xi_3 \widehat{RR}_t - \xi_4 CCC_t - \xi_5 \widehat{G}_t \tag{9}$$

Exports and imports

As can be seen in equation (10), the exports gap ($\widehat{X}_t$) is determined by a backward-looking element (which reflects the effect of adjustment costs), expected exports as well as the cyclical position of the key determinants: external demand ($\widehat{YW}_t$) and the cyclical component of the real exchange rate ($\widehat{Z}_t$), the competitive price of domestic products. Exports are also affected by an exogenous shock ($\varepsilon_{X,t}$), which captures the non-systematic behaviours of exports.

$$\widehat{X}_t = \theta_1 \widehat{X}_{t-1} + (1-\theta_1)\mathbb{E}\widehat{X}_{t+1} + \theta_2 \widehat{YW}_t - \theta_3 \widehat{X}_t + \theta_4 \widehat{Z}_t + \varepsilon_{X,t} \tag{10}$$

The difference term $\theta_2 \widehat{YW}_t - \theta_3 \widehat{X}_t$ is the approximation of the inverse of the market share of Hungarian exports and guarantees that if foreign demand increases more than exports, then exports will adjust in an attempt to keep the market share constant.

In equation (11), the total import gap ($\widehat{M}_t$) is decomposed according to the import content of the demand components. Thus the total import gap equals the sum of the cyclical position of imported consumption, investment, exports and government spending (consumption and investment). While imported consumption is thought to be heavily influenced by the expenditure switching motive, the imported part of other demand components are governed more by shifts in total expenditures. The reason behind this formulation is that consumption goods are thought to be more substitutable for imported goods (and thus more affected by relative price changes) than investment goods.

$$\widehat{M}_t = \kappa_1\left(\gamma_1 \widehat{C}_t - \gamma_2 \widehat{Z}_t\right) + \kappa_2 \widehat{I}_t + \kappa_3 \widehat{G}_t + (1-\kappa_1-\kappa_2-\kappa_3)\widehat{X}_t + \varepsilon_{M,t} \tag{11}$$

3.2.4 Exchange rate and financial variables

The dynamics of the nominal exchange rate (12) is described by a modified uncovered interest parity condition, a so-called hybrid UIP. The modification is necessary because, on the one hand, very few empirical results confirm a pure UIP context and, on the other, high nominal exchange rate volatility would make the forecast volatile as well. The equation deviates from the classic UIP in that today's nominal exchange rate (S_t) is defined not only by exchange rate expectations ($\mathbb{E}S_{t+1}$), interest rate differentials ($RW_t - R_t$) and the risk premium ($PREM_t$), but also by past exchange rate movements (S_{t-1}). As the steady state growth of the exchange rate is assumed to be zero, technically, the exchange rate is the weighted average of a "classical" UIP and a random walk.[12] The exchange rate also adjusts to exogenous fluctuations in the shock $\varepsilon_{S,t}$.

[12] Adolfson et al. (2008) argue that this model has an empirical advantage compared with the standard UIP specification.

$$S_t = \eta \left(\mathbb{E}S_{t+1} - \frac{R_t - RW_t - PREM_t}{4} \right) + (1 - \eta) S_{t-1} + \varepsilon_{S,t} \tag{12}$$

The parameter η is responsible for introducing persistence into the nominal exchange rate process. When η is equal to one, then equation (12) becomes the usual uncovered interest parity condition. It is important to note that the risk premium on Hungarian assets ($PREM_t$) is an important determinant of nominal exchange rate movements.

3.2.5 The rest of the world

Hungary, being a small, open, export-oriented economy, is prone to shocks coming from abroad. The country's foreign relations are strongly concentrated on the euro area with Germany, Austria and Italy being its main trade partners. For this reason, there is a small, but internally consistent block within the MPM describing the most important mechanisms of the euro area economy. There are endogenous behavioural equations for the euro area output gap (foreign demand) and inflation. A simple Taylor rule is also included to model the interest rate decisions of the ECB.

Equation (13) is an IS curve in which today's foreign demand gap ($\widehat{YW}_t$) depends on its past value, expectation of future demand, the real interest rate gap, which is the difference between the rest of the world real interest rate (RRW_t) and its trend ($\overline{RRW}_t$), and a shock ($\varepsilon_{YW,t}$).

$$\widehat{YW}_t = \varphi_1 \widehat{YW}_{t-1} + (1 - \varphi_1) \mathbb{E}\widehat{YW}_{t+1} - \varphi_2 \widehat{RRW}_t + \varepsilon_{YW,t} \tag{13}$$

Equation (14) is a hybrid new-Keynesian Phillips curve for foreign inflation (ΔPW_t) with an element capturing the demand pressures or foreign marginal costs ($\widehat{YW}_t$), as well as cyclical changes in oil prices ($\Delta\widetilde{POWEUR}_t$). It should be noted that in the long run (steady state), world oil prices are assumed to grow by an annualised quarterly rate of Δpow percent. As usual in the literature, cost-push factors matter only to the extent that they differ from their trend. To put differently, it is only the cyclical component of real marginal costs that appears in the Phillips curve.

$$\Delta PW_t = \varphi_3 \Delta PW_{t-1} + (1 - \varphi_3) \mathbb{E}\Delta PW_{t+1} + \varphi_4 \widehat{YW}_{t+1} + \varphi_5 \Delta\widetilde{POWEUR}_t + \varepsilon_{\Delta PW,t} \tag{14}$$

Equation (15) is a Taylor rule for the rest of the world, in which the foreign nominal interest rate (RW_t) depends on its lagged value, the deviation of annual foreign inflation from its target ($\widetilde{\Delta 4PW}_t$), the foreign output gap and a shock ($\varepsilon_{RW,t}$).

$$RW_t = \varphi_6 RW_{t-1} + (1 - \varphi_6) \left(\overline{RW}_t + \varphi_7 \widetilde{\Delta 4PW}_{t+3} + \varphi_8 \widehat{YW}_t \right) + \varepsilon_{RW,t} \tag{15}$$

where $\overline{RW}_t$ is the foreign natural rate of interest.

In the forecast exercise, based on information coming from international surveys of economic forecasts (Consensus Economics) and money markets, we exogenise foreign block variables on the horizon relevant for monetary policy. Model features only play a role in simulation exercises.

4 Parametrisation

Today, the most popular way of parameterising a rational expectations model is estimation. In this process, the model is fitted to historical data, typically through a criterion such as the likelihood function. Minimising the distance between the model predictions and the data is particularly useful if the model is to be used for forecasting purposes.

As an initial step, though, the MNB has chosen a calibration approach to parameterizing MPM. Calibration was designed to reflect the stylised facts about the Hungarian economy and particularly the systematic dynamic linkages among the main macro variables. To a large extent, parameters were also chosen in a way that the MPM delivers reasonable simulation properties, similar to the ones established by other central banks. Nevertheless, the success of a policy model also depends whether it is efficacious in projection exercises. For this reason, we examine the policy advices the model would have brought about in the past to strengthen the credibility of the model and prove that it can be a useful tool both in the projection and the monetary policy decision support process.

In the next step, following An and Schorfheide (2007) we evaluate the calibrated MPM based on Bayesian model checking. Our motivation behind the exercise is to verify our knowledge about the structural parameters in Hungary during the IT regime as well as to establish credibility of the model in policy-making by proving its time series fit. Here, it should be emphasised that even when estimation takes over as the main empirical strategy, some parameters will still be calibrated or fixed prior to estimation. This is either because of existing good knowledge about their value (e.g. long–run ratios) or because the data and/or the estimation procedure does not provide enough information to uniquely identify some parameters.

4.1 CALIBRATION

4.1.1 Monetary transmission

Calibration was designed to reflect the stylised facts about the Hungarian economy and particularly the systematic dynamic linkages among the main macro variables. First, we identified the main parameters of the model that govern the most important channels of the monetary transmission mechanism, and calibrated their values to match existing empirical evidence from other structural tools (i.e. SVAR and DSGE models).[13] This way, we had a relatively solid view about how monetary policy affects the most important macro variables in the model. Finally, when it came to designing the MPM, we kept in sight that a policy model also has to satisfy certain normative properties.

At the beginning, we focused on the key parameters of the model such as the strength of the interest rate channel in the Euler-equations or the sensitivity of the core inflation to the cyclical position of the real economy in the Phillips-curve. Although it sounds straightforward, the calibration exercise was far from trivial. The forward-looking terms in and the interactions among the equations make a direct comparison of coefficient values infeasible. Rather, we checked the empirical fit of the MPM via impulse response matching.

In what follows, we demonstrate where the MPM stands among the reference models regarding the sensitivity of CPI to monetary tightening. Figure 7 shows the CPI impulse responses of a policy rate hike compared to selected models of the MNB and the ECB. The effect of a monetary tightening is larger than that of the MNB's DSGE model, PUSKAS but smaller than that of the existing macroeconometric models and is in line with models designed for the Euro Area. The immediate effect is quite similar among the models probably due to the high exchange rate sensitivity of the non–core inflation while in the second and third years the MPM is more closer to the Euro Area simulations.

[13] Most of the original impulse response functions are presented in the model documentations of PUSKAS (see Jakab et al. (2008)), the NEM (see Benk et al. (2006)) and DELPHI (see Horvath et al. (2010)).

Figure 7
CPI effect of monetary tightening

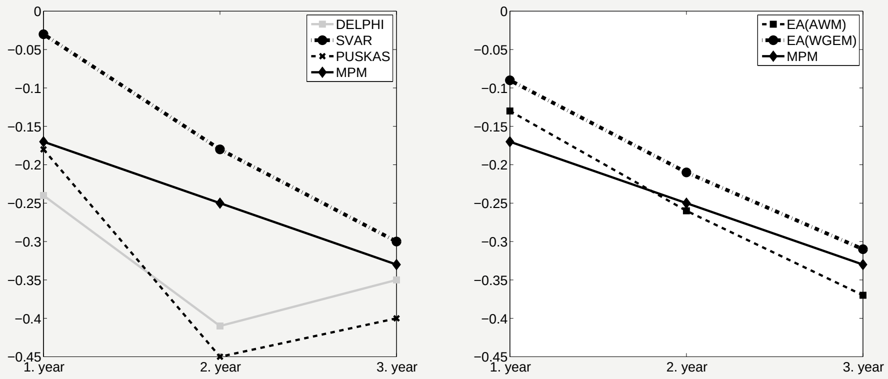
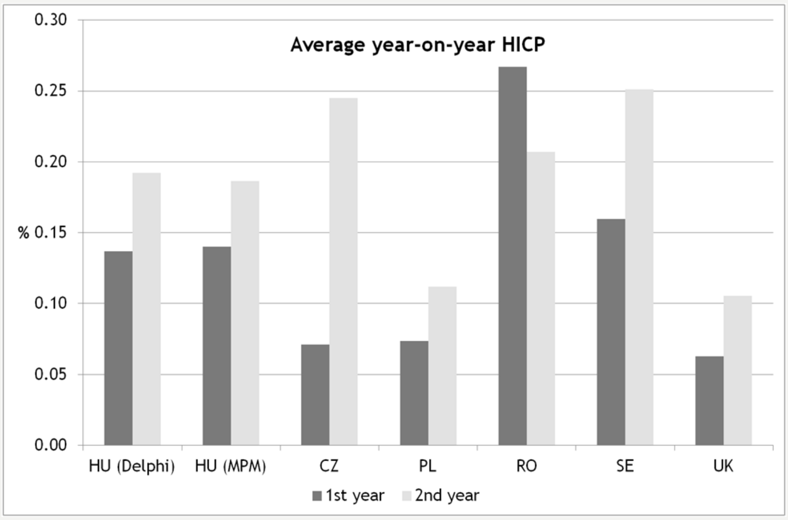


Figure 8 shows the size of the exchange rate pass-through into total CPI in selected European countries in case of a persistent exchange rate depreciation on the policy horizon [14]. The first year's effect is one of the highest among the examined Central and Eastern European countries but is well within the range if Sweden and the UK are also taken into account. In the second year, Hungary is below the average of the investigated countries resulting in a similar overall effect.

Figure 8
Exchange rate pass-through to CPI (year-on-year)



4.1.2 Normative properties

Regarding the calibration of the monetary policy reaction function, our purpose was to find a rule that meets two criteria. First, in case inflation deviates from the target the reaction of monetary policy should be aggressive enough to bring it back to the target on the policy horizon. Second, if monetary policy faces a trade-off between inflation and output gap stabilization (e.g. when the economy is hit by a cost-push shock), the policy rule should provide a reasonable trade-off between these two objectives. There is a wide range of policy rules that meets the first criterion. Therefore, we used the second one to fine tune the parameter values.

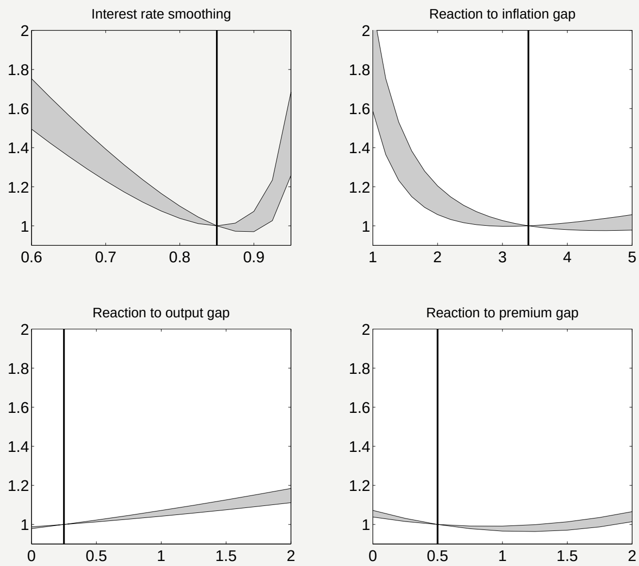
[14] Results based on data provided by the Working Group on Forecasting of the ECB.

In particular, we looked at two exercises. First, starting from the calibrated monetary policy rule we changed the parameter values one by one and simulated the model using the estimated variances of the shocks and evaluated the outcome by different loss functions.[15] We found that the calibrated policy rule performed well in minimizing a reasonable range of loss functions (see Figure 9)[16].

Second, we turned to the question how real economy considerations should be incorporated into the reaction function. The importance of this question is given by the fact that in certain cases inflation and output stabilization call for different monetary policy reactions. Therefore, real economy considerations usually appear explicitly in the policy function. An obvious way of inclusion would be if monetary policy reacted to the evolution of the output gap directly. In Figure 10, increasing the parameter of the output gap reaction δ_3 in Equation (1) results in moving from bottom-right to top-left on the stars, i.e. the volatility of output lessens but at the cost of higher inflation volatility.

On the other hand, there are several ways to take real economy considerations into account indirectly. We examine three of such solutions. First, certain one-off effects (e.g. VAT changes) can be filtered out of the price index and only this narrowly defined inflation enters the rule. Second, some component of the inflation that co-moves better with the output gap (e.g. core inflation) can get a higher weight relative to the other components of inflation. In Figure 10, increasing the weight attached to core inflation opposed to non-core inflation results in moving from bottom-right to top-left on the diamonds. Hence, putting more the weight on the more demand-sensitive component of inflation can decrease the volatility of output without significantly destabilizing inflation. Finally, monetary policy can react to inflation in a forward-looking manner, as the medium term outlook is more determined by excess demand conditions. In Figure 10, increasing the forward-looking nature of the inflation reaction results in moving from bottom-right to top-left on the circles. It seems that in the case of Hungary the forward looking inflation reaction provides the most favorable trade-off between the different monetary policy objectives.

Figure 9
The effect of different parameter values in the policy rule on the loss function



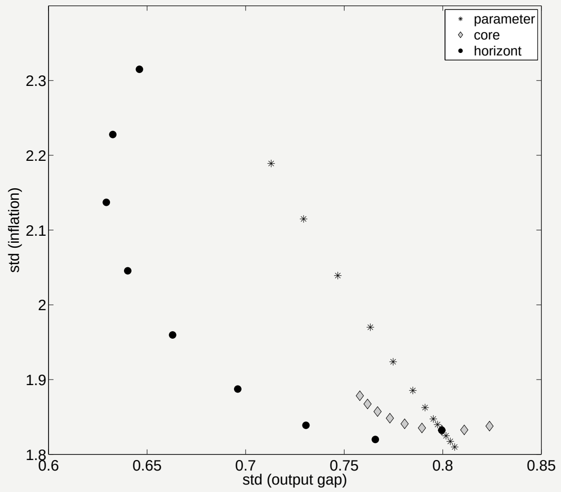
[15] Loss functions take the general form of:

$$L = w_1 var(\widetilde{\Delta 4P}) + w_2 var(\widehat{Y}) + w_3 var(\Delta R) \qquad (16)$$

In the first specification we put higher weight on inflation compared to the output gap. Then we consider loss functions with higher and lower weight on the output gap, and finally we add the variance of the exchange rate as well.

[16] The loss functions are standardized to one at the baseline parameter values. The vertical lines mark the baseline parameter values.

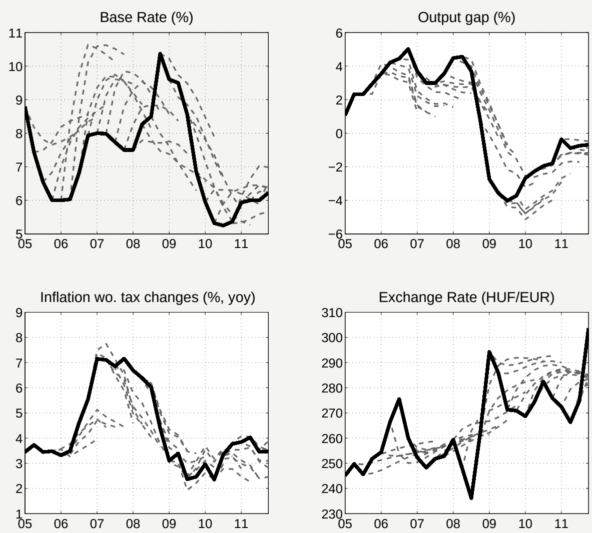
Figure 10
Volatility of output and inflation with different policy rules



4.1.3 Historical projection exercise

The next step in the empirical validation process is to check whether the MPM would have given reasonable projections and policy advices in the past. To sum up, from 2005 to 2011, the projected paths of the most important macro variables are in line with the data and deviations can typically be explained by the different monetary policy reactions, i.e. by the difference in the projected and actual paths of the monetary policy rate. As the inflation target was typically missed during the examination period, the MPM suggests a more restrictive monetary policy in comparison with what has been realised almost over the entire horizon. Consequently, we see a relatively larger decline in output and relatively lower inflation in the simulations.

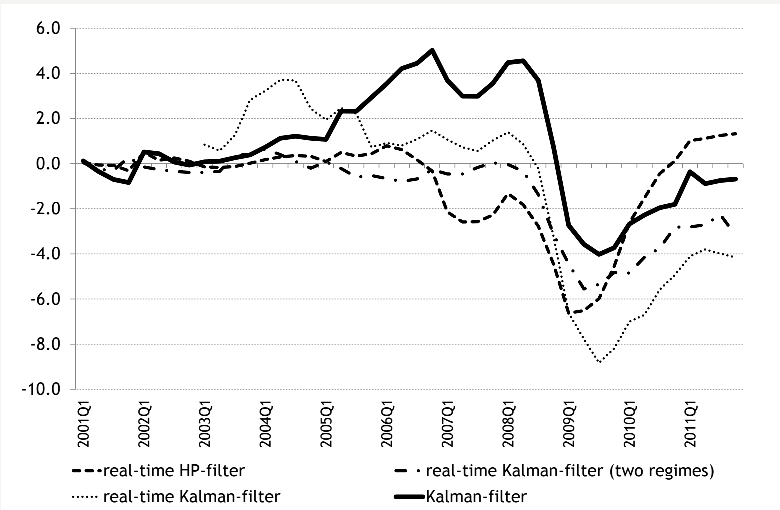
Figure 11
MPM projections on vintage data (2005-2011)



The main results are presented in Figure 11 using so-called worm charts, where one can see the respective projections of each quarter as well as our current knowledge about the variables. In the following, we will examine a few highlighted periods and quantify the effect of the simulated interest rate paths on the inflation path. In the exercise we mimicked our current projection practice in exogenising foreign variables (foreign demand, world interest rate and inflation), regulated prices, the indirect tax effect of CPI and the trends of financial variables on the entire policy horizon (eight quarters). For these variables we imposed the currently known values, while we used the vintage database in imposing oil futures as an assumption. All other variables were only fixed as initial conditions, including the estimated risk premium.

We will examine two periods in detail, namely the year 2006 and the period 2007–2008 when monetary policy arrived at a turning point and argue that the MPM would have given the right advice in these situations. Ex post it turned out that in 2006, monetary policy faced an increasingly positive output gap reflecting a primarily better disposable income situation of households as a result of fiscal loosening and lax credit conditions. In addition, on the policy horizon regulated price increases peaked at an annual 32% in 2007. According to the simulations, forward-looking monetary policy would have begun monetary tightening earlier than actually did. The resulting appreciation of the exchange rate and the decline in output would have delivered an inflation rate closer to the target.[17] From the perspective of the model, one of the possible reasons for the relatively late start of the tightening cycle was that the actual view of the output gap differed from our current knowledge. Monetary policy makers assumed a close to zero or even slightly negative output gap and hence a much lower inflationary pressure coming from the real economy. Figure 12 shows the output gap derived from real-time Kalman filters as well as the conventional HP-filter compared with our current knowledge. Moreover, the two real-time Kalman filters differ in the number of regimes assumed. The two-regime filter assumes that different mechanisms worked before the outbreak of the 2008 financial crisis.

Figure 12
Output gap estimates



[17] We would obtain a higher policy rate as well if the historical average of administered price increases were assumed on the projection horizon instead of the actual ones.

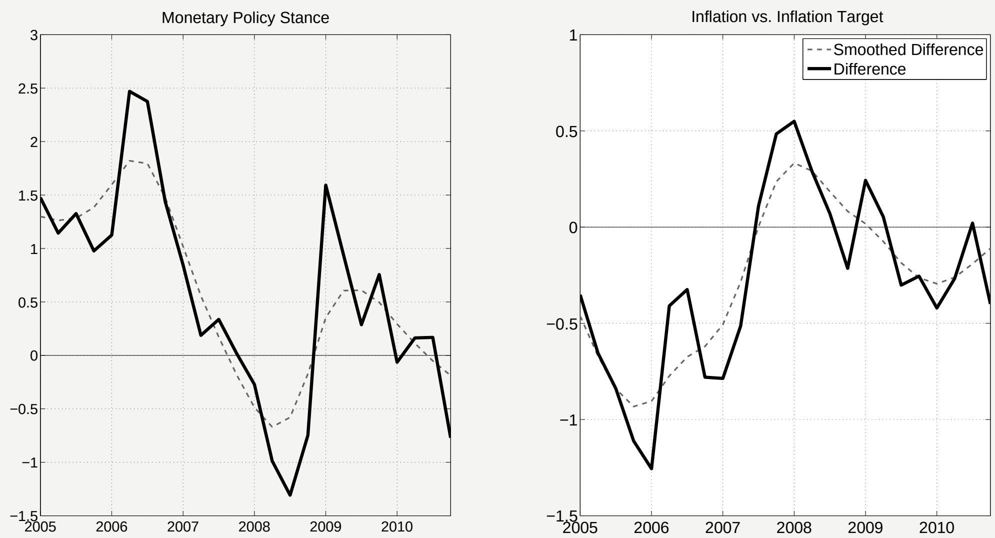
Although a two-year long disinflation period started in 2007, inflation remained well above target until the end of 2009. The main reasons behind sluggish inflation were increasing oil prices and the peak in food prices in 2007. Nevertheless, there was a temporary decline in output during the period, with the domestic demand gap remaining positive until the very start of the financial crisis. In this situation, forward-looking monetary policy would have increased interest rates to dampen the second-round effects of cost-push shocks. In reality, the extent of the historically severe food price shock, the fact that monetary policy makers still believed in a negative output gap (see Figure 12) and the existence of the exchange rate band until 2008 hindered the start of the tightening cycle.

By contrast, tighter monetary conditions would have led to a stronger exchange rate, lower output and inflation closer to target. This result is in line with Krusper (2012), who found that high inflation during this period cannot be solely explained by the food price shock, and in part it can also be attributed to country-specific factors. In particular, an important factor could have been the evolution of expectations. Gábriel (2010) analysed survey data and documented that households' inflation expectations increased sharply in 2007 and remained high for a prolonged period.

What we can learn from the historical projection exercise is that the volatility of non-core items of CPI (oil, food and administered prices) introduces a large amount of uncertainty into CPI forecasts. In addition, the (mis)measurement of the cyclical position of the real economy is a decisive factor in monetary policy decisions and calls for sophisticated and robust tools to estimate the degree of inflationary pressure coming from the real economy.

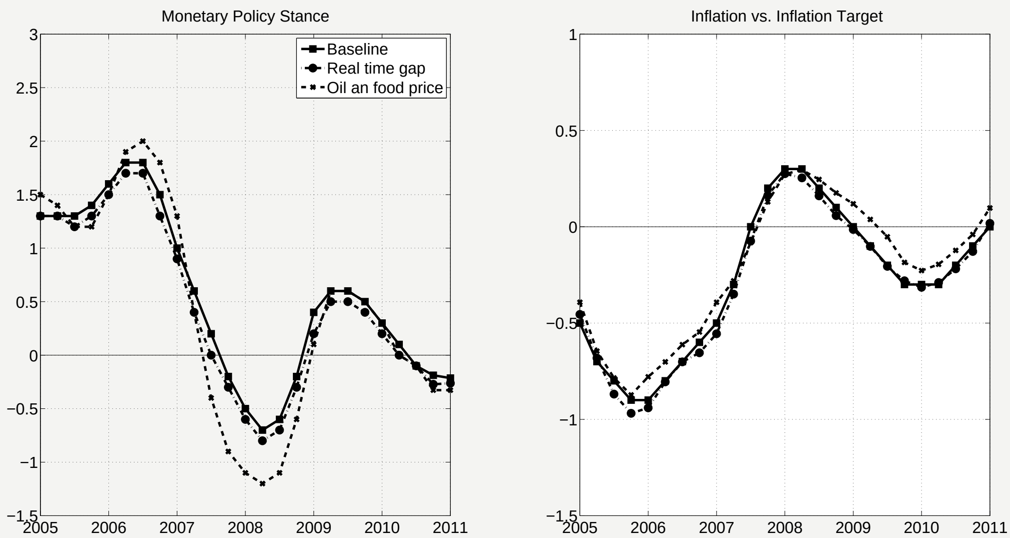
Based on the simulations, we can quantify the extent to which inflation would have been closer to the target as a result of the tighter simulated policy rate. Figure 13 shows that, with the exception of the immediate aftermath of the 2008 financial crisis, the projected interest rate paths would have been above the actually realised policy rates on average. As a result, projected inflation would have been closer to the target by 0.6 percentage points on average prior to the crisis (conditioned on the vintage initial conditions). At first sight, this figure might seem moderate but we have to underline that each projection exercise starts from the actually realised high initial conditions limiting the extent to which inflation can fall during the forecast horizon in response to restrictive monetary policy. In addition, if monetary policy would have acted along its Taylor-rule during the whole examination period, it might have better anchored inflation expectations, again resulting in even lower inflation.

Figure 13
Deviation of the simulated policy rate from actual and deviation of inflation from target



Robustness checks were carried out to examine whether the abovementioned results depend on the initial cyclical position as the real-time output gaps differ significantly from our current knowledge. In addition, we run simulations assuming the actually realized commodity (i.e. oil and food) prices in the simulation. Figure 14 shows that our main message does not change, the MPM would have suggested tighter monetary conditions that would have resulted in an inflation rate closer to target. Nevertheless, it is important to note that the resulting higher than actually realised interest rates would have probably persuaded Hungarian households and firms even more to accumulate debt denominated in foreign currency. Wherefore, without proper macro-prudential regulations, the consequences of the financial crisis might also have been more severe.

Figure 14
Smoothed deviation of the simulated policy rate from actual and deviation of inflation from target under different assumptions



4.2 BAYESIAN ESTIMATION

4.2.1 Data

We collected time series data for the real and nominal variables for the estimation period starting in 2001Q3 – i.e. when the MNB has implemented the inflation targeting regime – until 2012Q3. Time series are typically taken from the database of the Hungarian Central Statistical Office while foreign variables were constructed from Eurostat data. Bank lending rates were derived from the Monetary and Financial Institutions interest rate statistics of the ECB. Import-based foreign demand, the risk premium, disaggregated components and the indirect tax content of the CPI were constructed by MNB experts. For a summary of data series used and their statistical sources, see Table 1 below.

Foreign demand (*YW*) is defined as the weighted import demand of Hungary's trading partners. The measure of the risk premium (*PREM*) is generated by using selected financial market information, namely the zero coupon bond spread,the five-year sovereign CDS spread, the nominal exchange rate, the 5x5 euro spread and the corporate lending spread. In order to condense the information content of these data, the first component is extracted from these time series by factor analysis to capture the dynamics of the risk premium. As the first factor is normalised, it has to be rescaled in the end to obtain a meaningful risk premium time series. An ex ante premium, calculated by using Consensus Economics' exchange rate forecast and forint and euro yields, is used for that purpose. Unfortunately, the information content of certain financial variables is limited for the period before 2003, which restricts our estimation period for 2003 and 2011.

Table 1
Data series used for the Bayesian estimation procedure

Macroeconomic variable	Source
Real economy	
Real GDP (*Y*)	Central Statistical Office
Private consumption (*C*)	Central Statistical Office
Private investment (*I*)	Central Statistical Office
Real export (*X*)	Central Statistical Office
Real import (*M*)	Central Statistical Office
Government expenditure (*G*)	Central Statistical Office
Prices	
CPI (*P*)	Central Statistical Office
Core inflation (*PC*)	Central Statistical Office
Non-core inflation (*PNC*)	Central Statistical Office
Indirect tax effect in CPI (*PT*)	MNB estimation
Target (*TARG*)	MNB
Financial variables	
Domestic interest rate (*R*)	MNB
Nominal exchange rate (*S*)	MNB
Risk premium (*PREM*)	MNB calculation
Credit spreads (*CCH*, *CCC*)	MNB calculation
Rest of the world	
Foreign demand (*YW*)	MNB calculation
World interest rate (*RW*)	ECB
World inflation (*PW*)	Eurostat
Oil prices (*POWEUR*)	Bloomberg

Components of the non-core measure of inflation, that is, market energy (*PMNC*) and regulated prices (*PRNC*) are calculated by MNB experts from disaggregated items based on their weights in the consumption basket. The effect of VAT changes (*PT*) on CPI is estimated using SARIMA models with intervention variables. The procedure is applied at the disaggregated level (i.e. CPI items), estimates of the pass-through are constrained to be between 0 and 1, and results are aggregated to calculate the total effect on CPI. The calculation of the effects of other indirect taxes (e.g. excise taxes) is subject to expert judgement.

Here, the importance of the consumer and corporate credit spread variables has to be emphasised because the effective interest rate level determining economic agents' savings decision turned out to be quite different from that defined by monetary policy due to supply-side effects. In the early 2000s, the average interest rate faced by households was significantly lower than the monetary policy rate, because of the state subsidisation of mortgage loans, which contributed to the overheating of consumption growth. What is more, between 2006 and 2008, the proportion of relatively cheaper foreign currency-denominated loans increased both in the balance sheet of households and companies, resulting in negative effective spreads in the period. During the financial crisis, financial market liquidity fell sharply in the euro area as well as in Hungary. Therefore, the cost of newly issued loans became much higher than the policy rate. For this reason, the effect of the interest rate channel would probably have been underestimated without taking into account the data on credit spreads. For the purpose of the estimation, composite bank lending rates are constructed both for the household and the corporate sectors. Lending rates for different maturities and foreign currency denominations are weighted by the outstanding amount of debt for households and new-business loans in the case of corporations.

The importance of determining the inflationary pressure coming from the real economy is crucial in new-Keynesian models. Gap variables are derived in a consistent way using techniques of estimating latent variables with a Kalman filter.[18] For a model consistent gap-trend decomposition of the financial variables we use a separate small model block. The real interest rate trend is extracted using a Kalman filter based on real uncovered interest rate parity.

[18] The model used at the central bank of Hungary is presented in Tóth (2013).

4.2.2 Estimation procedure

DSGE estimates are overwhelmingly based on the use of a likelihood function, which is the model-implied probability distribution of a set of observables, indexed by a parameter vector. In this sense, estimates of the parameters are obtained by exploiting the full structure of the model.

First, the reduced form solution of the forward looking model is calculated and the model is written in its state space form. Maximum likelihood estimation is used to exploit the equilibrium law of motion that takes the form of a vector autoregressive moving average (VARMA) process. The evaluation of the likelihood function typically requires the use of numerical methods to solve for the equilibrium dynamics and to integrate out unobserved elements from the joint distribution of the model variables (see, for example, An and Schorfheide (2007)). A potential drawback of the ML approach is that identification problems can make it difficult to find the maximum of the likelihood function and render standard large sample approximations to the sampling distribution of the ML estimator and likelihood ratio statistics inaccurate.

A popular alternative to the frequentist ML approach is Bayesian inference. Bayesian analysis is also based on the likelihood but tends to interpret it as a density of the parameters given the data. Bayesian inference necessarily depends on the prior density as it alters the shape of the posterior. On the other hand, the prior allows the researcher to incorporate additional information into the time series analysis, which can help sharpen the inference. The implementation of Bayesian inference typically relies on Markov-chain Monte-Carlo methods that allow for random draws of the model parameters from their posterior distribution. Sample moments computed from these draws provide good approximations to the corresponding population moments of the posterior distribution. We calculate the likelihood function using a Kalman filter.

Prior distributions of the parameters are assumed to follow either normal or beta distribution. The prior means were basically set to the original calibrated values, although for a robustness check we applied alternative prior means as well. The MPM is a semi-structural model where there are no exact, theoretically based bounds of the parameters. For the determination of priors, we use the results of empirical impulse response matching and define relatively tight priors and low standard deviations (for the chosen specification, see the Appendix). In addition, we set reasonable bounds for all parameters (e.g. we restrict persistence parameters to lie between 0 and 1) to avoid instable or non-stationary solutions. We also estimated the standard errors of shocks to the main equations. These prior distributions follow inverse gamma distributions to ensure that estimated values differ from the calibrated only in the case of relatively large shocks. The rest of the model parameters were not estimated but fixed to their calibrated value for one of the following two reasons. Either they are unambiguously determined by the data like weights of the GDP and CPI components or they cannot be well identified such as the balance sheet channel parameter or the degree of hybridness of the UIP.

4.2.3 Estimation results

In this Section, we present the posterior distributions of the core Phillips-curve and the consumption gap equation parameters. In general we found that the estimated parameters were not far from the calibrated values and the comparison of impulse response functions shows no significant differences as well. The results of all estimated parameters and standard errors as well as impulse responses of all shocks are reported in the Appendix. We also present the results of the estimation for the monetary policy reaction function but be aware that the calibrated version is included in the MPM for the reasons underlined in section 4.1.2.

Figure 15 shows the prior and posterior distributions of the Phillips-curve (equation 3) parameters. The estimated parameters determining the core inflation process are the autoregressive parameter (β_1) and the coefficients of the following factors: domestic demand (β_2, β_5) and the pass-through of non-core components, i.e. oil and non-processed food prices into the core (β_6). Estimation results are again close to the calibrated parameter values. Persistence turned out to be somewhat smaller than the calibrated autoregressive parameter. On the other hand, it seems that the effect of the real economy might be somewhat higher than calibrated and also a non-zero effect was identified in the case of the government expenditure gap coefficient. We also obtain a non-zero effect of the delayed pass-through of market priced non-core items into the core [19].

[19] note the 10^{-3} multiplicator in the case of β_6

Figure 15
Prior and posterior distributions of the Phillips-curve parameters

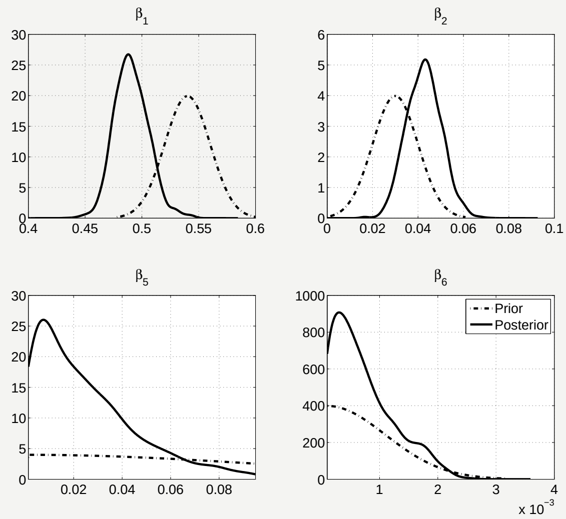


Figure 16 shows the prior and posterior distributions of the consumption gap (equation 7) parameters. The estimated parameters determining the consumption gap are the autoregressive parameter (α_1), the coefficient capturing the effect of monetary policy (α_2), credit conditions (α_3) and disposable income (α_4). With the exception of the parameter representing the income channel, estimated parameters do not differ markedly from calibrated values. The persistence of consumption is somewhat higher than what the initial prior would imply. It should be noted that although the posterior distribution did not differ decidedly from the prior distribution, we could confirm the existence of the interest rate channel in the data. We found that the credit spread data had a key role in the identification of the real interest rate gap parameter. Finally, the effect of the income channel on household consumption turned out to be considerably higher in the estimated posterior distributions compared with the calibrated value. A possible explanation would be that during the crisis liquidity constraints become effective for households and there were no means to counteract the effects of negative income shocks. The precautionary motive might have played a key role in the consumption decision of indebted households.

Figure 16
Prior and posterior distributions of the consumption gap parameters

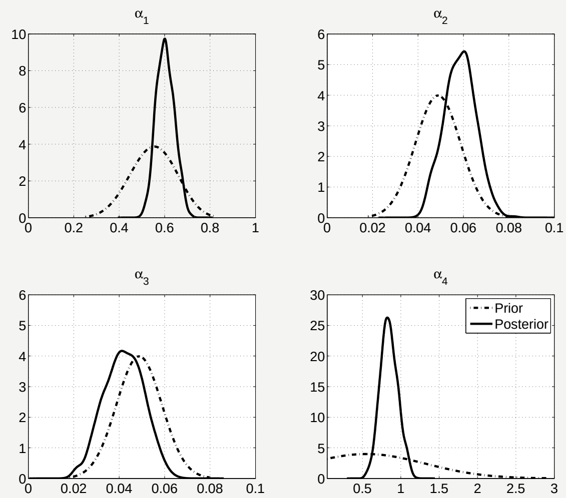


Figure 17 shows the prior and posterior distributions of the monetary policy reaction function (equation 1) parameters. The estimated parameters are the interest rate smoothing parameter (δ_1) and the coefficients of inflation (δ_2), output (δ_3) and financial stability (δ_4) considerations. In general, means of the estimated parameters are close to the original calibrated values. The prior for the interest rate smoothing parameter is assumed to be a beta distribution, hence the estimated mean is slightly below of the calibrated value (0.85). Strictly speaking, the inflation targeting aspect was weaker and the financial stability reaction was slightly stronger than prior means in the sample. On the other hand, there appears some uncertainty regarding the posterior distribution of the output gap parameter. Nevertheless, in case we estimate the parameters using real-time output gaps, the output gap parameter distribution would have one modus as well (see Figure 18) and shows a slightly stronger reaction to output considerations than the calibrated version of the Taylor-rule. In this case, inflation considerations are very close to the calibrated value and reaction to the cyclical component of the risk premium becomes somewhat lower.

Figure 17
Prior and posterior distributions of the monetary policy reaction function parameters

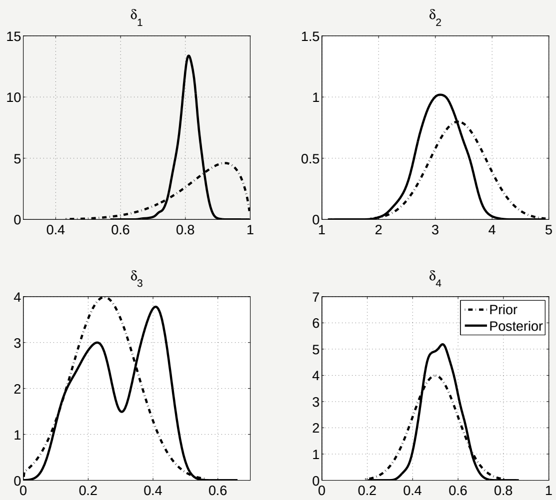
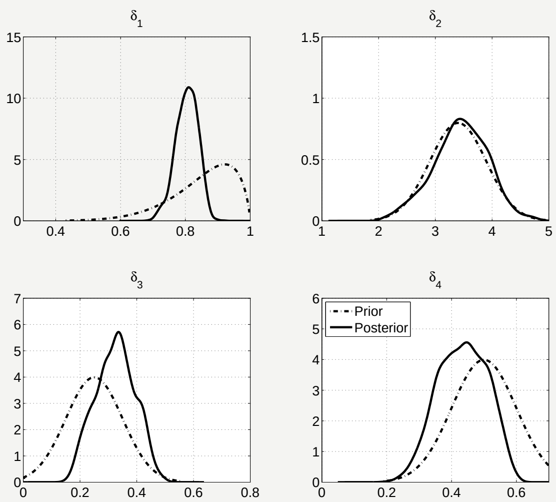


Figure 18
Prior and posterior distributions of the monetary policy reaction function parameters(using real-time output gaps)

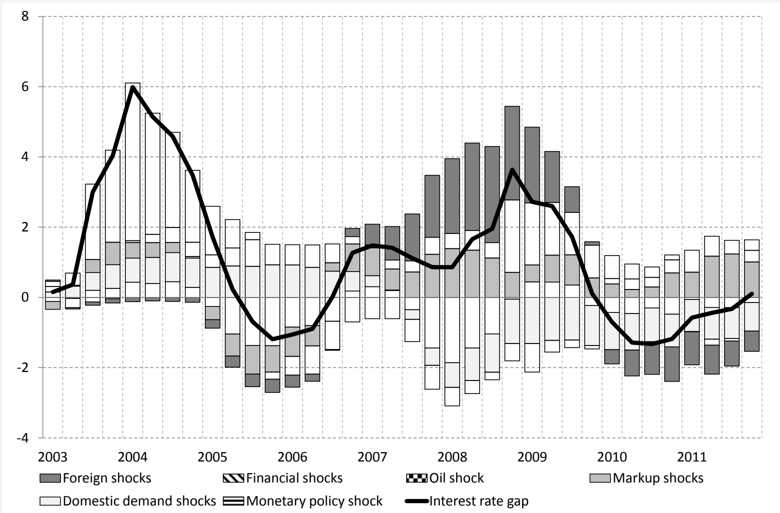


4.2.4 Historical shock decomposition

We use the mean of posterior estimates to carry out the historical decomposition of the monetary policy stance, i.e. the deviation of the policy rate from the natural interest rate. This exercise helps us to identify the role respective shocks played in the change of the monetary stance in particular episodes. We can also get a picture of the relative importance of historical demand and supply shocks in past monetary policy decisions assuming that the MPM is the right model to describe the economy.

The estimated version of the MPM serves as the basis for the historical decomposition. In the shock decomposition, the systematic part of the monetary policy has three main components: demand shocks, supply shocks and exchange rate or risk premium shocks. In Figure 19, demand shocks are decomposed into foreign and domestic demand components, supply shocks are composed of oil and mark-up shocks, while financial shocks are composed of exchange rate shocks.

Figure 19
Historical shock decomposition



The contribution of demand shocks changes abruptly when the financial crisis hits the Hungarian economy. At the end of 2008, the foreign economy was overheated, associated with commodity price shocks that drove up foreign inflation. As foreign output growth slowed and inflationary concerns diminished, the world interest rate started to fall and the contribution of foreign shocks became negative. Prior to the crisis, the contribution of domestic demand to the interest rate gap was positive and it only started to decrease in 2006, as a result of government austerity measures. After the crisis, domestic demand shocks ceteris paribus would have allowed to ease monetary policy conditions as consumption fall dramatically below potential in 2009 and the gap remained negative ever since. With the exception of the 2005-2006 period, supply-side, cost-push shocks (mainly oil and food price shocks) implied restrictive monetary conditions. The contribution of financial shocks (movements in the exchange rate and the risk premium) shows a strong reaction of monetary policy during financial market turbulence.[20]

[20] The risk premium peaked during the 2003-2004 period after the shift of the exchange rate band and also in the aftermath of the 2008 financial crisis.

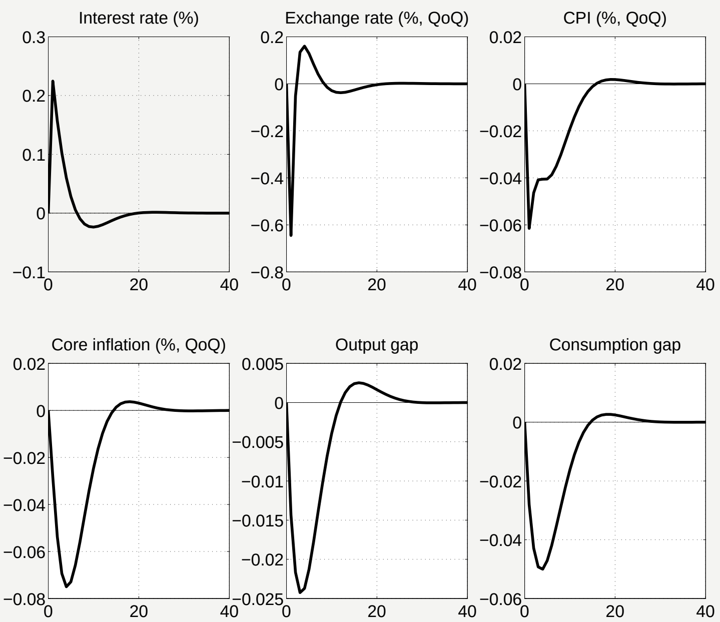
5 Economic implications and properties

With the parameters in hand, the model can be solved for its reduced-form or VAR representation, which in turn can be used for analysing the properties of the model and its economic implications. In this Section, we concentrate on the properties of the estimated MPM in terms of impulse responses to a selected number of shocks. Throughout, we will illustrate the role of monetary policy as a stabilising element, as it provides a nominal anchor in the medium to long run. We also illustrate the advantages of having a forward-looking model for policy analysis through related additional simulation exercises.

5.1 MONETARY POLICY SHOCK

Carare and Popescu (2011) find that in Hungary, monetary policy actions are highly volatile, which is a typical feature in the case of emerging economies. The model confirms this finding: the increase in the policy rate dies out relatively quickly (see Figure 20). The exchange rate appreciates following the monetary policy tightening of 100 basis points by about 2 percent on the impact, which is close to the finding of Carare and Popescu (2011) and Pellényi (2012), but the effect is much weaker than in Vonnák (2005).[21]

Figure 20
Monetary policy shock



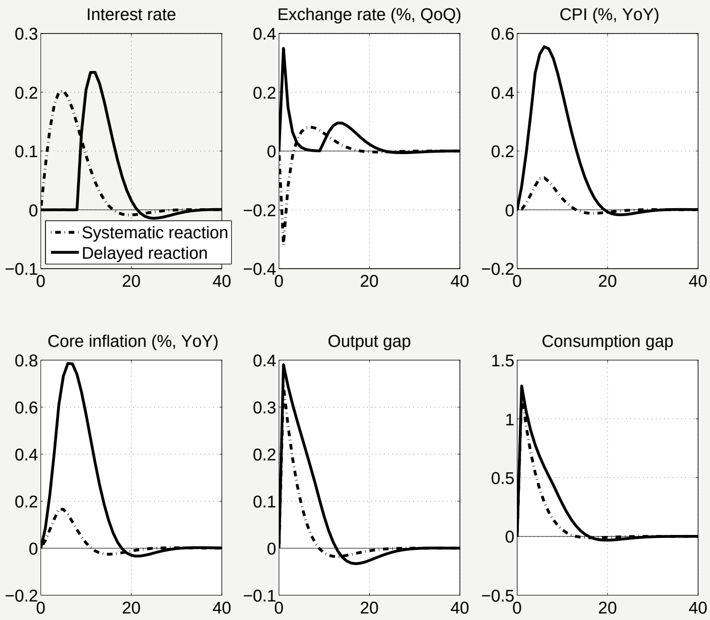
[21] Carare and Popescu (2011) discuss the possible causes for the differences in results. They claim that the main reason is methodological but sample differences also play a role. In terms of methodology, in Vonnák (2005) the monetary shock is much more persistent due to sign restrictions implemented for four quarters. Also, Vonnák (2005) includes the period of the crawling peg regime (between 1995 and 2001) in his sample, while Carare and Popescu do not.

We concur with the previous literature that the transmission of monetary policy shocks to prices is fast and effective, and occurs simultaneously with the decline in output. In the MPM, the disinflation induced by the monetary policy tightening is somewhat weaker than in Vonnák (2005) but slightly stronger than in Carare and Popescu (2011). However, the MPM confirms the consensus finding of all the empirically motivated papers on Hungary (including the two above) that in the very short run the exchange rate effect dominates, i.e. non-core tradable items of the CPI basket (such as fuel and market energy) adjust quickly and sharply. The results also indicate that the decline in economic activity induced by a monetary policy tightening is quite moderate, more so than in advanced economies, and this suggests that disinflation might be relatively less costly in Hungary. An explanation for this finding lies in the balance sheet channel that mitigates the direct impact of the interest rate (i.e. intertemporal substitution) channel. A monetary contraction is followed by an immediate appreciation of the currency, which in turn lowers the interest payments of households indebted in foreign currency.

5.2 POLICY TEST

In Figure 21, we investigate the effect of an unexpected exogenous increase in consumption demand ($\varepsilon_{C,t}$). The shock lasts just one period and is known to all agents in the economy immediately after it occurs. We study its effects under two different assumptions. Under the first assumption, the central bank immediately reacts to the shock while under the second assumption it chooses an anticipated wait-and-see strategy and delays its response for a few quarters, after which the interest rate is again allowed to move to respond to disturbances.

Figure 21
Consumption shock and delayed policy response



The shock that increases the demand for consumption goods immediately puts upward pressure on inflation. Under the first assumption, the central bank steps in immediately to address the inflation issue by raising the interest rate, which in turn triggers an appreciation of the currency. Currency appreciation immediately decreases import prices in domestic currency terms so that the initial total effect (an increase in domestic prices and a decrease in import prices) on inflation is negligible. Eventually, though, persistently higher consumption drives up core prices and passes through to the overall CPI index via the effect of core items on non-core items. Moreover, inflation increases further as the exchange rate depreciates to its new equilibrium level. The interest rate continues to increase to hold down expectations of future inflation and helps to contain core and headline inflation. The main message is that, in the face of a demand shock, monetary policy is highly effective in offsetting inflationary consequences. Monetary policy should raise the nominal interest rate strongly and persistently enough to keep the real interest rate above the steady-state for a prolonged period, thereby restraining demand and keeping overall inflation close to the target.

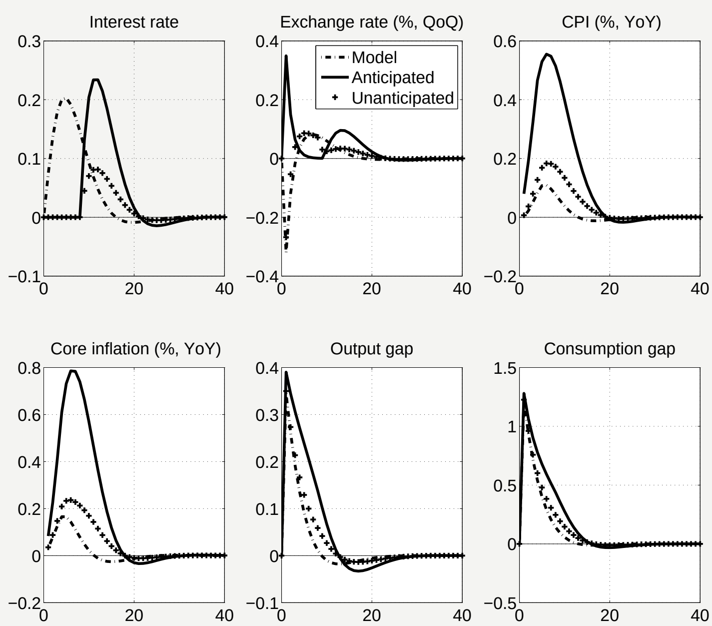
The dynamics of the system is different under the second assumption. When the central bank delays its response to the demand shock, the real interest rate gap remains negative for some time, thereby providing extra stimulus to demand on top of the initial shock. Moreover, the exchange rate depreciates absent the systematic monetary policy reaction, and consequently, forint import prices will rise and increase the initial impact of the shock on domestic inflation. As a result, total inflation jumps and expectations of higher future inflation increase as agents know that the interest rate will not respond before a certain time. Eventually, as the time when the interest rate starts responding draws nearer, expectations of future inflation decrease and current inflation starts falling. When the policy rate finally reacts, the central bank has to do more in the end than it would have done if it had responded immediately to the shock. In the end, the cumulative effect on, and thus the cost in terms of, the output gap, inflation and interest rates becomes relatively stronger.

In this way, the model shows the cost incurred by the economy if monetary policy fails to provide a nominal anchor. It also shows that it makes little sense to keep interest rates fixed in a forward-looking environment. If monetary policy fails to respond quickly to shocks, inflation may simply get out of control.

5.3 ROLE OF EXPECTATIONS

We demonstrate the role of expectations by showing the difference between an anticipated vs. an unanticipated shock. This time we simulate the delayed policy response of the previous section assuming that market participants know in advance that monetary policy will not react along its monetary policy rule (see Figure 22). In the exercise, a demand shock hits the economy, generating higher future inflation expectations. Forward-looking monetary policy would tighten monetary conditions immediately: consequently the appreciation of the exchange rate and the gradual contraction of domestic demand result in inflation returning to the target in the medium-term.

Figure 22
Anticipated vs. unanticipated monetary policy behavior

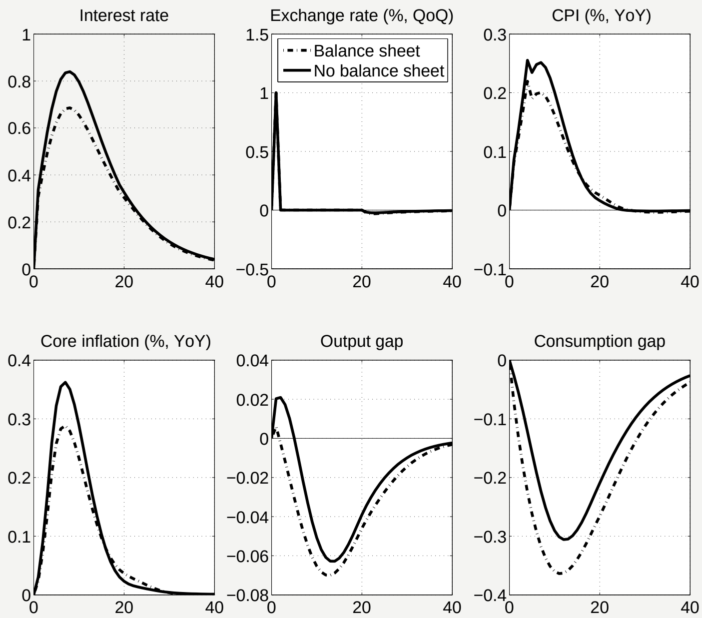


On the other hand, we would like to simulate what happens if monetary policy does not react to the shock, i.e. it keeps its base rate unchanged over the policy horizon (eight quarters ahead). If the deviation of monetary policy from the systematic behaviour is unanticipated by market participants, then the effect of keeping the interest rate flat is subdued. It even seems that it is worth not to react immediately, as there will only be a modest adjustment needed in the future. However, in this case the credibility of monetary policy is not questioned, each market participant assumes in each future time period that the central bank would still act along its monetary policy rule afterwards. Hence, although everyone is surprised again and again by the unchanged interest rates, they think that this has been the last occasion that monetary policy deviated from its rule. One can immediately see the difference if the same exercise is carried out by assuming that market participants anticipate, i.e. know in advance, that the central bank will not react along its rule (for whatever reason). In this case, everyone knows that inflationary pressures will not be counteracted resulting in a situation where monetary policy cannot stabilise expectations.

5.4 PREMIUM SHOCK AND BALANCE SHEET EFFECTS

We investigate the effect of a persistent increase in the risk premium ($\varepsilon_{PREM,t}$), resulting in a 1% depreciation of the exchange rate (see Figure 23). We examine the effects under two different assumptions. In the first assumption, there is a balance sheet effect in the sense that a currency depreciation directly lowers the current disposable income of households. Translated in model terms, the coefficient α_6 entering the equation (7) is different from zero. In the second assumption there is no balance sheet effect ($\alpha_6 = 0$).

Figure 23
Risk premium shock with and without balance sheet channel



The risk premium shock leads to an increase in the policy rate. Moreover, whether the risk premium shock is contractionary or not depends on the assumption about the importance of balance sheet effects. In any case, the risk premium shock leads to a massive depreciation of the currency. In local terms, import prices increase and their inflation is passed through to overall CPI. Under the first assumption, because of the balance sheet effect, households' income falls and thus their consumption as well. The interest rate increase combined with the negative balance sheet effect amplifies the fall in consumption. On the other hand, the currency depreciation means that domestic producers become more competitive, and, as a result, the volume of exports increases. Given the high degree of openness of the Hungarian economy, the improving trade balance more than offsets the fall in consumption, and, as a result, the output gap becomes positive.

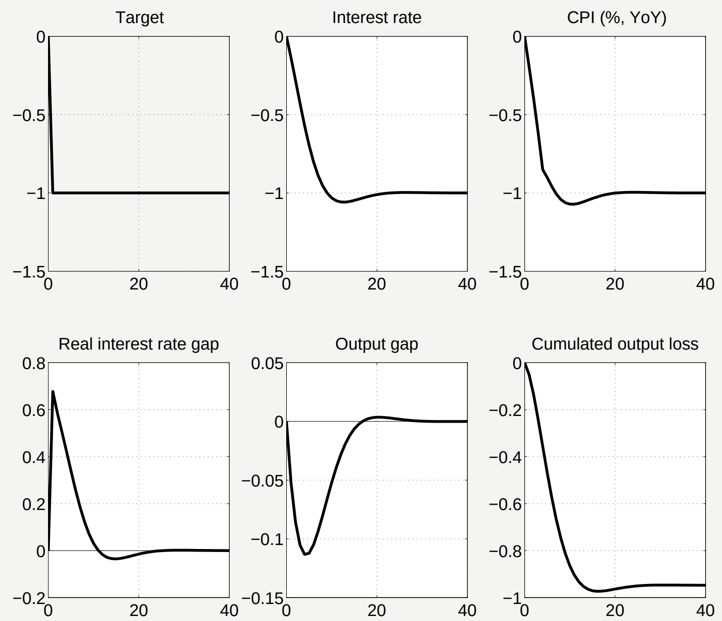
Under the second assumption of no balance sheet effects, the currency depreciation does not lead to a direct decline in households' income. As a result, in the absence of an increased FX liability, consumption does not fall initially, due to higher real income earned in the export sector. Consequently, there is more pressure on inflation and monetary policy reacts more aggressively to fight the second-round effects (working through increased demand pressures) of the shock.

5.5 DISINFLATION AND THE SACRIFICE RATIO

One of the most important policy experiments is permanent disinflation through the reduction in the inflation target (see Figure 24). In this simulation, we assume that the model is in the initial steady state when the decision maker lowers the inflation target by 1 percentage point immediately. As a result, the natural interest rate ($\overline{R_t}$), the policy rate (R_t) and CPI (ΔP_t) fall immediately as well because of the credibility of monetary policy. On the other hand, the real interest rate gap ($\widehat{RR_t}$) rises, and consequently output ($\widehat{Y}_t$) falls. The sacrifice ratio is the cumulative loss in output until the economy reaches the new steady state characterised by lower inflation and a lower natural interest rate in approximately two years.

The sacrifice ratio is an easily available and straightforward indicator, and as such is widely used to describe the real economy costs of disinflation. The empirical estimates of sacrifice ratios vary in quite a big range with some systematic regularities, i.e. disinflation is found to be less costly in more open economies and in countries with more flexible prices and wages. However, a sacrifice ratio of around 1 is most widely viewed as 'normal' for a small open economy reflecting the usual costs of disinflation.[22]

Figure 24
Disinflation in the model



[22] For an all-encompassing summary of the disinflation periods – applying Ball (1994) methodology – from 1972 to 2008 and sacrifice ratios for both OECD and non-OECD countries see Mazumder (2012). For a less rigid definition of disinflation periods, see Goncalves et al. (2008).

5.6 ANALYSIS OF THE SADDLE-PATH PROPERTIES WITH NO PRO-ACTIVE POLICY

An important feature of a policy model is its stabilisation property, i.e. a proper policy response is required to stabilise inflation. Put differently, in the face of increased demand, the rate of inflation would explode in the model, unless monetary policy stepped in and adjusted the nominal interest rate sufficiently to raise the real rate and thus to eliminate inflationary pressures. This property implies that with passive monetary policy, the system has no stable solution.

This property is tested in the following way. We check the eigenvalues of the model solution under two scenarios. Under the first one, we use the usual Taylor rule (equation 1) to describe monetary policy behaviour, while in the 'passive policy' scenario the policy rate is kept constant and equal to the trend rate of interest ($R_t = \overline{R}_t$). What we see is that with the original Taylor rule (pro-active monetary policy) the solution of the system is stable, and it has the same number of forward-looking variables and eigenvalues greater than one. However, the model has no stable solution if the central bank keeps the policy rate unchanged. In the latter case, the number of eigenvalues greater than one exceeds the number of forward-looking variables.

6 Challenges and successes in past forecast rounds

6.1 CHANGES IN EXTERNAL AND INTERNAL COMMUNICATION

Following an official shadow forecast round in November 2010, the MPM was introduced as the main structural framework for macroeconomic projection and policy analysis in March 2011. Accordingly, the MPM exhibits significant structural and logical differences when compared with our previous models. Its predecessors typically used a bottom-up forecasting approach (by aggregating sector-level developments), thereby yielding a rather detailed and highly disaggregated snapshot of the Hungarian economy, in which monetary policy transmission did not play a central role. On the other hand, the MPM typically represents a top-down approach, in which the focus is intentionally shifted on variables that are relevant in terms of monetary policy. The more transparent economic structure also implies that the impact mechanisms of the key monetary transmission channels are easier to trace and interpret. For this reason, the MPM offers not only background support but also improves transparency both in forecasting and in pre-decision processes, within the central bank's own internal staff as much as outside of the bank. It is a tool for arranging the Bank's existing expert knowledge into a uniform framework and a logically consistent structure. Indeed, the introduction of the MPM was a real success in terms of policy communication. Decision-makers found it relatively easy to familiarise themselves with the most important mechanisms of the model and found the endogenous policy responses very helpful in framing policy discussions.

In the new system, the MPM presents an interest rate path which, while ensuring the achievement of the inflation target, can also provide a starting point for the decision-making process of monetary policy makers. The assumed policy rate path has not yet been made public in the Quarterly Report on Inflation, but qualitative suggestions are given concerning the expected direction of policy rate measures. This explained by the fact that the baseline scenario of the forecast is to reflect the opinion of the staff, which may differ from the position held by the Monetary Council. This is all the more so, as Monetary Council members always request alternative interest rate path simulations and risk scenarios as well. As a result, contrary to previous practices, it is now the Monetary Council that pronounces, based on its own risk assessment, the main risks inherent to MPM-based forecasting. Once Council members assessed all possible scenarios, the decision on the policy rate is based solely on their discretion.

The significance of endogenous interest and exchange rate trajectories was also reflected in the updated structure of the MNB's Quarterly Report on Inflation. Reflecting the fact that endogenous projections made policy decisions more forward-looking, the qualitative evaluation of the interest rate path and the forecast chapter comes before the significantly shortened version of the Council's assessment of it's policy stance. In this new format,the Report not only places more emphasis on the projection as opposed to the current stance of the economy,but it also discusses the relevant risks to the forecast and their monetary policy implications in a different new chapter. The terms used to speak about policy relevant issues also shifted significantly: the more disaggregated, bottom-up view on macro variables was replaced by a top-down approach and more discussion of the cyclical position of the economy, expectations and policy dilemmas.

Not only external communication has changed as a result of the application of the MPM, but internal processes have also been adjusted. For example, the policy team became an active player in the projection exercise and the MPM served as a catalyst in developing the tools and methods of sectoral experts. A good example for the latter is that, from the staff's point of view, one of the main challenges was technical and involved the trend-cycle decomposition. As the equilibrium trend developments are kept outside the core projection model and treated exogenously, sectoral experts responsible for imposing short-term judgment on the model forecast were required to provide consistent trend projections for the forecast horizon as well as initial conditions for the gap variables. Therefore,the experts applied techniques of estimating latent variables with a Kalman filter and started communicating in terms of trends and gaps.

Moreover, another important lesson learned is, that it is very helpful to have a unified platform to integrate all processes of the projection exercise. The technical assistance of the IMF proved extremely useful in designing a well-functioning practical system to cover all the operations of the projection process. All the tasks of the projection are easily handled using the Iris toolbox (developed by Jaromir Benes) from data management to filtering and from simulation to reporting.

6.2 POLICY DILEMMAS OF THE YEAR 2011

At the time of the introduction of the model, the Hungarian Monetary Council – similarly to its foreign counterparts all over the world – faced the dilemma of rising inflationary pressures from global commodity prices, on the one hand, and a negative output gap, on the other. While the former implied the need for a near-term tightening in monetary conditions, the latter called for lowering the policy rate. The interest rate path consistent with the baseline forecast reflected the following dilemma: the opposing forces resulted in a hump-shaped but relatively flat path. Supported by a consistent analytical framework, policy communication became more forward-looking. Both the Quarterly Report on Inflation and the minutes of the Council's meetings emphasised that the Council intended to keep the policy rate constant for a prolonged period of time. This had a significant effect on longer-term rates as well, causing the yield curve to flatten out.

During the second half of the year, the Monetary Council faced new policy challenges. The gradual increase in the country-specific risk premium, combined with a significant depreciation of the exchange rate resulted in large capital outflows and problems in the banking sector. Financial stability considerations started to play an ever greater role in shaping interest rate setting decisions. As Council members expressed their desire to base the forecast on the most likely path of the policy rate (as opposed to the one consistent with pure IT considerations), the projection team had to incorporate financial stability considerations into the Taylor rule.[23] Decision-makers finally agreed that it is mostly short-term abrupt changes in investor sentiment that they should (and successfully could) counteract by adjusting in the policy rate.

This recognition inspired the solution, which was introduced into the model in the 2011 Q4 forecast round. In this setup, financial stability concerns are translated as extra incentives to raise the policy rate during times of abrupt temporary increases in the country-specific risk premium. The policy rate modelled this way is presented in equation (1) above. The main issue for policy makers was to decide on their preference parameter δ_4 that reflects their propensity to target short-run movements in the risk premium. The choice of the parameter value reflected a strong revealed preference for counteracting financial market disturbances through interest rate movements. It remains to be seen when the Council can return to normal times, i.e. to a pure Inflation Forecast Targeting regime.

[23] Horváth et al (2011) present the original rule reflecting pure IT considerations.

7 Conclusion

Following best practices in central banking in terms of inflation targeting, the MNB developed a tool that can be used simultaneously for forecasting and supporting monetary policy decision-making. When designing the MPM, a key aspect was to provide a firm grasp on monetary transmission, using the most transparent structure possible. Therefore, in comparison with earlier macroeconometric models, the MPM operates with a less disaggregated economic structure, while it still manages to integrate all variables relevant to monetary policy.

There are several lessons to learn from the Hungarian case. First, small-scale standard models are extremely helpful to begin with, as they facilitate communication and help to frame policy discussions. Second, country-specific elements or non-standard features can easily be introduced into a standard framework already at work. New policy challenges may require new features that could be dealt with in a model-consistent way on demand. Third, introducing a forward-looking policy model with endogenous interest rates and exchange rates brings about substantial changes in central banking practices and can have important consequences for the structure and content of regular communication tools.

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Appendix A

A.1 PRIOR AND POSTERIOR DISTRIBUTIONS OF PARAMETERS AND STANDARD ERRORS

Figure 25
Prior and posterior distributions of the investment equation parameters

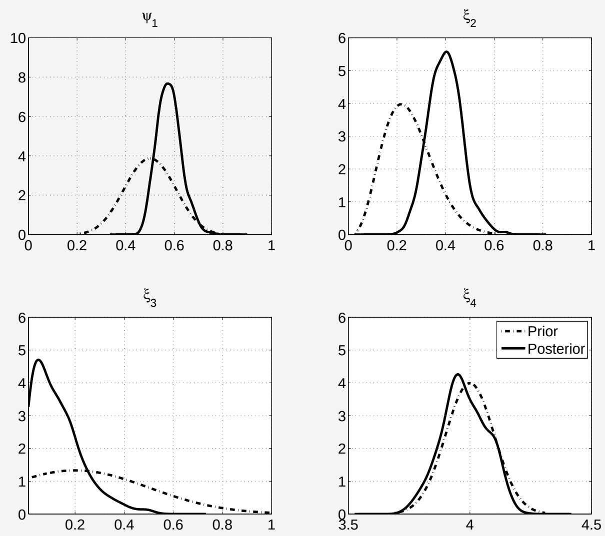
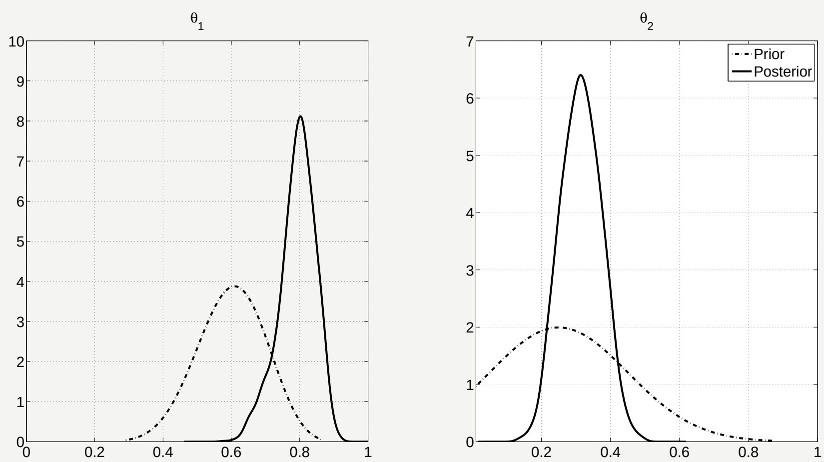


Figure 26
Prior and posterior distributions of the export equation parameters



A.2 PARAMETER VALUES

Table 2
Estimated parameter values

		Prior distribution			Estimated posterior		
		Type	Mean	Stand. err.	Mode	Mean	90% prob. int.
Consumption equation							
Persistence	α_1	Beta	0.550	0.100	0.592	0.603	[0.537-0.665]
Interest rate channel	α_2	Normal	0.049	0.010	0.058	0.058	[0.046-0.069]
Credit spread	α_3	Normal	0.049	0.010	0.044	0.042	[0.027-0.055]
Income channel	α_4	Normal	0.072	0.100	0.109	0.110	[0.086-0.135]
Investment equations							
Persistence	Ψ_1	Beta	0.500	0.100	0.567	0.578	[0.491-0.654]
Real economy	ξ_2	Normal	0.250	0.100	0.272	0.397	[0.276-0.497]
Interest rate channel	ξ_3	Normal	0.200	0.300	0.000	0.129	[0.000-0.264]
Credit spread	ξ_4	Normal	4.000	0.100	4.050	3.977	[3.829-4.133]
Core Phillips curve							
Persistence	β_1	Beta	0.540	0.020	0.494	0.491	[0.466-0.514]
Real economy	β_2	Normal	0.030	0.010	0.047	0.043	[0.029-0.054]
Government spending	β_5	Normal	0.000	0.100	0.000	0.025	[0.000-0.056]
Non-core pass through	β_6	Normal	0.010	0.001	0.001	0.001	[0.000-0.0015]
Taylor rule							
Interest rate smoothing	δ_1	Beta	0.85	0.100	0.819	0.808	[0.755-0.859]
CPI reaction	δ_2	Normal	3.400	0.500	3.412	3.081	[2.524-3.659]
Output gap reaction	δ_3	Normal	0.250	0.100	0.319	0.296	[0.128-0.458]
Premium reaction	δ_4	Normal	0.500	0.100	0.462	0.524	[0.415-0.635]
Export equation							
Persistence	θ_1	Beta	0.600	0.100	0.759	0.792	[0.705-0.859]
Foreign demand	θ_2	Normal	0.250	0.200	0.282	0.314	[0.220-0.407]
Standard errors							
Consumption gap	σ^{Cg}	Inv. Gamma	1.000	1.000	0.612	0.666	[0.532-0.798]
Investment gap	σ^{Ig}	Inv. Gamma	1.000	1.000	1.829	1.936	[1.526-2.287]
Government expenditure gap	σ^{Gg}	Inv. Gamma	1.000	1.000	2.365	2.399	[1.991-2.847]
Export gap	σ^{Xg}	Inv. Gamma	1.000	1.000	2.282	2.475	[2.053-2.923]
Import gap	σ^{Mg}	Inv. Gamma	1.000	1.000	0.270	0.283	[0.227-0.339]
Output gap	σ^{Yg}	Inv. Gamma	1.000	1.000	1.011	1.022	[0.847-1.220]
Taylor rule	σ^{R}	Inv. Gamma	1.000	0.500	0.900	0.900	[0.723-1.037]
Core inflation	$\sigma^{\Delta PC}$	Inv. Gamma	1.000	1.000	0.665	0.693	[0.555-0.817]

Table 3
Calibrated parameter values

Domestic prices		
Weight of core in CPI eq	λ_1	0.655
Weight of market price in non-core eq	λ_2	0.4456
Real economy in core eq	β_3	0.75
Real exchange rate in core eq	β_4	0.5
Persistence in Market energy eq	ω_1	0.2
Core pass-through in Market energy eq	ω_2	0.2
Exchange rate and oil in Market energy eq	ω_3	0.3
Real economy		
Weight of consumption in GDP eq	ζ_1	0.5305
Weight of investment in GDP eq	ζ_2	0.1778
Weight of export in GDP eq	ζ_3	0.8963
Weight of import in GDP eq	ζ_4	0.8335
Technical variables	α_5	0.13
Balance sheet channel	α_6	0.078
Tobin-Q in investment eq	ψ_2	0.05
Technical variables	ψ_3	0.1
Discount factor in Tobin-Q	ξ_1	0.7
Crowding-out parameter	ξ_5	0.1
Technical variables	θ_3	0.14
Real exchange rate in export eq	θ_4	0.08
Weight of consumed import	κ_1	0.37
Weight of invested in import eq	κ_2	0.1
Weight of import for government exp	κ_3	0.03
Elasticity of consumption	γ_1	0.8
Elasticity of real exchange rate	γ_2	0.1
Exchange rate		
Hybrid UIP	η	0.7
Rest of the world		
Persistence of foreign demand	φ_1	0.4
Interest rate channel	φ_2	0.0053
Persistence of foreign inflation	φ_3	0.42
Real economy in foreign Phillips curve	φ_4	0.058
Oil pass-through in foreign Phillips curve	φ_5	0.0018
Foreign interest rate smoothing	φ_6	0.85
Foreign inflation reaction	φ_7	2
Foreign output gap reaction	φ_8	0.174

A.3 IMPULSE RESPONSE FUNCTIONS

Figure 27
Monetary policy shock

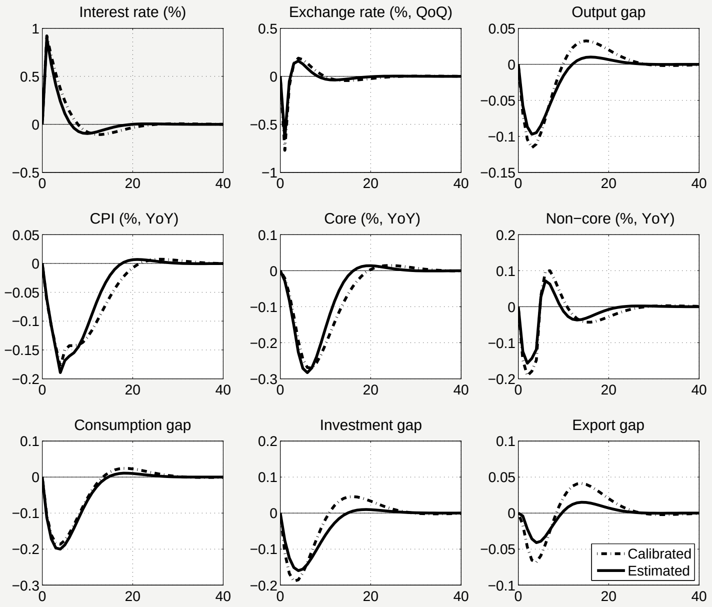


Figure 28
Risk premium shock

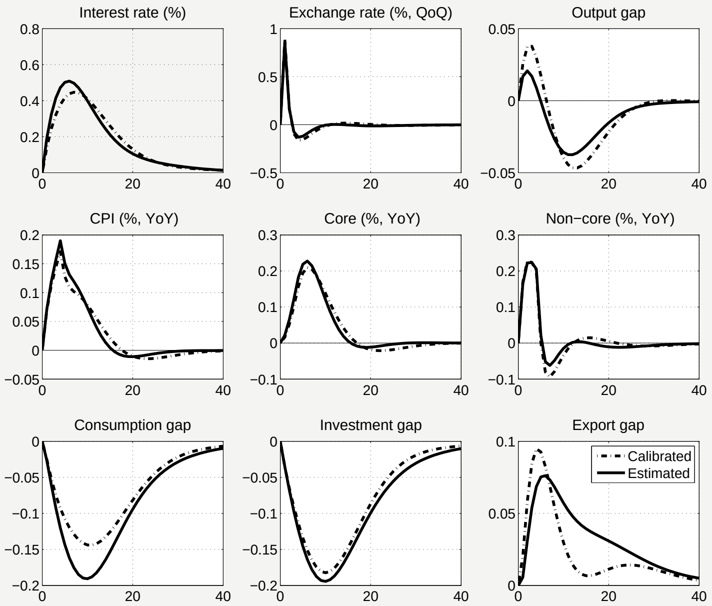


Figure 29
Core markup shock

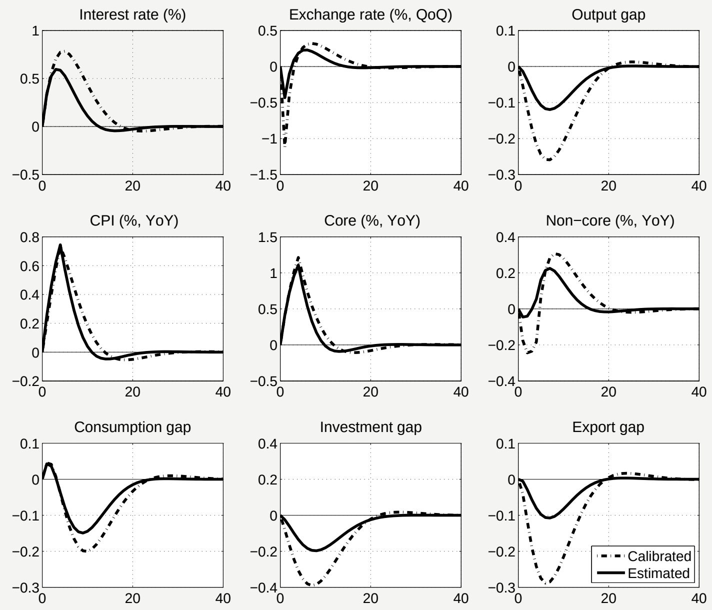


Figure 30
Market priced non-core markup shock

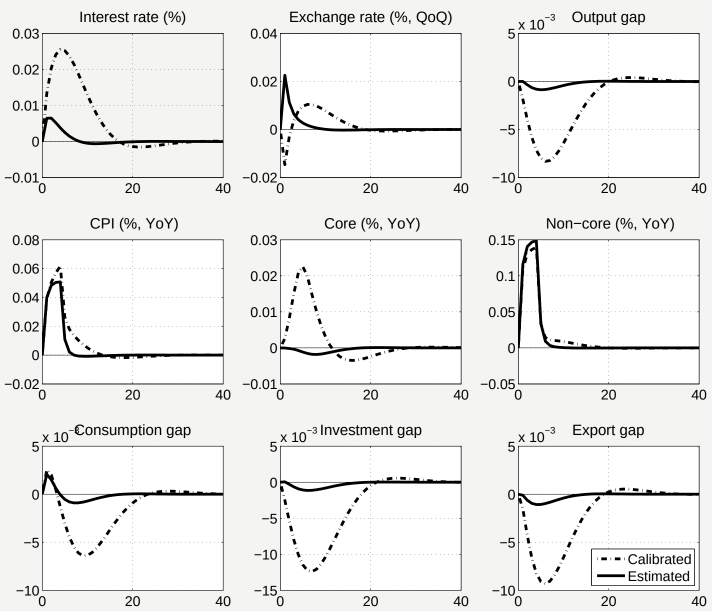


Figure 31
Consumption shock

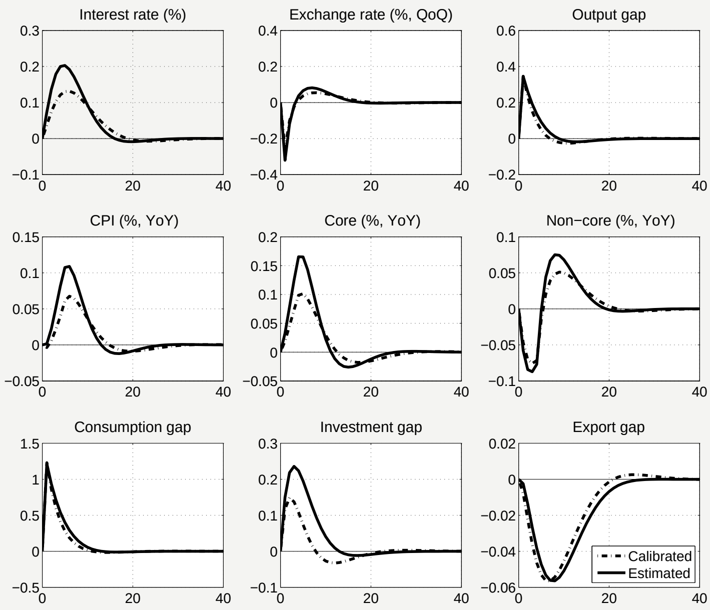


Figure 32
Household credit condition shock

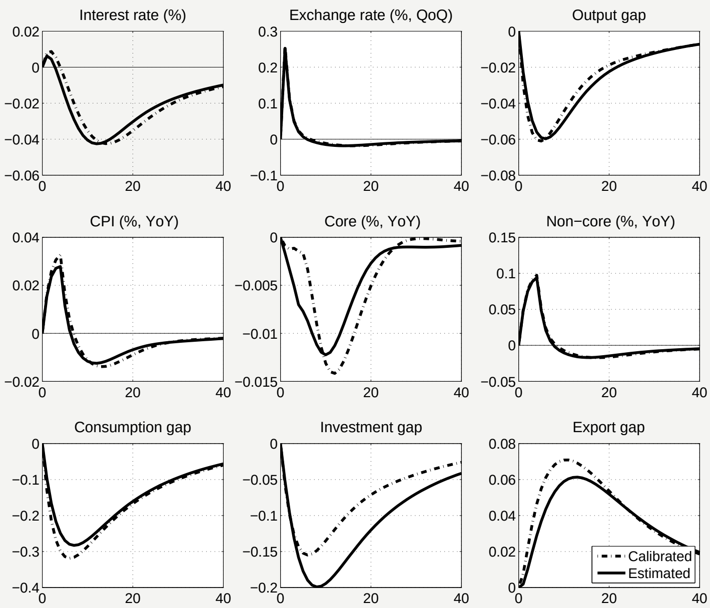


Figure 33
Investment shock

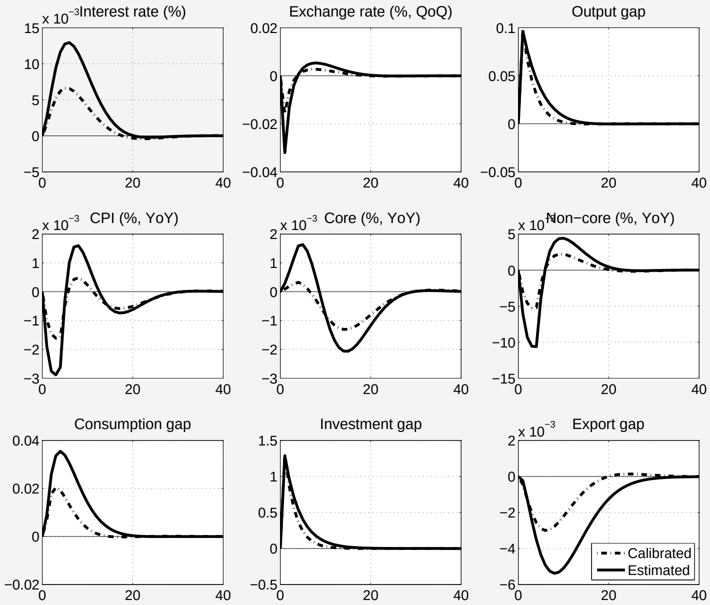


Figure 34
Corporate credit condition shock

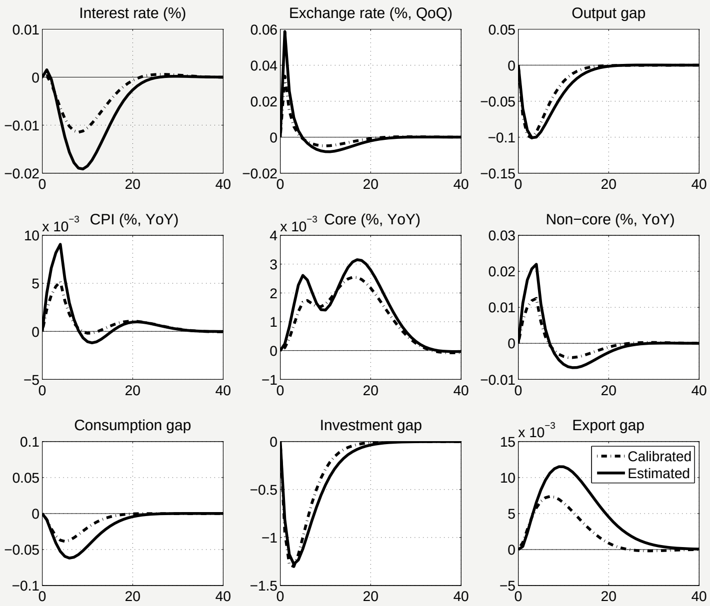


Figure 35
Export shock

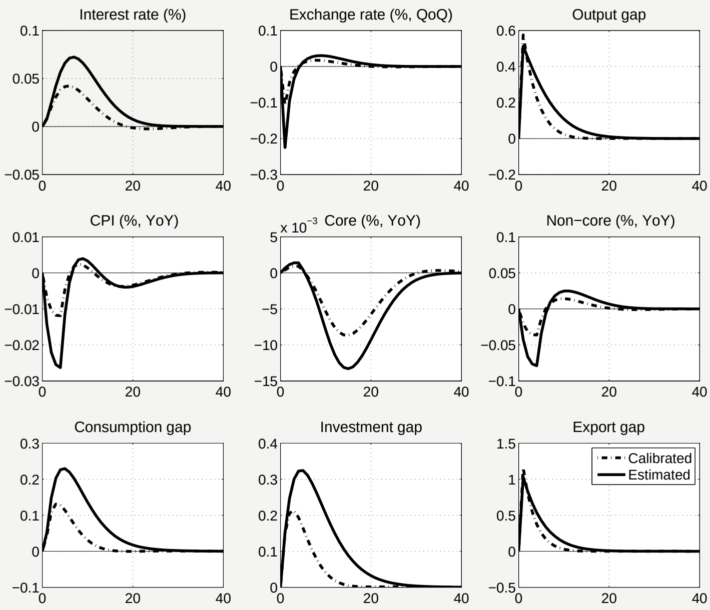


Figure 36
Foreign demand shock

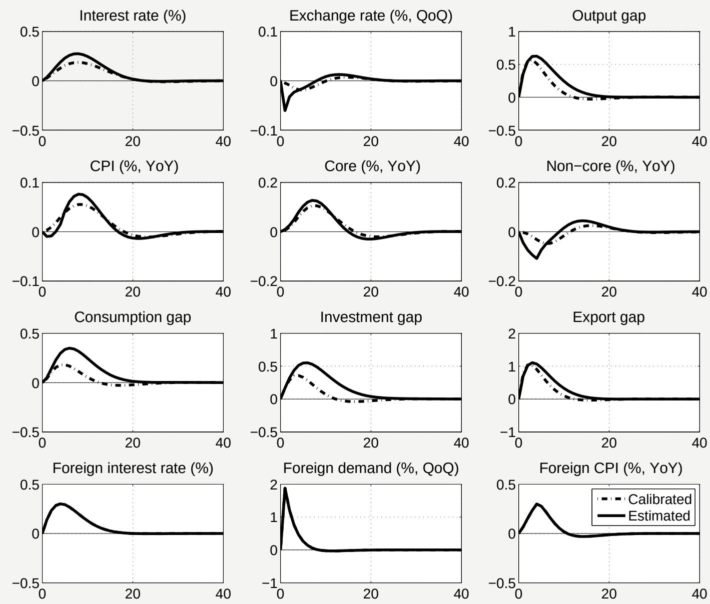


Figure 37
World interest rate shock

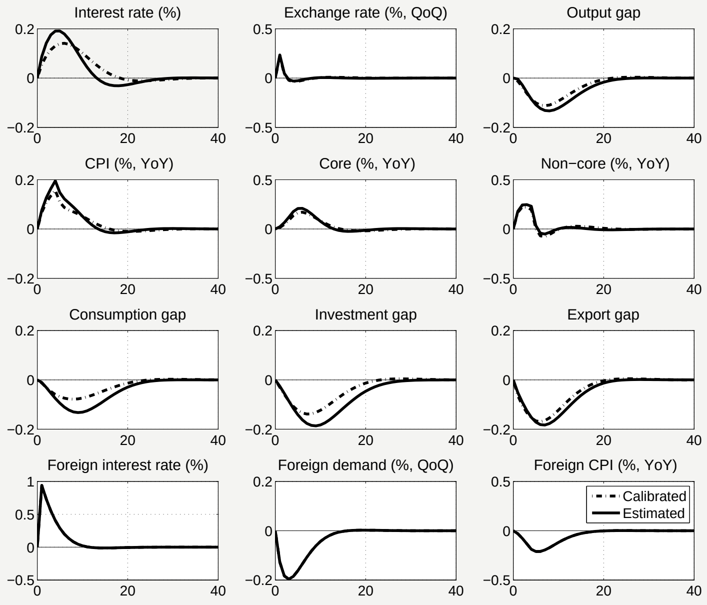


Figure 38
Oil price shock

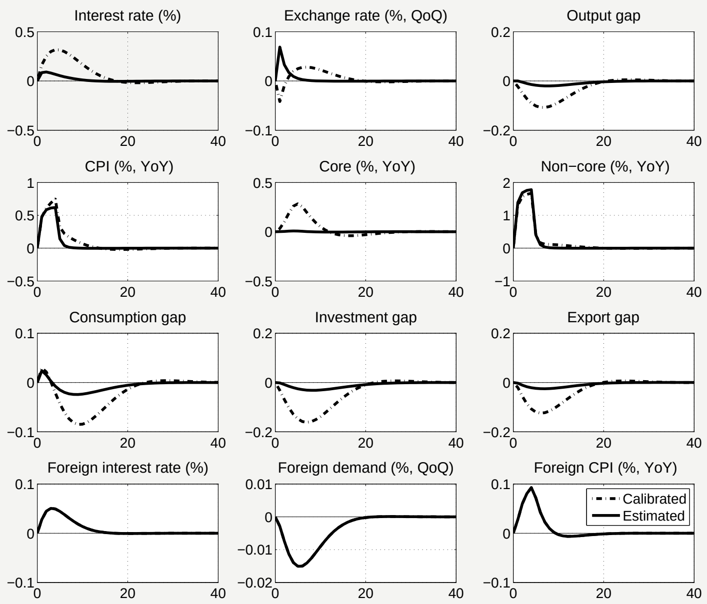
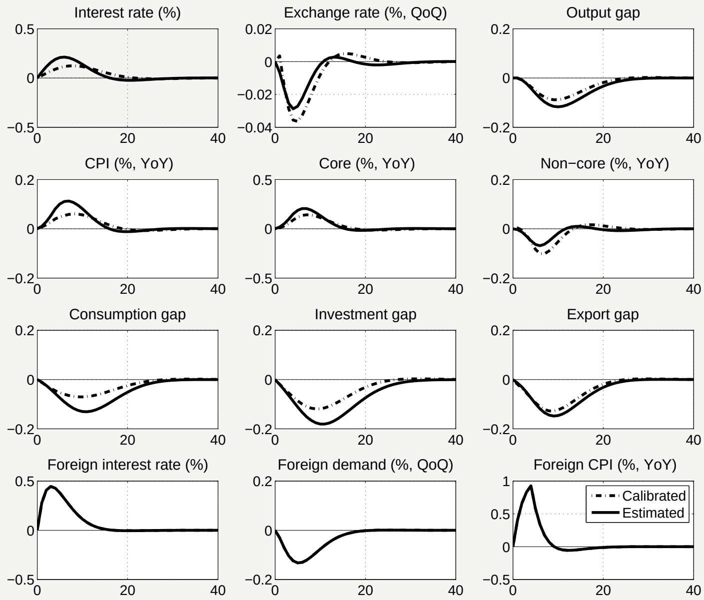


Figure 39
World inflation shock



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