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Monetary Policy and Risk-Premium Shocks in Hungary: Results from a Large Bayesian VAR

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Monetary Policy and Risk-Premium Shocks in Hungary: Results from a Large Bayesian VAR

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Abstract

We document the transmission of monetary policy and risk-premium shocks in Hungary, by applying recent advances in the Bayesian estimation of large VAR models. The method allows extracting information from over 100 series, opening the "black box" of the transmission mechanism to provide the most comprehensive description to date of the impact of these two shocks on the economy under the inflation-targeting regime. We find novel evidence that most of the channels of transmission are operational in Hungary, in spite of large liability euroization and high foreign ownership of banks and corporations. Due to financial stability concerns, monetary policy responds procyclically to risk-premium shocks. We also find that the use of such a large panel of data improves inflation forecasting performance over smaller models and renders this model suitable for policy purposes.

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I. Introduction

Prior to the financial crisis, central banks with an inflation targeting framework focused mostly on delivering price stability and were concerned with understanding the monetary transmission mechanism and improving their inflation forecasting capabilities. However, in the aftermath of the recent financial crisis, the interplay between monetary policy and macro-financial stability has come to the forefront of the policy and academic debate. In particular, the importance of financial market shocks for macroeconomic outcomes and the constraints they impose on policy-making has been highlighted.

Like in other inflation targeting frameworks, maintaining price stability is the primary goal of monetary policy for the Hungarian Central Bank. However, special features of the Hungarian economy, such as the high degree of euroization of private sector liabilities, reliance of funding from foreign parent companies and high external indebtedness have rendered monetary transmission more difficult to analyze and monetary policy more challenging to implement. Financial stability concerns related to the risk of an abrupt currency depreciation have played a significant role in the conduct of monetary policy.

This paper takes a fresh look at the transmission mechanism of monetary policy and the effects of risk-premium shocks in Hungary, during the inflation targeting period, using the most comprehensive approach to date. By extracting information from more than 100 macroeconomic and financial series we look inside the "black box" of monetary transmission and shed light on the interactions between monetary policy and risk-premium shocks to a level not possible before. This allows us to put into perspective the developments during the financial crisis as well.

To understand the monetary transmission mechanism and to forecast inflation central banks routinely use Vector Autoregressions (VARs). These approaches are "reduced form", as they generally employ significantly fewer varibles than the rich set of information available to the central bank. To address the issue of overly simplistic VARs, central banks have generally used a multiprongue approach. First, these models are complemented by a suite of other models used in estimation and policy analysis (multiple large sectoral or structural models, dynamic stochastic general equilibrium models, etc).[2] Second, research has been conducted to incorporate more information into VARs.

The latter effort has led to the development of data-rich empirical models which fall into two categories: (i) factor models, which decompose large panels of data into a small number of common factors (Stock and Watson, 1999 and 2002, Forni and others, 2009), and (ii) large Bayesian VARs, which use prior beliefs on the parameters and set the tightness of the priors in relation to model size (De Mol and others, 2008, Banbura and others, 2010). In terms of

[2] The National Bank of Hungary has recently developed a DSGE model (Jakab and Világi, 2008) and uses a structural quarterly projections model (Benk and others, 2006) to forecast the main variables of interest and provide policy advice. MNB is also working with the IMF Research Department into developing a fully fledged DSGE model to inform monetary policy decisions by allowing consistent model policy projections and risk assessment.

forecasting performance, both factor models and large BVARs generally outperform smaller VAR models by a large margin and large BVARs have been found to outperform factor models (Banbura and others, 2007 and Koop, 2010).

In this paper we employ a large BVAR and confirm that it is a very potent tool that can be successfully applied to an emerging economy with a relatively limited data span. We capture the complex dynamic relationships between a large set of variables, commonly analyzed by a central bank, starting from the introduction of the inflation targeting regime in Hungary and including a large part of the recent financial crisis (from June 2001 until September 2010). We study how a monetary policy shock and a risk-premium shock feed through the economy and additionally evaluate the forecasting perfomance of the large BVAR in comparison with smaller scale models.

We find that the transmission of the monetary policy signal throughout the economy is fast and effective, which we attribute to the high degree of openness and flexibility of the economy. In addition to the interest rate and exchange rate channels which the previous literature on Hungary has emphasized,[3] we find novel evidence of the balance sheet channel, the asset price channel and the expectations channel. Despite the large degree of euroization and high foreign ownership in both the banking and corporate sectors—which one expects to make monetary policy less effective—we find that the decline in economic activity induced by a monetary policy tightening is quite sharp, more so than in advanced economies.

We document that risk-premium shocks lead to an endogenous procyclical monetary policy response (due to financial stability concerns) that compounds and deepens the economic downturn.[4] However, this monetary policy tightening response does not fully offset the risk premium shock to avoid an excessive contraction, leading to some depreciation. As a result, the net worth of foreign currency indebted private agents declines and these negative balance sheet effects reinforce the contractionary effects of the risk-premium shock.

Moreover, we also compare the forecasting performance of the large model to smaller specifications and find that adding information significantly improves results. This points to the large BVAR as an appropriate tool for the central bank's toolkit.

The structure of the paper is as follows. In the second section we present some stylized facts about the Hungarian economy and the policy decision framework. The third section describes the method and the data used. We present the results in the fourth section: the impulse response functions for a monetary policy and a risk premium shock, their variance decomposition and forecasting performance. We conclude and draw some policy implications in the fifth section.

[3] See, for example, Csermely and Vonnák (2002), Vonnák (2005, 2007, 2010), and Rezessy (2005).

[4] Similar procyclical policy responses were documented in Latin American countries, also characterized by a high degree of dollarization (see, e.g., Chang and Velasco, 2001, Calvo and Reinhart, 2000).

II. Stylized Facts

In many ways, Hungary fits the profile of a "textbook" small open economy, with developments in the rest of the world having a strong effect on Hungary, through trade and capital flows, but not vice versa. Prior to the implementation of the inflation targeting regime, the exchange rate followed a crawling-peg.[5] Even after 2001 the exchange rate continued to play a relatively important role, as the exchange rate moved within horizontal bands of ±15 percent (which was removed in February 2008). The IMF-supported program introduced in November 2008 did not change this institutional framework and allowed for intervention, in line with the central bank's mandate, to avoid disruptive movements in the exchange rate.

Among regional peers (Central European countries like the Czech Republic and Poland, CE-3), Hungary stands out in several ways (see Figure 1). Government bond yields and the country risk premium have been systematically higher than in the peers for the most part of the last decade due to higher government debt and fiscal deficits. The forint did not experience a nominal appreciation trend vis-a-vis the euro (as in the other CE-3 after 2004) and episodes of speculative pressure on the currency were more frequent. The policy rate has been systematically higher and appears to have been more responsive to movements in government bond yields than in Hungary's peers.

Some of these developments can be explained by macroeconomic and financial features of the Hungarian economy (the figures mentioned below refer to 2010Q3). General government debt at close to 90 percent of GDP and gross external debt of over 160 percent of GDP are quite high for emerging economies, much higher than in regional peers, and imply substantial vulnerability to exchange rate depreciation and changes in foreign investors sentiment. The private economy is highly euroized[6] (both on the asset and liability side). Deposits in foreign currency are about one fifth of the total, and the share of foreign currency liabilities of households exceeded 60 percent, while for corporations it amounted to around 25 percent.

Capital markets are very open and are dominated by foreign investors. Portfolio investments held by nonresidents were close to 50 percent of GDP, of which about half was government debt. The banking sector is largely foreign owned, with foreign bank subsidiaries holding about two thirds of total banking assests. Banks funded themselves to a significant extent from the wholesale market, as loans exceeded deposits by about 30 percent.

Given these features of the economy, international shocks drive developments in Hungary. International risk premia are correlated with government yields and policy rates, which are then passed on to private sector lending rates (see Figures 1, 2 and 3). A rise in the relative risk premium compared to the regional peers, especially if perceived to be permanent, would

[5] The central bank preannounced a rate of depreciation and allowed some deviations (±2.5 percent) from this path.

[6] Throughout the paper, we use the term "euroization" somewhat liberally, to refer generically to both euro and swiss franc denominated debt.

lead to a tightening, even in the presence of large capacity gaps, and relatively low inflation (see Inflation Reports 2008-10 and Vonnák, 2007). During the latest financial crisis, the risks of an abrupt depreciation posed substantial threats to inflation and financial stability, given the substantial stock of liabilities in foreign currency (see Figures 4 and 5).

III. The Model

A. Methods of Estimation Large Panels of Data

Vector Autoregressions (VARs) are a standard tool of macroeconomic analysis and forecasting, as they capture largely unrestricted interactions between variables and provide a broad representation of the economy. However, the high level of generality of VARs comes at the risk of over-parameterization, since the number of unrestricted parameters that can reliably be estimated with classical methods is rather limited with the typical time span available for macroeconomic applications. Until recently, the "curse of dimensionality" has limited the number of variables incorporated in a VAR to usually a handful, potentially generating an omitted variables bias, with negative implications for inference and forecasting (see, e.g., Christiano and others, 1999, Giannone and Reichlin, 2006).

Several solutions have been proposed to address this issue. Some papers have used a "marginal approach", by which a core set of variables is defined and the remaining variables of interest are added one by one (see, e.g., Christiano and others, 1996, or Kim, 2001). However, this approach does not address the problem arising from omitted variables and makes the comparison of impulse responses across models problematic.

The recent econometric literature has made substantial progress in developing methods to reduce the curse of dimensionality problem inherent in large VARs, thus allowing the exploitation of a more comprehensive set of information than before. The literature pioneered by Sims and Sargent (1977), Stock and Watson (2002), and Forni and others (2009) addresses the issue of the curse of dimensionality by employing dynamic factor models. These are based on the premise that a small number of unobserved common dynamic factors drive most of the observed co-movements of economic time series. Bernanke and others (2005) propose a "Factor Augmented" VAR (FAVAR) model, in which they identify the effects of monetary policy shocks using factors from a large cross section of economic indicators that are included as additional endogenous variables in a VAR. One of the key shortcomings of the FAVAR methodology, however, rests in the difficulty of assigning an economic interpretation to the factors.

A parallel strand of research has addressed the issue of the proliferation of parameters by using large Bayesian VARs. A seminal paper by De Mol and others (2006) finds that Bayesian shrinkage (see also Doan and others, 1984, Litterman, 1986, Sims, 1992, Leeper and others, 1996,) is sufficient to deal with very large models, provided that the tightness of the priors is increased as more variables are added to the system. The intuition behind the result is that with highly collinear macroeconomic series, the relevant signal can be extracted from a large data set in spite of the stronger shrinkage applied to filter out the unsystematic component. Banbura and others (2010) apply this result to post-war US data and show that a large Bayesian VAR outperforms FAVARs and smaller VARs in terms of forecasting accuracy, while at the same time allowing for a very comprehensive structural analysis.

The development of such methods has proven to be useful for policy analysis and forecasting. As these methods gain traction, one can expect that this would support efforts by policy makers to include them in the standard policy toolkits. In addition to the major central banks, we are aware of related work at the New Zealand Central Bank, also an inflation targeting institution (see Bloor and Matheson, 2008).

B. Estimation of a Large Bayesian VAR

The priors required for estimation are based on the Minnesota prior, augmented with an inverse Wishart prior distribution for the covariance matrix of the residuals (as in Kadiyala and Karlsson, 1997 and Sims and Zha, 1998) and a prior on the sum of the coefficients (as in Doan and others, 1984). The Normal inverted Wishart prior has the advantage that it is a natural conjugate prior, which means that the posterior can be derived analytically and shown to belong to the same class of distributions – thus eliminating the need for posterior simulation.

In addition to this already traditional Bayesian aparatus, De Mol and others (2008) showed theoretically that Bayesian shrinkage is suitable when dealing with large models, in that the Bayesian forecast converges to the optimal forecast, provided that the tightness of the prior (degree of shrinkage) increases as more variables are added to the model. Intuitively, Bayesian shrinkage allows extracting the relevant signal from a large data set, because macroeconomic series are highly collinear, so adding more information allows a tighter prior, filtering out the unsystematic component.

In the implementation strategy we follow the procedure described in Banbura and others (2010). For the precise technical details on the implementation of the priors, see Appendix 1. The overall tightness of the shrinkage hyperparameter and the sum-of-coefficients prior are set in relation to model size.[7] The method consists of several steps. First, a small benchmark model is evaluated for the in-sample fit. The model consists of the following time-series: industrial production, core inflation,[8] the nominal effective exchange rate and the monetary policy rate. The rationale behind this choice is that a benchmark regression in these variables can be deemed to reasonably represent an open-economy Taylor rule which the authorities may have at least partially followed. The benchmark VAR represents merely a starting point for setting the overall tightness parameter thus has no further implications.

After finding the in-sample fit of the small VAR (estimated by OLS), we use this as the desired in-sample fit for the large model as well. We then choose the overall tightness so that the larger model yields an in-sample fit as close as possible to that of the smaller VAR for the four variables of interest. This is in order to ensure comparability across models of different

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[7] We are grateful to Domenico Giannone for providing the codes.

[8] We use net core inflation, where we deduct indirect taxes and excises from the core (series kindly provided by the MNB).

sizes, i.e. to penalize for over-fitting in the large model by increasing the tighteness of the prior. Also, the sum of coefficients prior is set to be proportional to the overall tighteness.

C. Data

We use monthly series from June 2001 to September 2010 from MNB and other official sources. This rich dataset[9] contains 98 domestic real and nominal indicators, at the aggregate and sectoral level, which are routinely analyzed by the MNB. They fall into the following categories: industrial production, construction, housing starts, retail trade, prices, labor markets (unemployment, hours and wages), monetary and credit aggregates, interest rates (short and long-term rate, for government, corporations and households), exchange rates (bilateral, effective nominal and real), survey measures of expectations of economic activity, the stock market index, the foreign currency sovereign bond yield spread (EMBI global). We also add in the estimation a block of 13 "foreign" variables: international commodity prices, industrial production and imports in Germany (main trading partner) and the world, economic sentiment in Germany, stock market indices in Germany and the world (MSCI) and the Euro area policy rate.

IV. Estimation Results

A. Structural Analysis of the Impact of Monetary Policy and Risk-Premium Shocks

First, we analyze the transmission of a monetary policy and a risk-premium shock respectively (both set to a one time increase of 100 basis points).[10] The advantages of using the large BVAR are aparent, because it enables the estimation of the response of a much larger set of variables than those included in previous estimates for Hungary (typically small VARs, with less than six variables). In addition to the wealth of information, the use of a large data set alleviates problems from a possible omitted variables bias.

We use a recursive identification, which implies exclusion restrictions on contemporaneous responses. The Cholesky decomposition of the variance-covariance matrix has been widely used to identify monetary policy shocks (see Christiano and others, 1999, Stock and Watson, 2005, etc.) We argue that a similar strategy works well for the identification of risk-premium shocks, when the data frequency is monthly, although we also conduct some robustness experiments.

For the identification of the monetary policy shock, the ordering of the variable is as follows. First we group the slow-moving (i.e., business cycle) variables: the external block is placed first, followed by domestic variables: real activity (industrial production, construction, sales, hours, trade), nominal variables (prices and wages), confidence measures as well as the monetary and credit aggregates. The policy rate is ordered next. The third block is comprised of fast-moving variables, i.e. financial variables: interest rates, exchange rates, the stock market index and the country risk-premium.

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[9] A detailed list of the time series, together with the transformations applied, can be found in Appendix 2.

[10] We follow the standard literature to show a tightening shock. Results are symmetric.

The block of external variables is placed first, on the assumption that it is not affected by developments in Hungary, but can contemporaneously influence the domestic economy as well as policy setting in Hungary. At the same time, the central bank observes the slow-moving variables during the same period, while the information set of the central bank contains only past values of the fast-moving variables. In other words, the identification assumption is that slow-moving variables respond with a lag to a monetary policy shock, while the financial variables react contemporaneously.

For the identification of the risk-premium shock, we order the variables as follows. First we place the block of slow-moving variables (as before). The EMBI sovereign spread is next. The third block comprises fast-moving variables (as before), including the policy interest rate (which is placed right after the shock in the benchmark calibration). This identification captures the fact that monetary policy may respond contemporaneously to a risk-premium shock, which may also influence, within the period, the other fast-moving variables, including the exchange rate. In robustness exercises we have placed the monetary policy rate prior to the risk-premium without a significant impact on the results.

It is important to stress the novelty of our investigation compared to the previous literature. In Vonnák (2005), a sign restrictions approach is used in which monetary policy shocks result in an exchange rate appreciation and higher policy rate for four quarters. In a similar manner to Vonnák (2007), all shocks that lead to a positive correlation between the exchange rate and the interest rate are labelled monetary policy shocks, while those that lead to a negative correlation are identified as risk-premium shocks. In both cases the restrictions are imposed for one year.

The approach of this paper avoids such restrictive identifying assumptions and by employing a more general identification allows the data more freedom to speak. Using data at monthly frequency partly mitigates the simulaneity problem, although we do test for robustness by using alternative orderings in the case of the risk-premium shock. In addition, by employing a much larger set of variables we are able to fully describe the transmission mechanism of these shocks, arguably providing a more convincing picture.

The results are interpreted below, shown in figures 6 and 7, and detailed in tables 1 and 2 in Appendix 3.

Impulse Responses to a Monetary Policy Shock

We investigate, as it is customary in this literature, the effects of an unexpected tightening of 100 basis points. When analyzing the results we compare them, where available, with two benchmarks: first, previous findings from small VARs for Hungary and second, results obtained from a large BVAR for the US (in Banbura and others, 2010). For the sake of brevity, we discuss only the key results (complete results are available upon request and are summarized in Appendix 3 Table 1).

An unanticipated policy rate hike of 100 basis points in Hungary has a persistence of about four months, which is about half of the typical duration of such shocks in advanced economies (US). Afterwards, monetary policy becomes accomodative in less than one year, as the policy rate falls about 25 basis points under the equilibrium value, again a faster easing than in advanced economies. The comparably higher policy volatility is not surprising for an emerging market (partly for institutional/political reasons), although it does raise the question of potential welfare losses.

While the previous literature has tended to emphasize the exchange rate channel and downplay other channels of transmission in Hungary, we find evidence of all channels being present. The method does not allow to identify the relative magnitude of each channel, which opperate simultaneously, but we present evidence of the first stage of each channel and discuss the overall effects on the economy at the end of the section.

Interest Rate Channel

We find strong evidence that the monetary policy signal is transmitted fast along the entire yield curve and to private sector lending rates. Government bond yields rise along the entire term structure and the yield curve tilts downwards. The yield on the 3-month treasury bills increases by 75 basis points, while the yield on 10-year treasury bonds goes up by 10 basis points immediately after the shock and it declines by 25 basis points after a quarter. The latter reflects expectations of lower future policy rates, as economic activity is expected to contract due to the tightening. The swift transmission of the monetary policy signal along the government yield curve is linked to the high openness of the economy,which allows fast portfolio rebalancing by international investors in the sovereign debt market.

The monetary tightening feeds through to private sector lending rates. Corporate borrowing rates react significantly, with a hump-shaped response, reflecting a fast but still gradual pass-through from banks of the higher borrowing costs they face themselves. Corporate short and long-term lending rates (in domestic currency) increase by 0.6 and 0.5 percent, respectively, peaking at about three months and going back to zero in approximately one year. The relatively fast pass-through is consistent with lending practices in Hungary, where the maturity of loans is typically shorter than in advanced economies and the corporate interest rate is linked to the 3-month interbank lending rate, making it liable to frequent repricing.

Higher policy rates also feed into higher lending rates for households, in particular for consumption credit (which goes up by about 25 basis points). Mortgage loan rates increase by about 15 basis points, which can be explained by the longer average maturity of such loans (the overwhelming majority of mortgage lending in Hungary has a maturity of ten or fifteen years). One reason why the pass-through of the monetary tightening is less aggressive to household borrowing rates may be linked to the fact that households in Hungary are significantly less indebted than corporations. Thus banks may be competing more aggresively to retain individual customers in the face of the economic downturn and they can maintain attractive rates for households as they have higher margins from which to do so.

Exchange Rate Channel

In line with the previous literature, we find that the exchange rate appreciates following the monetary tightening, as portfolio substitution effects would suggest. However, this appreciation, of about 1 percent after three months[11] is much smaller than found previously. For example, in a sample covering 1995-2004, Vonnák (2005) finds an impact approximately four times larger.

The different result compared to the earlier literature may be due to two possible causes: methodological and sample differences. We believe that the former plays the most important role in the quantitatively different responses of the nominal effective exchange rate (as we compared our results with several small VARs that we estimated across various samples as well). Vonnák (2005) covers a sample that includes the crawling peg (1995-2001) and his four variable VAR imposes sign restrictions. We find that the forint appreciation is not very persistent—being reversed after about six months—unlike in Vonnák (2005), where such a sign restriction is implemented for four quarters.

Balance Sheet and Credit Channels

In the context of highly euroized economies, such as Hungary, a monetary tightening and the accompanying nominal appreciation can have significant positive balance sheet effects that reduce the value of foreign currency denominated debt. Consequently, the improvement in the net worth of debtors should counter some of the negative effects of the monetary contraction on activity. We find strong evidence of balance sheet effects for corporations and households. The stock of forex loans declines significantly by about 1 percent for the first three months after the shock, due to the valuation effects of a stronger currency. There is on the other hand little change in the stock of forint-denominated debt for both types of private agents.

We also find strong evidence that new bank credit to the private sector declines. In particular, our results show a significant decline in net loans (transactions) to corporates immediately after the shock. While loans in forint fall by about 20 percent immediately after a 100 basis point tightening, foreign currency loans increase initially, pointing to some substitution effect. Forint lending recovers first, after less than six months, while foreign currency lending takes around nine months to revert to equilibrium.

We conjecture that the sharp decline in bank lending to firms may be attributable to some extent to substitution from bank credit to intra-company credit. Loans from the parent company are available for a number of domestic firms at advantageous rates, even if monetary policy is tight in Hungary, since these loans are in fact internal financing at firm level or the cost of raising additional funds from external sources is not affected by Hungarian monetary policy.

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[11] A similar response is observed when one uses either the bilateral euro/forint rate or the nominal or real effective exchange rate.

Net loans to households decline comparably less, to the tune of 5 percent, both in the case of forint-denominated loans and foreign currency lending. Part of the weaker response of household borrowing may be related to the fact that the interest rate hike has been partly "cushioned" by banks by the incomplete pass-through of the interest rate increase.

In the absence of data on credit conditions for the entire duration of our sample, one should be cautious about interpreting the decrease in the quantity of credit as evidence for the credit channel. The data does not allow us to distinguish whether this is due to a demand effect (decline in activity, confidence, etc) or to supply-side constraints (the classic credit channel—i .e. banks curtailing the amount of credit extended due to funding pressures). The credit channel has been considered to be generally weak in Hungary in the previous literature, due to the reliance of the non-financial corporate sector and domestic banks on funding from foreign parent companies.

However, in a highly euroized economy like the Hungarian one, an argument can be made that a downward shift in credit demand would affect credit by domestic agents both in the domestic credit market and in the foreign market, while a shift in credit supply would only affect the domestic market and not the foreign market. In our estimates, the quantity of credit for domestic agents falls in both the domestic and foreign market by a comparable amount, providing evidence of a shift in credit demand due to lower expectations of economic activity and scaled-back investment projects.

Asset Price and Expectations Channels

Unlike previous studies, we find that the monetary tightening impacts the stock market substantially, leading to a decline of around 4 percent for about one quarter. However, once the monetary policy reverses its stance, confidence in the stock market rebounds. For comparison, in the US the decline is significantly smaller, 1.3 percent after three months (Banbura and others, 2010).

Confidence in the economy falters, as expectations of economic activity measured by several indices fall temporarily. However, these effects appear to be short-lived (about two quarters) and are followed by a medium-term improvement in sentiment. Linked to the increased uncertainty, the asset price collapse and the expectations of a recession, the external risk-premium increases, as the country risk goes up by 20 basis points. The EMBI spread remains elevated for about three quarters before returning to equilibrium.

Overall Effects on Activity, Labor Market and Prices

As a result of all the channels discussed above (with the exception of the balance sheet channel which operates in the opposite direction), one expects a sharp decline in real activity following an unanticipated monetary tightening. Aggregate and sectoral indices of industrial production and manufacturing fall between 1 and 2 percent, in a hump-shaped response, with the trough being reached after approximately one quarter and reversion to trend after about one year.[12] These responses are consistent with the decline in borrowing due to tighter financing conditions and their expected effect on investment.

Overall, the effect of a tightening on industrial production is of a similar magnitude to Vonnák (2007), where a 25 basis points rate hike leads to a decline in industrial production of about 0.3 percent. By comparison, Banbura and others (2010) find that in the US the decline in activity is milder (i.e. 0.7 percent drop in industrial production after six months and a 0.8 percent decline in manufacturing after one year), pointing to a larger cost of disinflating in terms of output in Hungary than in an advanced economy.

The economic contraction is also reflected in the labor market with a short lag, as unemployment rises by about 0.05 percent and hours worked decline by 0.5 percent. Consistent with weaker activity and a soft labor market, wages also fall for approximately one year, by up to 0.5 percent, although the result is not significant. Hours revert back after one year, in line with the recovery in industrial activity. Retail sales do not decline significantly, due to the relative resilience of wages, the substitution effect from the appreciation and the positive balance sheet effects, thus pointing also to a moderate effect on private consumption (although not included in our analysis since it is a quarterly variable). This is consistent with the previous literature, which found that the transmission of monetary policy to aggregate demand seems to be stronger on the investment rather than on the consumption side.

Finally, following a tightening and decline in activity consumer and producer prices inflation fall. Core CPI and net core CPI fall by approximately 0.1 percent after six months and PPI by 0.3 percent.[13] The transmission of monetary policy to prices is fast and occurs simultaneously with the adjustment in output. We concur with the previous literature (Vonnák, 2007) that this effect may be driven by the fast response in the price of tradeables, reflecting the exchange rate response. However, we find a much lower impact on prices than Vonnák (2007), where a 25 basis points tightening leads to a fall in inflation of about 0.1 percent.[14]

Overall, we find evidence of most transmission channels, some of which have not been documented for Hungary in the previous literature (in particular the balance sheet channel, the asset price channel and the expectations channel). We find that the transmission of the monetary policy signal is fast, which we attribute to the high degree of openness of the

[12] As this model is estimated on monthly data and does not include GDP, we do a simple back of the envelope calculation of the potential effects on output and find that this implies about 0.3 percent decline in GDP after a quarter. This is based on a simple OLS regression of GDP on industrial production, by which an increase of 1 percent in industrial production translates into an increase of about 0.3 percent in GDP. GDP = 1.00(3.83) + 0.30(12.39)*IP, $R^2 = 0.74$, t-stats in brackets.

[13] The disinflationary effect of monetary tightening is significant and there is no evidence of a "price puzzle" - where a tightening leads to a rise in prices, which often can be found in small VARs and is generally attributed to the models' being too parsimoniously specified (resulting in omitted variable bias), although other authors also document its absence in Hungary (Vonnák, 2005).

[14] The difference in results is consistent with the weaker exchange rate response documented previously.

economy. Also, the monetary tightening induces a substantial economic contraction, more so than in advanced economies.

Impulse Responses to a Risk-Premium Shock

The second part of our structural analysis deals with the effects of a risk-premium shock. We directly identify the shock as an unexpected rise in Hungary's external sovereign risk-premium as measured by JP Morgan's EMBI Global bond spread. For comparability with the monetary policy shock, we consider the effects of a 100 basis point increase in the sovereign risk-premium, which can be thought of as an "external tightening". To the best of our knowledge, this is the first time risk-premium shocks have been identified in this manner for Hungary (the previous literature looked instead either at exchange rate shocks or at shocks causing a negative correlation between the interest rate and the exchange rate). From this perspective, most of the following results are new.

We find that risk-premium shocks in Hungary are quite persistent, more so than monetary policy shocks, lasting for about nine months. Such shocks cause an endogenous monetary policy response. The central bank immediately tightens by about 65 basis points and keeps the rate high for one quarter. This finding is consistent with the announced MNB response of countering a relative increase in external spreads to stem a potential capital flight. As the risk premium shock subsides, monetary policy embarks on an easing half a year after the onset of the disturbance.

The risk premium shock and the associated policy response have a fast effect along the yield curve, with short and long-term government yields rising. The term structure flattens or inverts in anticipation of a coming slow-down in activity and lower policy rates (the 3-month rate increases more than the long-term yield, by about 45 basis points versus 2 basis points).

Private sector lending rates increase, as banks pass-through part of the rise in the country risk-premium and the domestic rate hike to borrowers. Corporate lending rates increase by about 35 and 55 basis points for the short-term and long-term rates respectively. Mortgage interest rates go up by about 15 basis points after the shock-induced monetary tightening, while consumption lending rates go up by about 50 basis points. This is consistent with anecdotal evidence on lending practices of Hungarian subsidiaries of foreign banks, who price-in the increase in sovereign spread that they are charged by the mother bank in intra-bank credit lines.

The forint depreciates by almost 2 percent on impact, as a lack of confidence prompts investors to flee domestic assets. The depreciation persists as long as the shock, for about nine months after which it reverts back to equilibrium. The response of the central bank prevents an even stronger depreciation due to the significant financial stability risks and the downside risks to the economy.

Credit to the private sector declines, in some cases more than the response estimated in the monetary policy shock. In particular, new forint corporate loans fall by about 10 percent, after an initial increase of about 10 percent, and new foreign-currency corporate loans fall on impact by about 30 percent. Both recover after 2-3 quarters. Many Hungarian corporations, being exporters, see their revenues increase due to the currency depreciation, which raises their implicit collateral value for banks.

It is again difficult to disentangle demand from supply side factors. It is important to note that compared to other capital account crisis in emerging market countries, foreign mother bank lending to subsidiaries in Hungary during this crisis remained strong, due partly to the European Bank Coordination Initiative. However, this has not necessarily translated to more credit for the Hungarian private sector, as banks preferred to hoard liquidity or invest in liquid assets. We conjecture that absent the Initiative, the collapse in credit would have been more drastic.

Net loans to households decline by less, but more persistently. In particular, domestic currency denominated loans fall by 7.5 percent, while foreign currency denominated loans decline by about 12 percent, in both cases not recovering before one year. A potential reason why household lending recovery is slower relative to the one for corporates is that households are not hedged against a currency depreciation and their balance sheets take longer to recover.

The depreciation increases the forint value of foreign debt thus reducing agents' net worth and generating strong negative balance sheet effects. Both the stock of foreign corporate and household loans expressed in forint terms increase by about 2 percent, while forint-denominated loans are largely unaffected (as the decline in the flow is relatively small compared to the stocks). The balance sheet effects in this case reinforce the contractionary effect of the risk-premium shock on the Hungarian economy.

Economic confidence declines, more persistently than after the monetary policy shock (for up to twelve months compared to only six months). The stock market follows the same dynamics, falling by about 4 percent and the decline lasts for about one year.

Real activity contracts more significantly and takes longer to rebound than in response to a monetary policy shock. The drop in industrial production is twice as large as in the case of a monetary tightening (about 2 percent, lasting for one year), mostly on the account of the sharp fall in manufacturing activity (by about 2.5 percent). This finding is entirely consistent with the sharper deceleration in lending and confidence discussed previously. The potentially positive effect from net exports (not captured here) is probably small, as Hungary's exports are more demand than price sensitive (Allard, 2009).

Conditions in the labor market deteriorate. Unemployment rises by approximately 0.2 percent, about four times as much as in response to a monetary tightening. Hours decline by about 0.5 percent and wages in manufacturing by about 1 percent, remaining depressed for a long period of time (eighteen months to two years). The much stronger response of the labor market to risk-premium shocks highlights the dilemma that the central bank is faced with: a nonresponse would accentuate the negative balance sheet effects, while a tightening aggravates the impact on economic activity and its social cost.

The disinflationary effect of the risk-premium shock is larger, in line with the sharper fall in economic activity. The price level declines significantly and persistently, as measured both by consumer and producer prices, the net core CPI falls by 0.25 percent, core CPI by 0.5 percent, and PPI by over 0.5 percent.

Our results show that MNB tried to counter the increase in relative risk premium, yet not fully, due to the cost of a sharper economic contraction. Risk-premium shocks have had significant contractionary effects over the sample under consideration. We believe the method explains most of the difference with the previous literature, which emphasizes a complete policy response to a risk premium shock, and hence a lack of further depreciation. For example, Vonnák (2007) mentions that "in several cases Hungarian monetary policy has been successful in preventing the real economy from being affected by risk premium shocks. It achieved this by quickly countering exchange rate movements induced by sudden shifts in risk assessment of foreign investors. As a result, these shocks have had virtually no effect on output and prices."

Between 2001-07, against a background of high global risk appetite, Hungary's risk-premium has been relatively stable, fluctuating on average around 40 basis points. Two episodes of increased pressure on sovereign bond yields, in 2003 and 2006, were countered by rate hikes, yet the currency depreciated moderately. During the recent financial crisis, Hungary was particularly affected due to its large sovereign foreign debt and balance sheet exposures. In October 2008 there was a 350 basis points increase in the EMBI spread, to which the MNB responded with a tightening of 300 basis points, while the currency depreciated by about 30 percent (see Figure 3, right-hand side chart). Continued turbulence on global financial markets led to a further increase in the EMBI spread up to 500 basis points by mid-March 2009. Monetary policy was loosened by 200 basis points as the spread starting coming down in 2010 (partly as a result of the IMF program, and partly as a result of much faster loosening in the regional peers, which allowed an attractive premium on risky Hungarian assets), while the currency regained some of the losses.

This narrative and the raw data support our finding that the MNB responses indeed tried to partly match the increase in *relative* risk premium, weighing the cost of a sharper economic contraction against the risk of a financial sector collapse. The latest financial crisis episode highlights perhaps more poignantly than before the trade-offs that an inflation targeting central bank faces between financial stability concerns and the objective of domestic stabilization.

B. Variance Decomposition

In the previous section, we highlighted the result that risk-premium shocks appear to have larger macroeconomic effects than monetary policy shocks of similar size (on the basis of the magnitude of the impulse response and the persistence of the effects). Balance sheet vulnerabilities which engender a monetary policy tightening in response to risk-premium shocks were found to be a key explanation behind this finding. We further investigate the forecast error variance decomposition of the panel of variables to the two types of shocks, to document further the relative impact of these shocks. The variables are ordered as in the benchmark identification and the maximum horizon is twenty four months (the results for all the variables are presented in the right-hand side panels of Tables 1 and 2 in Appendix 3).

Both monetary and external risk-premium shocks appear to explain a relatively small part of the variation of most non-financial variables. However, this is neither surprising nor different in Hungary compared to other countries (see Banbura and others, 2010). In the real business cycle literature, nominal shocks have been found generally to contribute significantly less than other types of shocks such as productivity, investment, demand, or preferences to the variability of other variables (in particular in the real economy).

The variance decomposition reveals that risk-premium shocks play a larger role in explaining fluctuations in real activity than monetary policy shocks. Economic activity (industrial production, unemployment, hours, wages, etc) is more affected in the short-term by the volatility of the country risk-premium. This is an important result and shows that in a small open economy such as Hungary, risk-premium shocks emanating from the external environment make a larger contribution to economic fluctuations than monetary policy shocks.

C. Forecasting Performance Evaluation

Out-of-sample forecast evaluation is a useful tool for "validating" econometric models. This assessment seems particularly important for a large scale model like ours, where the proliferation of parameters and estimation uncertainty may outweigh the benefits from reducing model misspecification.

Prior literature has shown that large BVARs are able to forecast at least as well or even better than smaller VARs and than factor models (see, e.g., Banbura and others, 2010, and Koop, 2010). We perform a similar exercise in which we compare the performance of increasingly larger models, starting with a very small model—similar to the one estimated in the previous literature on Hungary—, followed by a medium-sized model and finally, the very large cross-section of variables which we have analyzed in this paper.

More specifically, the three specifications we evaluate are:

- a "small-size" VAR: a four variable benchmark model of industrial production, interest rate, (net core) inflation and the (nominal effective) exchange rate. This model can be thought of as describing an open economy Taylor rule and is also a specification close to what has been analyzed previously for Hungary;

- a "medium-size" VAR: a ten variable VAR model, guided by variables found most important to describe monetary policy in the literature. This includes beyond the variables in the "small" VAR: wages (industry), the unemployment rate, the producer price index, money (M1), a measure of economic sentiment, and the risk-premium;

- a "large-size" VAR: containing our full specification, covering both aggregate and sectoral variables and representative of the set of information routinely analysed by the central bank.

In order to simulate a real-time forecasting experiment, we estimate the model until 2006:12 and conduct a forecasting performance evaluation for the remainder of the sample. We compare the forecasting performance of the three models up to twelve months ahead for the bechmark variables: industrial production, inflation, policy interest rate and the exchange rate.

Table 1 presents the relative mean square forecast errors relative to the the benchmark model, the naive random walk model (for computational details, see Appendix 1). Point forecasts are based on the posterior mean of the parameters. As we are comparing models of different size, the overall shrinkage parameter increases with the size of the model, so that the models are comparable in terms of overall fit. A number smaller than one indicates that the respective model performs better than the naive benchmark.

Several conclusions can be drawn from this exercise. For most forecast variables and horizons, when increasing the scale of the model, predictions become more reliable. The large BVAR performs considerably better than the smaller models, highlighting the benefit of conditioning on more information in improving forecasting accuracy. In particular, the large BVAR outperforms other specifications when forecasting inflation up to the twelve month horizon. Forecasting performance is good also for industrial production, especially in the first two quarters and for the nominal exchange rate around one year ahead. The large BVAR is also able to forecast the policy rate at least in the short-term, lending credibility to the idea that the central bank does incorporate such a large set of information in its interest rate setting decision.

V. Conclusions and Policy Implications

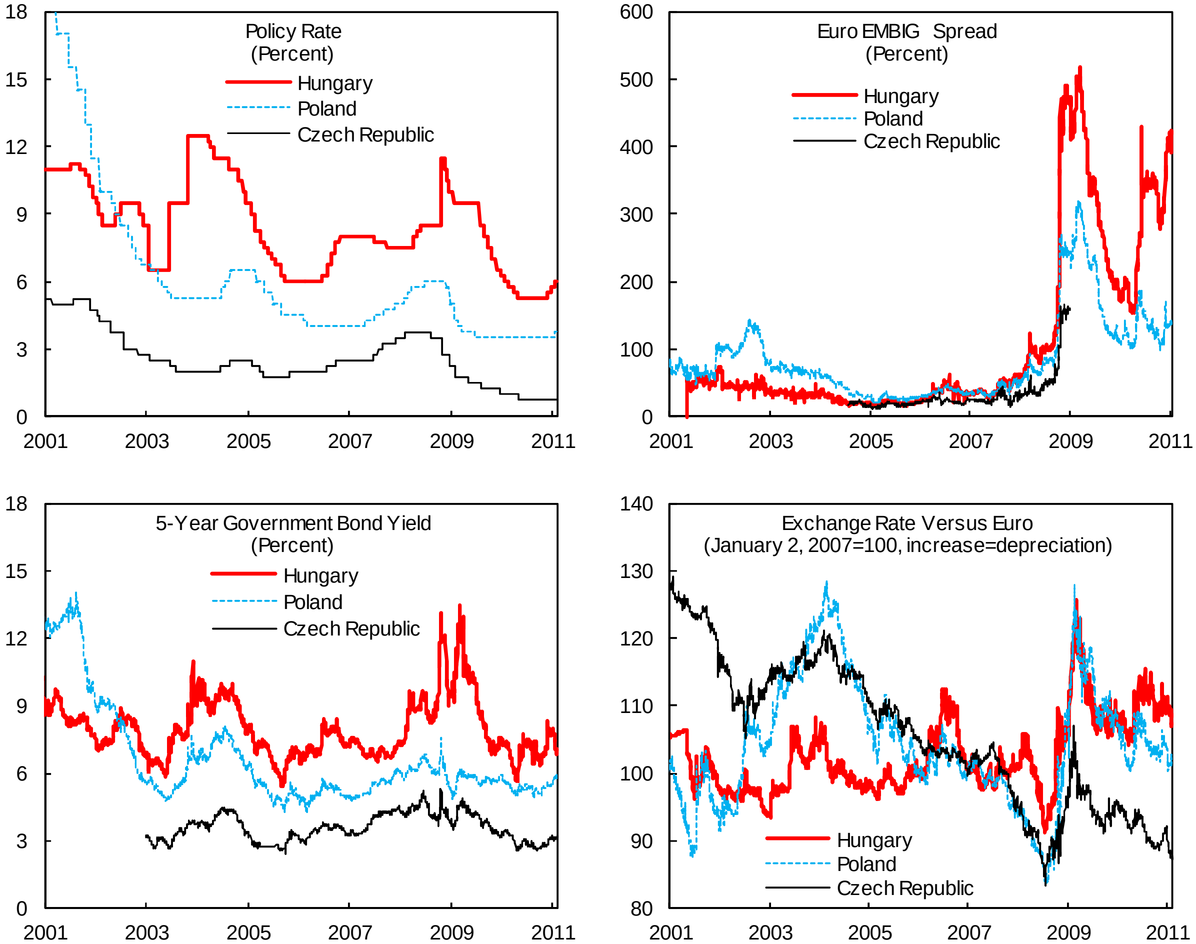
This paper analyzes monetary policy and risk-premium shocks in Hungary in the last decade when monetary policy was conducted in the context of an inflation targeting framework. The explicit commitment of the central bank to exchange rate stability during most of this period can be linked largely to the euroization of liabilities of the private sector. Furthermore, the large level of public debt, including a large foreign exchange denominated component, added to the financial stability concerns of the central bank.

We thoroughly document how monetary policy operated in this challenging environment and find that the transmission mechanism functioned fast and efficiently. In particular, we are able to document for the first time balance sheet effects that operate in the opposite direction than other channels of transmission, yet do not alter the conclusion that monetary policy is contractionary for activity.

We find that risk premium shocks lead to an endogenous pro-cyclical monetary policy response. Depreciation ensues though, as the central bank is trying to balance the risk of a financial meltdown with the output and social cost. This leads to a deeper economic contraction than in the case of a pure monetary policy shock. This result highlights the dilemma that a central bank like the MNB faces, which is sometimes referred to as “perverse depreciation effects”, meaning that the positive effect of a depreciation on the trade balance might be countered by stronger negative balance sheet effect.

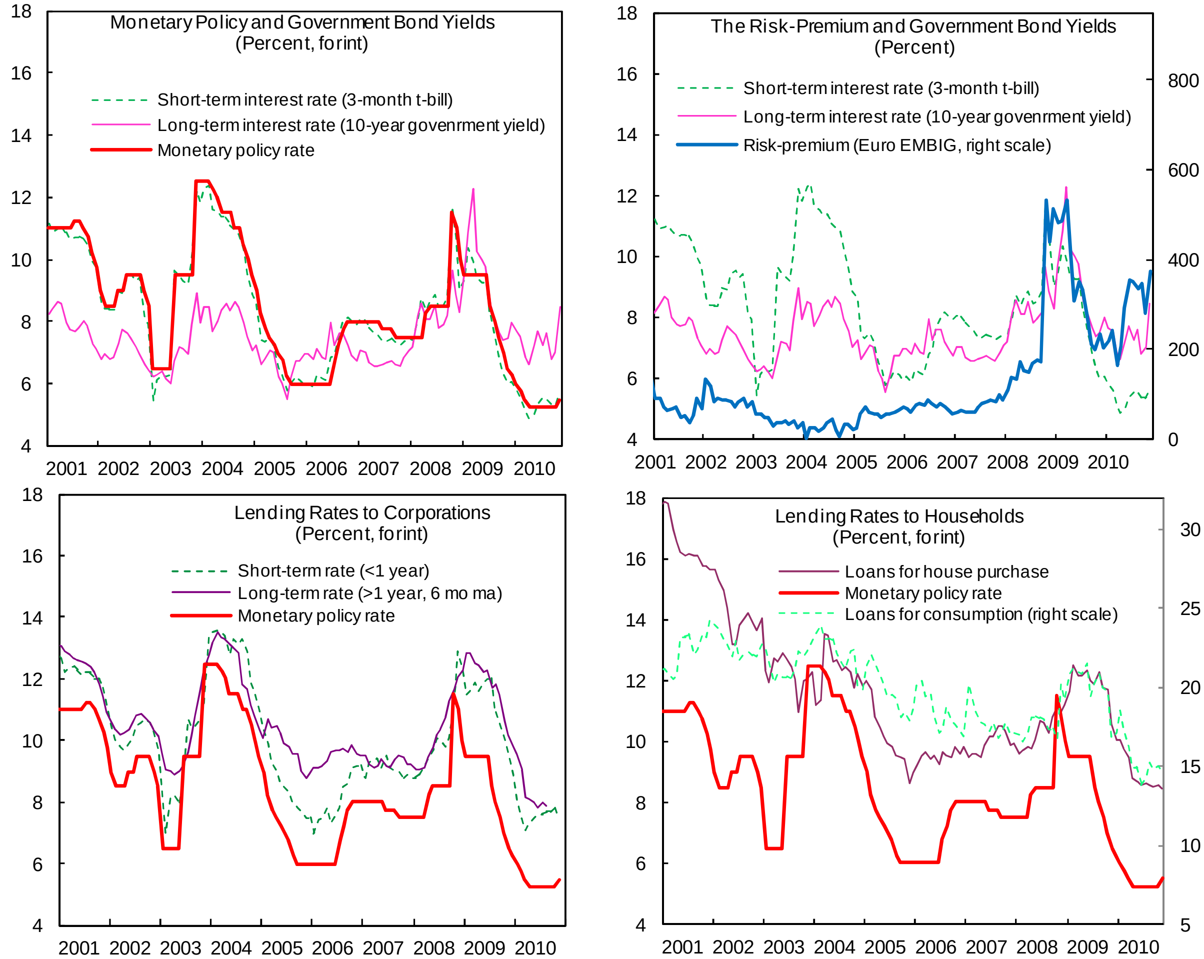
The lessons for policy makers are multiple. Significant balance sheet vulnerabilities (public or private) may render monetary policy hostage to macro-financial stability considerations which could outweigh domestic stabilization objectives. Policy measures which prevent the economy from building these types of vulnerabilities would leave monetary policy free to pursue its traditional role, which should be welfare enhancing. Macro-prudential measures, which have received a lot of attention in the aftermath of the financial crisis, are some examples of such beneficial policies (ex-ante). Strengthening the financial stability mandate of the central bank may also yield financial stability as well as macroeconomic benefits in the long run.

Figure 1. CE3: Monetary and Financial Developments



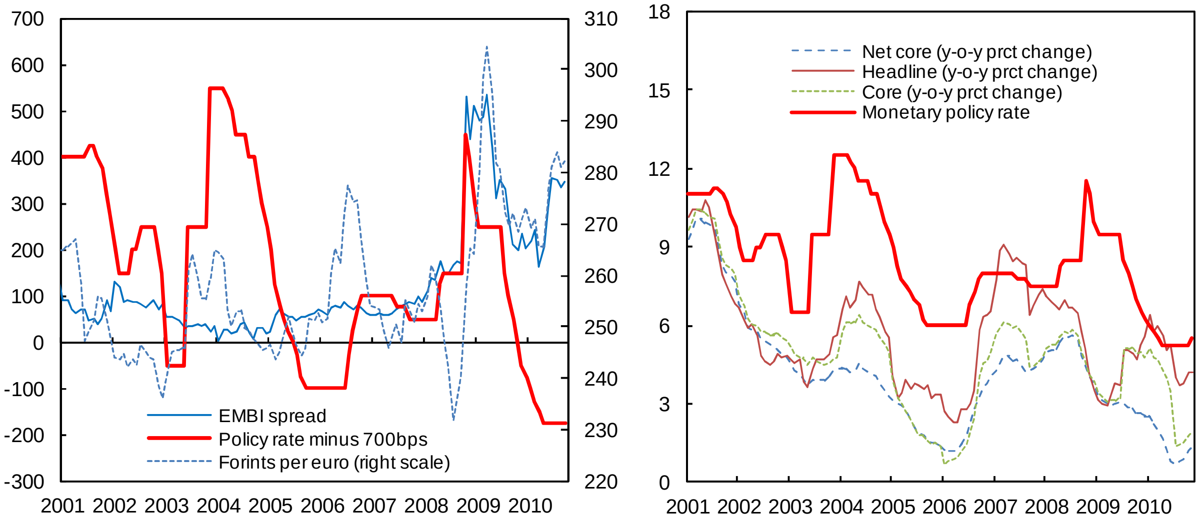
Sources: Haver; Bloomberg; and JPMorgan.

Figure 2. Hungary: Interest Rate Transmission



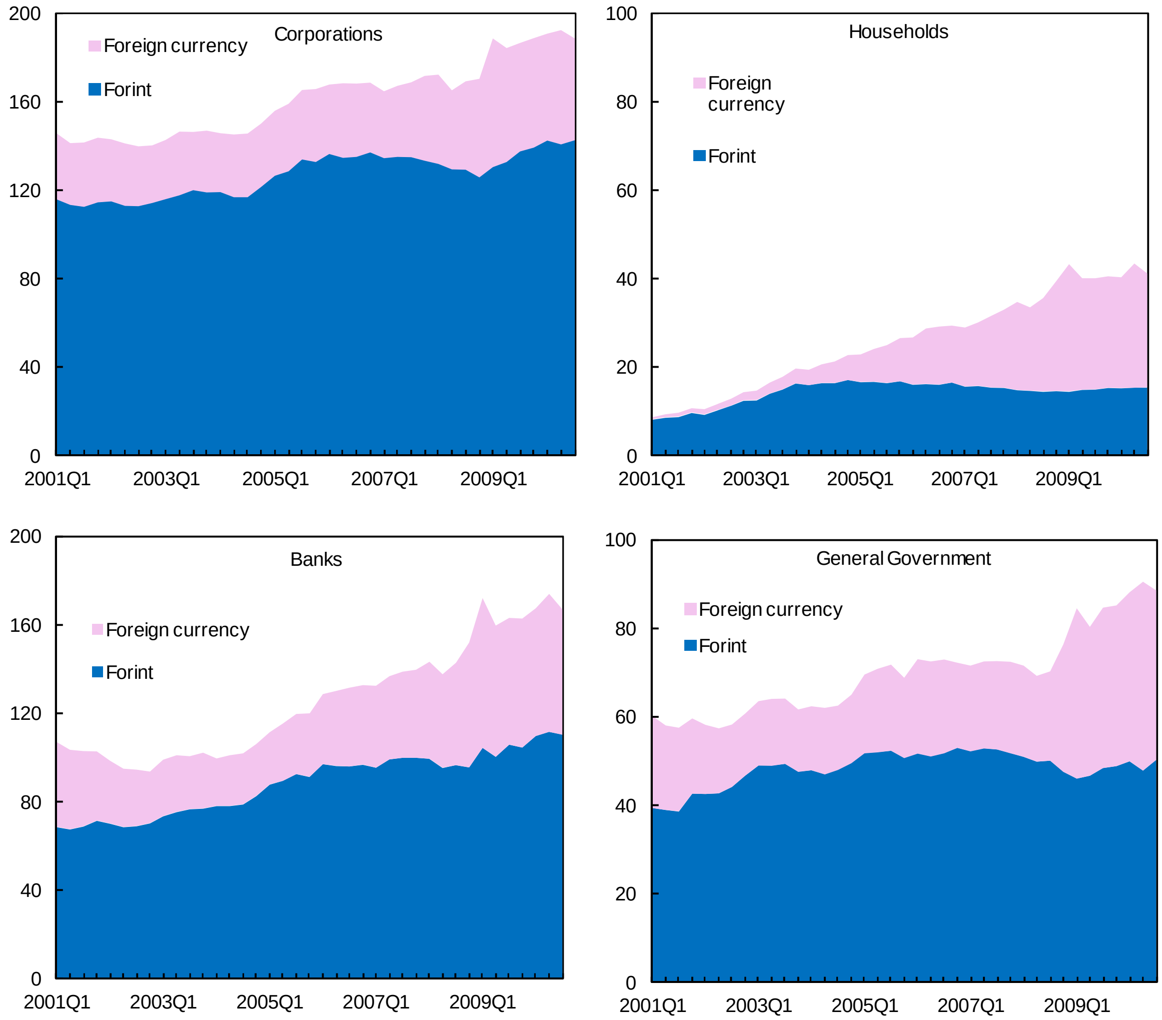
Sources: MNB; Haver; and Bloomberg.

Figure 3. Hungary: Monetary and Financial Developments
(Basis points left chart and percent right chart)



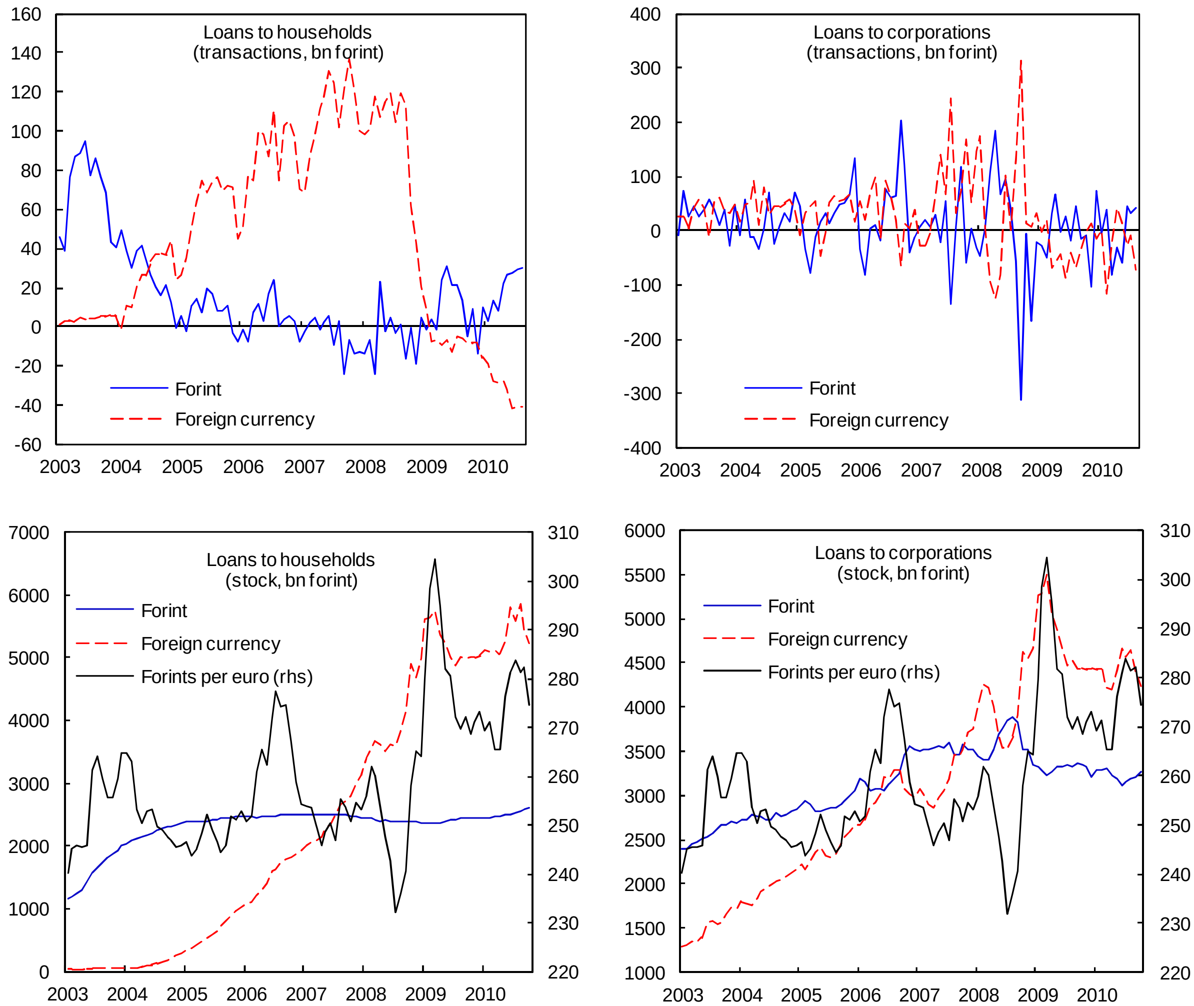
Sources: MNB; and Haver.

Figure 4. Hungary: Indebtedness—Total Stock of Liabilities
(Percent of annual GDP)



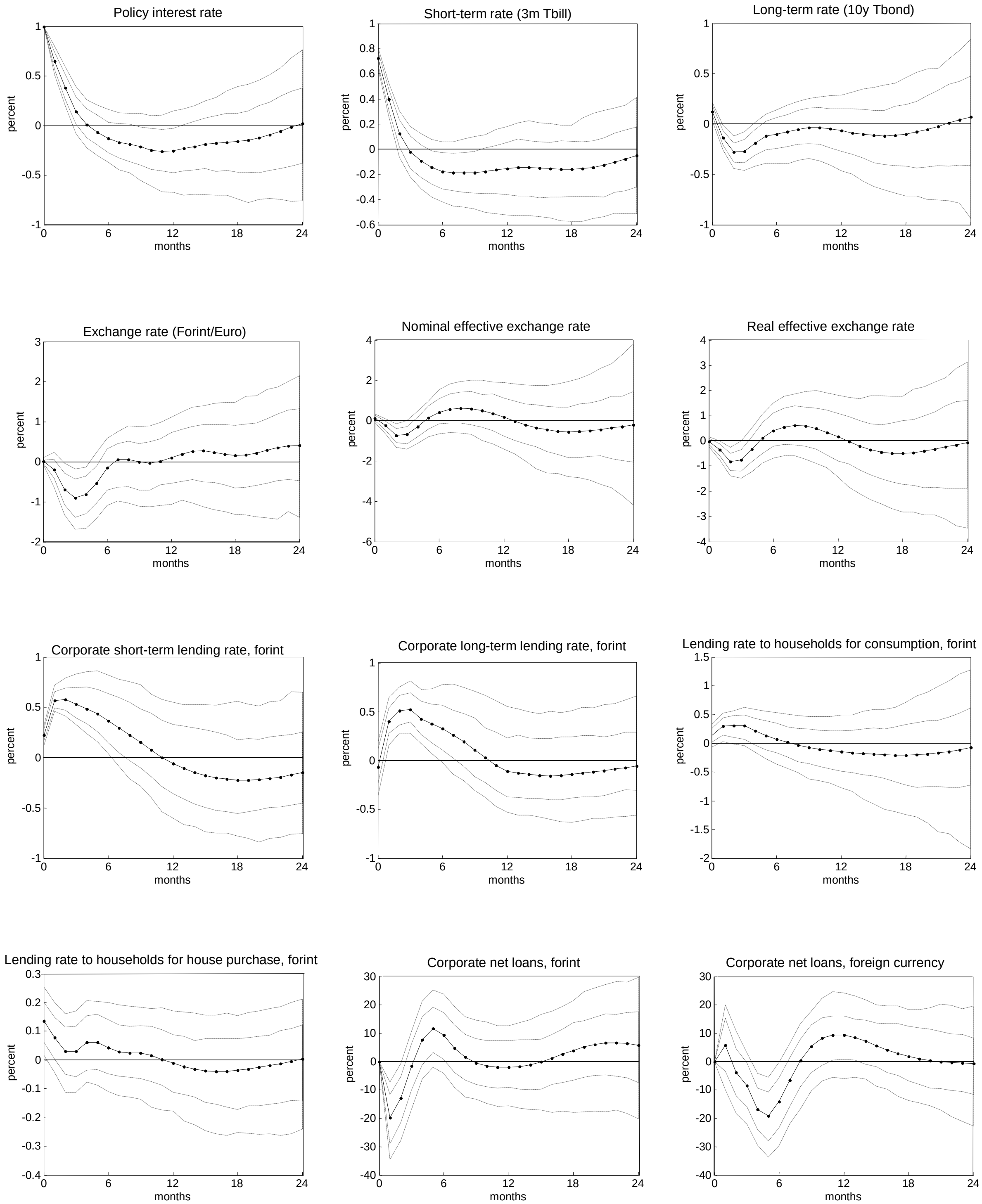
Source: MNB.

Figure 5. Hungary: Loans to the Non-Financial Private Sector



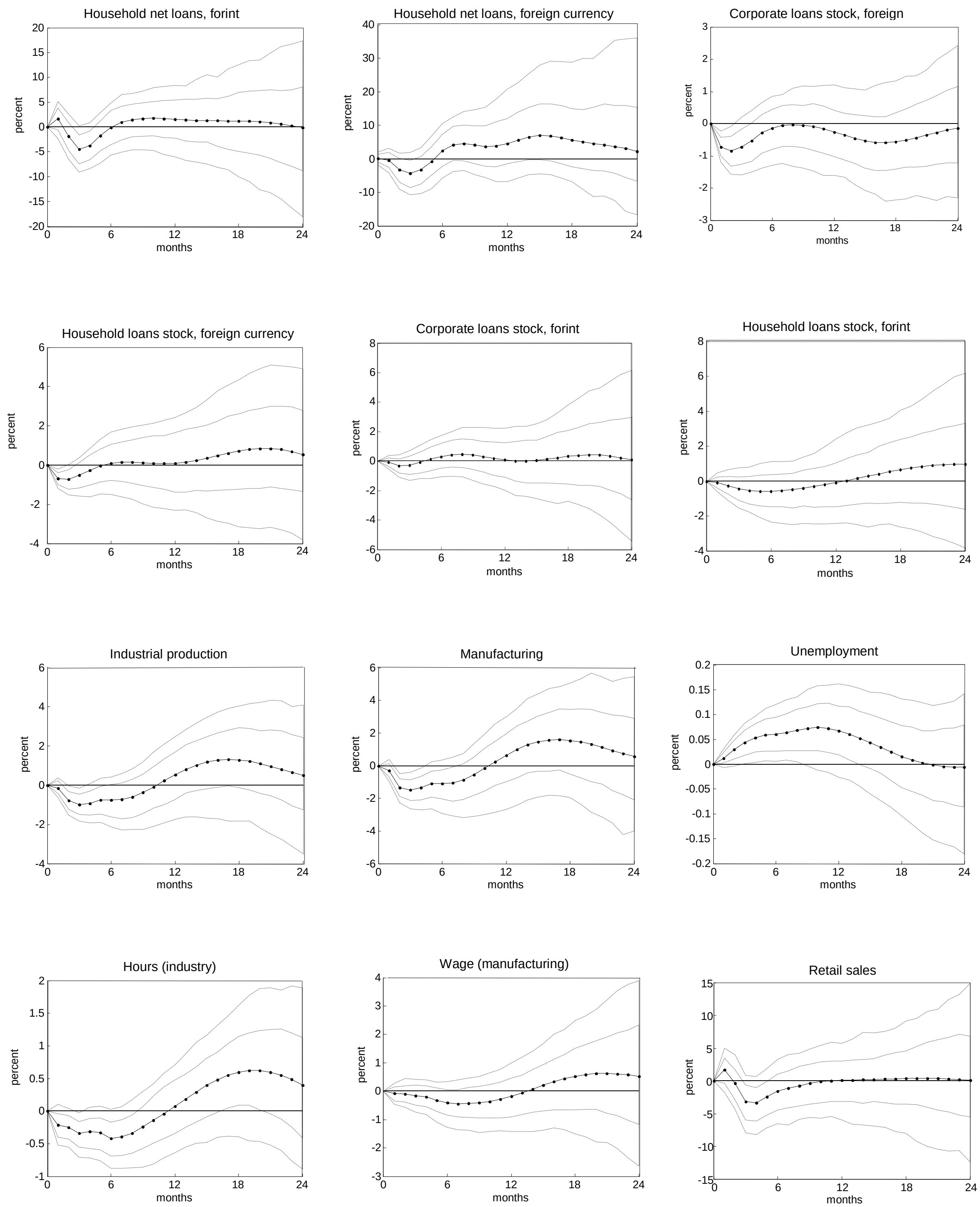
Source: MNB.

Figure 6.1. Selected Impulse Responses to a Monetary Policy Shock



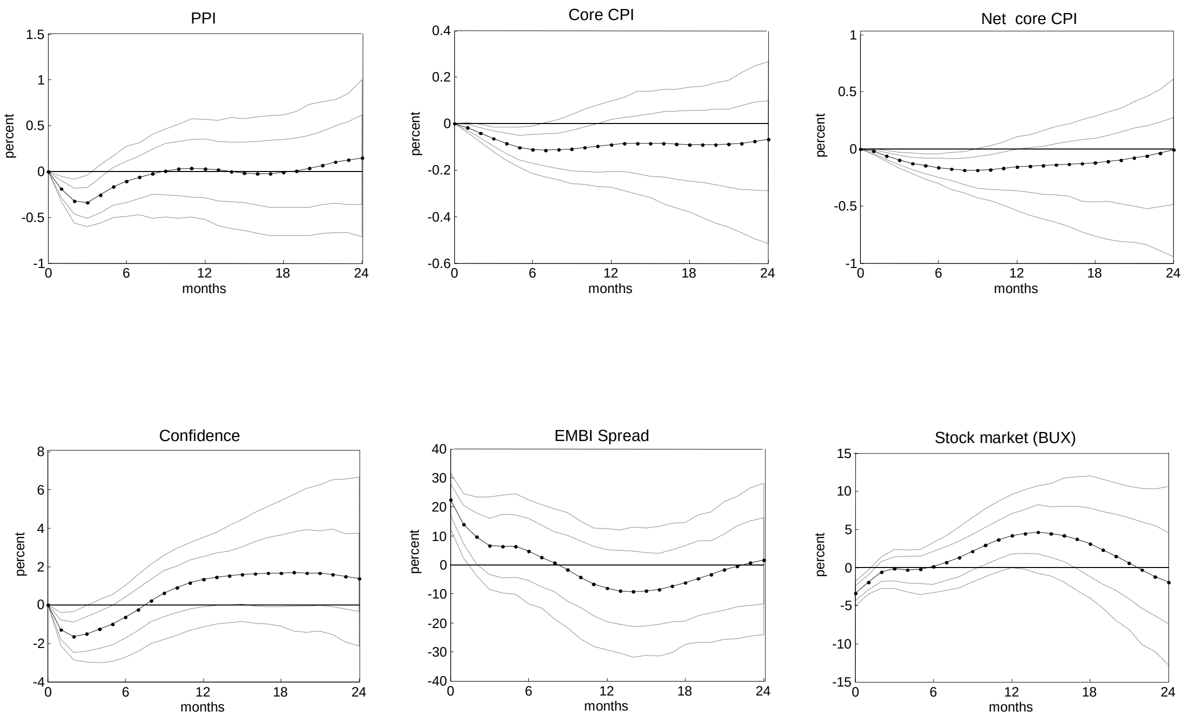
Note: The figure presents the impulse response functions to a monetary policy shocks and the corresponding posterior coverage intervals at 0.68 and 0.9 level estimate in the large BVAR.

Figure 6.2. Selected Impulse Responses to a Monetary Policy Shock



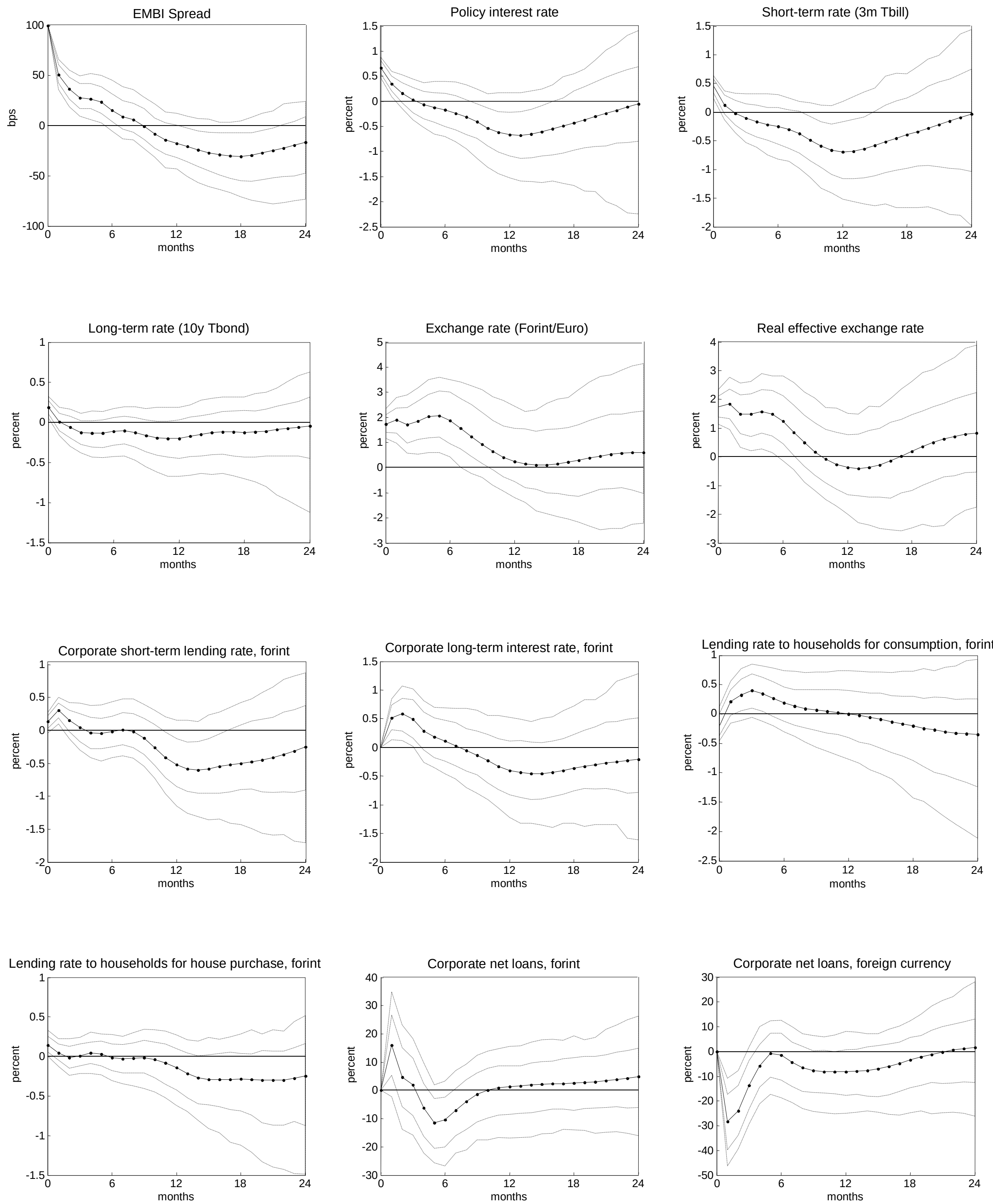
Note: The figure presents the impulse response functions to a monetary policy shocks and the corresponding posterior coverage intervals at 0.68 and 0.9 level estimate in the large BVAR.

Figure 6.3. Selected Impulse Responses to a Monetary Policy Shock



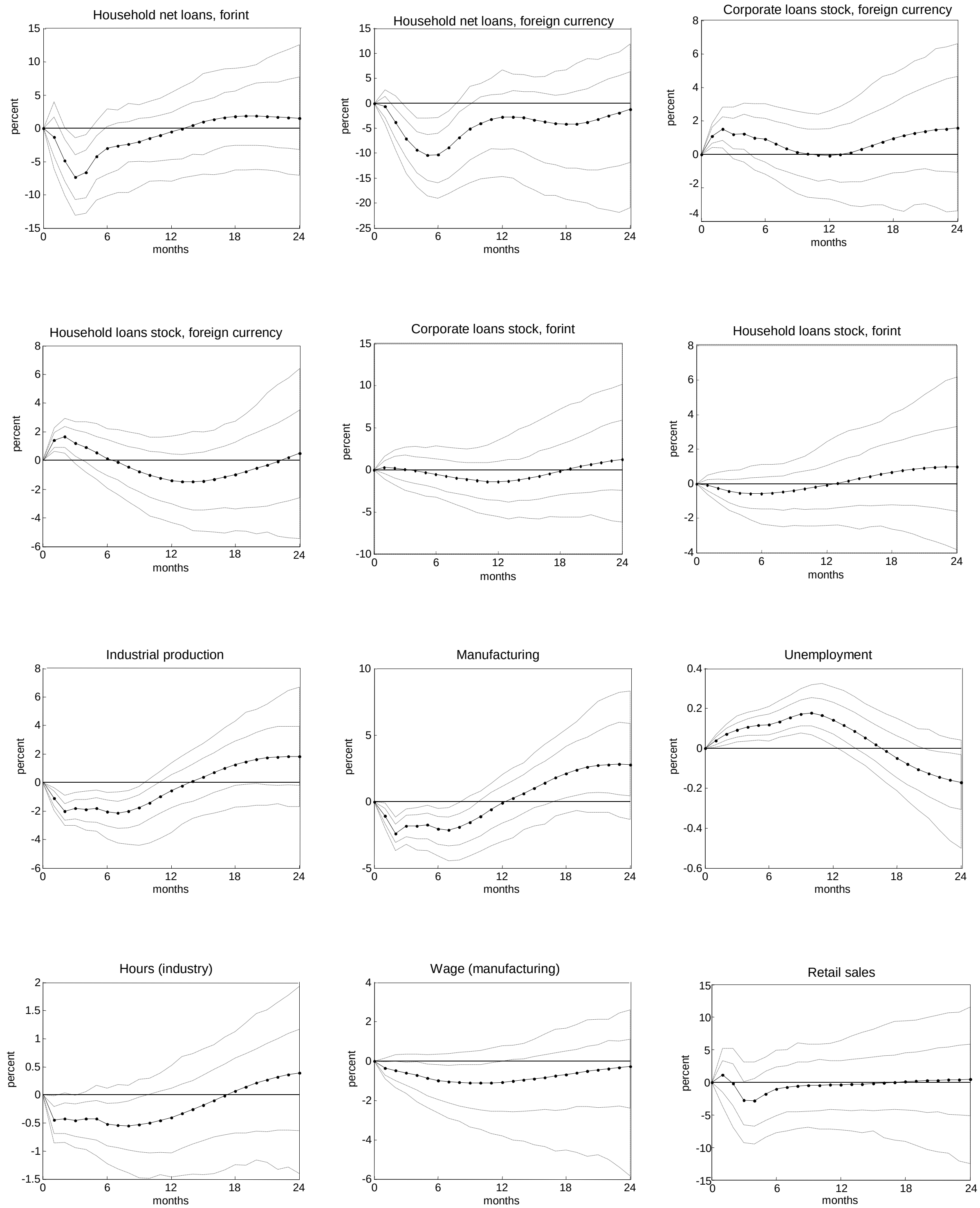
Note: The figure presents the impulse response functions to a monetary policy shocks and the corresponding posterior coverage intervals at 0.68 and 0.9 level estimate in the large BVAR.

Figure 7.1. Selected Impulse Responses to a Risk-Premium Shock



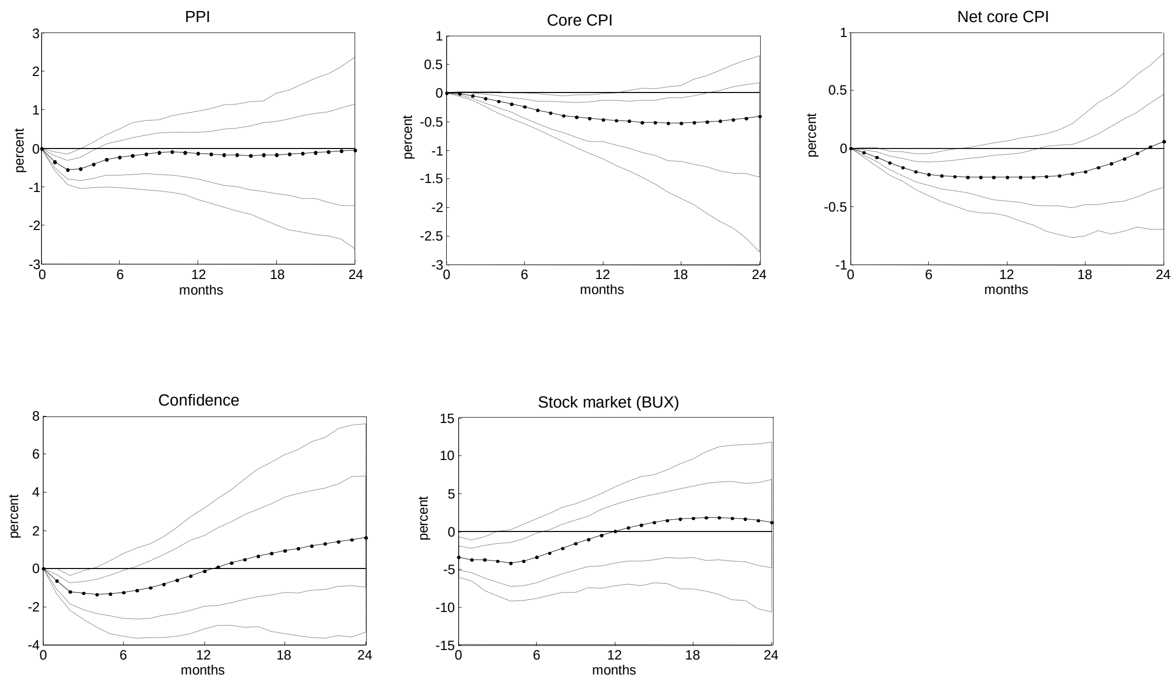
Note: The figure presents the impulse response functions to a risk-premium shock and the corresponding posterior coverage intervals at 0.68 and 0.9 level estimate in the large BVAR.

Figure 7.2. Selected Impulse Responses to a Risk-Premium Shock



Note: The figure presents the impulse response functions to a risk-premium shock and the corresponding posterior coverage intervals at 0.68 and 0.9 level estimate in the large BVAR.

Figure 7.3. Selected Impulse Responses to a Risk-Premium Shock



Note: The figure presents the impulse response functions to a risk-premium shock and the corresponding posterior coverage intervals at 0.68 and 0.9 level estimate in the large BVAR.

Table 1. Relative Mean Squared Forecast Error

Model	*Variable*	*Forecast horizon*				
		1	3	6	9	12
SMALL	IP	1.95	1.59	1.73	1.45	1.63
	CPI	1.05	1.14	1.24	1.44	1.81
	IR	1.45	1.66	1.87	1.98	2.26
	NEER	2.61	2.47	1.74	2.08	1.96
MEDIUM	IP	1.12	0.94	0.89	1.34	1.45
	CPI	0.84	0.94	1.18	1.23	1.42
	IR	1.14	0.92	1.49	1.59	1.77
	NEER	1.77	1.59	1.62	1.36	1.06
LARGE	IP	0.78	0.86	0.75	1.05	1.34
	CPI	0.62	0.51	0.67	0.86	0.95
	IR	0.77	0.85	0.98	1.13	1.37
	NEER	1.34	1.27	1.31	0.88	0.65

Appendix I: Methodology

A. Prior Distributions

In this section we describe in detail the prior specification we use (following BGR). It is based on a modified Litterman (1986) prior, which follows the by now standard modifications proposed by Kadiyala and Karlsson (1997), Sims and Zha (1998) and Robertson and Tallman (1999).

More precisely, let's consider the reduced form VAR:

$$Y_t = c + A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + u_t$$

where Y_t is a the potentially large n variable data set and u_t is a n -dimensional Gaussian white noise with covariance matrix E $u_t u_t' = \Psi$. The Minnesota prior amounts to setting the following moments for the distribution of the coefficients:

$$E[(A_k)_{ij}] = \begin{cases} \delta_i, j = i, k = 1 \\ 0, \text{ otherwise} \end{cases}, V[(A_k)_{ij}] = \begin{cases} \frac{\lambda^2}{k^2}, j = i \\ \vartheta \frac{\lambda^2}{k^2} \frac{\sigma_i^2}{\sigma_j^2}, \text{ otherwise} \end{cases}$$

The coefficients A_k are assumed to be independent and normally distributed, while the prior on the intercept is diffuse.

For all variables which exhibit high persistence, we set $\delta_i = 1$, i.e. the prior of a random walk with drift, while stationary variables are assumed to follow a white noise process, by setting $\delta_i = 0$.

The prior on the variance of the coefficients implies the assumption that more recent lags are assumed to provide more information than more distant lags and own lags have more influence than lags of other variables. The factor $\frac{1}{k^2}$ governs the (geometric) rate of decay of the information comprised by the longer lags, while the variance ratio $\frac{\sigma_i^2}{\sigma_j^2}$ accounts for the different scale and variability of the data. The coefficient $\vartheta \in (0, 1)$ governs the relative importance of the lags of other variables relative to the own lags.

The hyperparameter λ controls the overall tightness of the prior distribution around the random walk or white noise and determines the importance of the prior relative to the information from the data in extracting the posterior distribution. In particular, the lower λ , the stronger the influence of the prior (for $\lambda = 0$, the posterior equals the prior). Oppositely, for $\lambda = \infty$, the prior has no influence on the result and the posterior is equal to the result from an OLS estimation. To set λ we follow a procedure described in more detail in the following section. At this stage, we can just anticipate by mentioning that the hyperparameter λ will be very tight and will be set in relation to the cross-section of variables in the BVAR, in the senses that more variables would require more tightness in order to avoid overfitting.

While the original Litterman (1986) article assumes the covariance matrix of residuals to be diagonal $\Psi = diag(\sigma_1^2, \ldots, \sigma_n^2)$, in order to take into account the possible correlation among the residuals, we follow Kadiyala and Karlsson (1997) and Robertson and Tallman (1999) and impose a Normal inverted Wishart prior (which retains the principles of the Minnesota prior and assumes $\vartheta = 1$).

More precisely, re-writing the VAR in the more compact companion form

$$\underset{T\times n}{Y} = \underset{T\times k}{X} \ \underset{k\times n}{B} + \underset{T\times n}{U}$$

where $Y = (Y_1, \ldots, Y_T)', X = (X_1, \ldots, X_T)', X_t = (Y'_{t-1}, \ldots, Y'_{t-p}, 1), U = (u_1, \ldots, u_T)'$ and $B = (A_1, \ldots, A_p, c)'$ and $k = np + 1$.

The Normal inverted Wishart prior has the form

$$vec(B)|\Psi \sim N(vec(B_0), \Psi \otimes \Omega_0) \text{ and } \Psi \sim iW(S_0, \alpha_0)$$

where the prior parameters $B_0, \Omega_0, S_0, \alpha_0$ are chosen such that prior expectations and variances of B coincide with those implied by the Minnesota prior and the expectation of Ψ is equal to the fixed residual covariance matrix of the Minnesota prior (for details see Kadiyala and Karlsson, 1997).

The implementation of the prior is done by adding dummy observations. It can be shown that adding T_d dummy observations Y_d and X_d is equivalent to imposing the Normal inverted Wishart prior with:

$$B_0 = (X'_d X_d)^{-1} X'_d Y_d, \Omega_0 = (X'_d X_d)^{-1}, S_0 = (Y_d - X_d B_0)'(Y_d - X_d B_0) \text{ and } \alpha_0 = T_d - k.$$

The dummies are defined in the following way, in order to match the moments of the Minnesota prior:

$$Y_d = \begin{pmatrix} diag(\delta_1\sigma_1,\ldots,\delta_n\sigma_n)/\lambda \\ 0_{n(p-1)\times n} \\ \ldots \\ diag(\sigma_1,\ldots,\sigma_n) \\ \ldots \\ 0_{1\times n} \end{pmatrix} \quad X_d = \begin{pmatrix} J_p \otimes diag(\sigma_1,\ldots,\sigma_n)/\lambda & 0_{np\times 1} \\ & \ldots \\ 0_{n\times np} & 0_{n\times 1} \\ & \ldots \\ 0_{1\times np} & \epsilon \end{pmatrix}$$

where $J_p = diag(1,2,\ldots,p)$.

We follow common practice (see e.g. Litterman, 1986, Sims and Zha, 1998) and set the scale parameters σ_i^2 equal the variance of a residual from a univariate autoregressive model of order p for the variables y_{it} .

The regression model augmented with the dummies can be written as:

$$\underset{T_*\times n}{Y_*} = \underset{T_*\times k}{X_*} \underset{k\times n}{B} + \underset{T_*\times n}{U_*}$$

where $T_* = T + T_d, Y_* = (Y', Y_d'), X_* = (X', X_d')$ and $U_* = (U', U_d')$. To insure the existence of the prior expectation of Ψ it is necessary to add an improper prior $\Psi \sim |\Psi|^{-(n+3)/2}$. With this, the posterior distributions can be shown to be also Normal-Inverted Wishart, more specifically:

$$vec(B)|\Psi, Y \sim N(vec(\widetilde{B}), \Psi \otimes (X_*'X_*)^{-1}) \text{ and } \Psi/Y \sim iW(\widetilde{\Sigma}, T_d + 2 + T - k)$$

where $\widetilde{B} = (X_*'X_*)^{-1}X_*'Y_*$ and $\widetilde{\Sigma} = (Y_* - X_*\widetilde{B})'(Y_* - X_*\widetilde{B})$. It can be easily checked that this corresponds to the posterior mean from the Minnesota prior. Computationally, adding the dummy observations acts as a regularization device to the matrix inversion problem (the dimension of the matrix is $k = np + 1$).

We also use a prior on the sum of the coefficients, as the literature suggests that this can improve forecasting performance (see e.g. Sims, 1992, Sims and Zha, 1998, Robertson and Tallman, 1999). BGR also show that this prior improved forecasting performance for certain variables in the large BVAR. This is implemented in the following way.

Re-writing the VAR in error correction form
$\Delta Y_t = c - (I_n - A_1 - \ldots - A_p)Y_{t-1} + B_1 \Delta Y_{t-1} + \ldots + B_{p-1}\Delta Y_{t-p+1} + u_t$

The sum of coefficients prior implies the restriction $I_n - A_1 - \ldots - A_p = 0,$ i.e. restricts the sum of lagged AR coefficients to be equal to one. Following Doan et al. (1984), we set a prior that shrinks $\Pi = I_n - A_1 - \ldots - A_p$ to 0 . The implementation of the prior is done adding the following dummy observations

$$Y_d = diag(\delta_1 \mu_1, \ldots, \delta_n \mu_n)/\tau \quad X_d = \left((1\ 2 \ldots p) \otimes diag(\delta_1 \mu_1, \ldots, \delta_n \mu_n)/\tau \ \ 0_{n \times 1}\right)$$

The hyperparameter c controls for the degree of shrinkage: as $\tau \to 0$, we approach the case of exact differences and as $\tau \to \infty$, we are back to the case with no shrinkage on the sum of coefficients. The parameters μ_i , which aim to capture the average level of variable y_{it} , are set equal to the sample average of y_{it} , as in Sims and Zha (1998). τ is set to be relatively loose in relationship to λ, i.e. $\tau = 10\lambda$ (however, the proportionally coefficient does not turn out to be critical, as experiments with different values from 1 to 100 show).

B. Model Selection: the Tightness of the Prior

We use a training sample, the first half of the sample, to set the overall tightness hyperparameter λ . More specifically, we compute the average in-sample fit in the small model for the 4 variables of interest (IP, IR, CPI and NEER) in the pre-sample. We then do a grid search for the larger model m to find the degree of shrinkage so that the large model generates as close as possible an in-sample fit. The idea, as mentioned before, it that we need an algorithm to allow us to shrink more as more variables are added to the model. This approach, which follows the suggestion in BGR, simply penalizes the larger model for lack of parsimony and insures comparability across specifications of different cross-sectional size.

More specifically, the procedure follows these steps:

1. Set the training sample (the first half of the sample) and compute the average in-sample fit for the 4 variables in the "small" VAR (IP, IR, CPI and NEER), defined as

$$Fit = \frac{1}{4} \sum_i \frac{MSFE_i^{(\lambda,m)}}{MSFE_i^{(0)}} \Bigg|_{\lambda=\infty, m=SMALL}$$

Where

$$MSFE_i^{(\lambda,m)} = \frac{1}{T-p-1} \sum_{t=p}^{T-2} (y_{i,t+1|t}^{(\lambda,m)} - y_{i,t+1})^2$$

is the one-step-ahead mean squared forecast error evaluated using the training samples *t=1,…,T-1.*

2. Define a large grid for λ. Set the prior on the sum of the coefficients $\tau = k * \lambda$, where k

is a proportionality coefficient (as in the original paper, we experiment with $k = 0.01, 0.1, 1$ without affecting the results).

3. Estimate the Bayesian VAR to get the fit corresponding to each prior λ

4. Search for λ yielding the desired fit, that is

$$\lambda_m(Fit) = \arg \min_{\lambda} \left| Fit - \frac{1}{4} \sum_i \frac{MSFE_i^{(\lambda,m)}}{MSFE_i^{(0)}} \right|$$

C. Forecast Evaluation

We consider a training sample between T_0 and T_1 which we use to estimate the model. We then construct h -step ahead forecasts (*H* is the longest horizon to be evaluated), using all available observations at each point in time. Let's denote by $\hat{y}_{i,T+h|T}^{(\lambda,m)}$ the h -step ahead forecast for variable i from model m with overall tightness λ , which is estimated using the posterior mean of the parameters.

We evaluate forecast accuracy in terms of the relative mean squared forecast error compared to the benchmark model (which is the naive random walk model for which the prior restriction is imposed exactly, i.e. $\lambda = 0$), i.e.

$$MSFE_{i,h}^{(\lambda,m)} = \frac{MSFE_{i,h}^{(\lambda,m)}}{MSFE_{i,h}^{(0)}}$$

The mean squared forecast error is given by

$$MSFE_{i,h}^{(\lambda,m)} = \frac{1}{T_1 - T_0 - H + 1} \sum_{T=T_0+H-h}^{T_1-h} (\hat{y}_{i,T+h|T}^{(\lambda,m)} - y_{i,T+h})^2$$

If $RMSFE_{i,h}^{(\lambda,m)} < 1$ then the model m performs better than the benchmark, which is the naive prior model.

Appendix II: Data

The data come from the standard sources, the National Statistic Agency and the Hungarian Central Bank. Wherever available and applicable, seasonally (and working day) adjusted have been used, adjustment performed by the source, and are expressed in real-terms. The loan data are not seasonally adjusted, reflect end-of-period information and are expressed in HUF. The lending rates for households are computed as monthly average agreed interest rate of HUF loans and HUF deposits to households weighted by the amount of new business. The following transformations have been applied to the series: 1=no transformation, 2= log multiplied by 100. Note that, unlike in papers estimating factor models (e.g. Stock and Watson, 2002), we do not need to transform the data to stationarity, instead, we preserve the information in the trends.

No	Variable	Transformation
	Real activity	2
1	Industrial Production: Industry Including Construction	2
2	Industrial Production: Mining and Quarrying; Manufacturing	2
3	Industrial Production: Manufacturing	2
4	Industrial Production: Food, Beverage and Tobacco Products	2
5	Industrial Production: Textiles and Wearing Apparel	2
6	Industrial Production: Leather and Related Products	2
7	Industrial Production: Wood Products Ex Furniture	2
8	Industrial Production: Paper, Printing and Reproduction of Recreational Media	2
9	Industrial Production: Chemicals, Basic Pharmaceutical Products	2
10	Industrial Production: Rubber and Plastic Products	2
11	Industrial Production: Other Non-Metallic Mineral Products	2
12	Industrial Production: Basic Metals/Metal Prods, Ex Machinery/Equipment	2
13	Industrial Production: Computer, Electronic and Optical Equipment	2
14	Industrial Production: Machinery and Equipment n.e.c.	2
15	Industrial Production: MV, Trailers and Other Transport Equipment	2
16	Industrial Production: Furniture; Other Manufacturing	2
17	Industrial Production: Repair and Installation of Machinery and Equipment	2
18	Construction Output	2
19	Building Permits: Residential Ex. Community Residences	2
20	Building Permits: Office Buildings	2
21	Building Permits: Non-Residential Ex Office Buildings	2
22	Retail Sales Volume Index: Adjusted for Calendar Effects	2
23	Retail Trade: Non-Food Products Incl Fuel	2
24	Retail Trade Excluding Autos and Motorcycles	2
25	Retail Trade: Food, Beverages and Tobacco	2
26	Retail Trade: Automotive Fuel at Gas Stations	2
27	Retail Trade: Clothing and Footwear	2
28	Retail Trade: Pharmaceutical and Cosmetic Goods	2
29	Retail Trade: Computers/Software, Telecom Equipment	2
30	Retail Trade: AV Equipment, Hardware and Household Appliances	2
	Labor market	
31	Unemployment Rate	1
32	Wages and Salaries: Industry Excl Construction	2
33	Wages and Salaries: Industry Excluding Energy	2
34	Wages and Salaries: Mining, Mfg and Energy	2
35	Wages and Salaries: Intermediate and Capital Goods	2

36	Wages and Salaries: Consumer Goods	2
37	Wages and Salaries: Energy	2
38	Wages and Salaries: Mining and Manufacturing	2
39	Wages and Salaries: Mining and Quarrying	2
40	Wages and Salaries: Manufacturing	2
41	Hours Worked: Industry Excluding Construction	1
42	Hours Worked: Industry Excluding Energy	1
43	Hours Worked: Mining, Manufacturing and Energy	1
44	Hours Worked: Intermediate and Capital Goods	1
45	Hours Worked: Consumer Goods	1
46	Hours Worked: Energy	1
47	Hours Worked: Mining and Manufacturing	1
48	Hours Worked: Mining and Quarrying	1
49	Hours Worked: Manufacturing	1
50	Hours Worked: Electricity/Gas/Steam and Water/Waste Management	1
	Confidence indicators	
51	IFO climate	1
52	IFO situation	1
53	IFO expectations	1
54	EABCI	1
55	Economic Sentiment Indicator	1
56	Industrial Confidence Indicator, Percent Balance	1
57	Consumer Confidence Indicator, Percent Balance	1
58	Retail Trade Confidence Indicator, Percent Balance	1
59	Construction Confidence Indicator, Percent Balance	1
	Prices	
60	Consumer Price Index (CPI)	1
61	CPI-Food	1
62	CPI-Alcoholic Beverages and Tobacco	1
63	CPI-Clothing and Footwear	1
64	CPI-Consumer Durable Goods	1
65	CPI-Electricity, Gas and Other Fuels	1
66	CPI-Other Goods Including Motor Fuels and Lubricants	1
67	CPI-Services	1
68	Core CPI	1
69	Core CPI net of indirect taxes	1
70	Producer price index	1
	Monetary and credit aggregates	
71	M1	2
72	M2	2
73	M3	2
74	MFI Loans to Non-Financial Corporations	2
75	MFI Loans to Other Financial Intermediary and Financial Corporations	2
76	MFI Loans to General Government	2
77	MFI Loans to Households	2
78	Loans to Non-Financial Corporations, Transactions, HUF	2
79	Loans to Non-Financial Corporations: Transactions, FX	2
80	Loans to Households, Transactions, HUF	2
81	Loans to Households, Transactions, FX	2
82	Loans to Non-Financial Corporations, Stock, HUF	2
83	Loans to Non-Financial Corporations, Stock, FX	2
84	Loans to Households, Stock, HUF	2
85	Loans to Households, Stock, FX	2

	Interest rates	
86	Monetary Policy Interest Rate	1
87	Yield on 10 Year Government Debt securities	1
88	Yield on 3-Month Government Debt Securities	1
89	Lending Rate to Nonfinancial Corporations: Short-term	1
90	Lending Rate to Nonfinancial Corporations: Long-term	1
91	Lending Rate to Households - Loans for consumption	1
92	Lending Rates to Households - Loans for house purchase	1
93	JPM EMBI Global Hungary - blended spread	1
94	JPM EMBI Global Hungary - blended yield to maturity	1
95	BSE: Market Index: Budapest Stock Index (BUX)	2
96	Nominal effective exchange rate, all countries	2
97	Real effective exchange rate, CPI based, all countries	2
98	Forint/Euro exchange rate	2
	External environment	2
99	Germany: Industrial Production: Total Industry including Construction	2
100	Germany: Ifo Business Climate Index: All Sectors	2
101	Germany: Imports of Goods	2
102	Euro Area11-16: Main Refinancing Operations: Minimum Bid Rate (EOP, %)	1
103	World: Industrial Production ex Construction (Import-Weighted)	2
104	Germany: Capital Market Indexes: DAX	2
105	World: MSCI Share Price Index, US$ (EOP)	2
106	World: Import Volume	2
107	All primary commodities price index	1
108	Non-fuel primary commodities	1
109	Energy price index	1
110	APSP petroleum price index	1
111	Raw materials price index	1

Appendix III: Detailed Results

Table 1. Full Model Impulse Response and Variance Decomposition—Monetary Policy Shock

		Impulse Response					Variance Decomposition				
	Horizon (months)	0	3	6	12	24	0	3	6	12	24
1	Industrial Production: Industry Including Construction	0	-1.03	-0.83	0.18	0.30	0	0.38	0.64	2.46	3.75
2	Industrial Production: Mining and Quarrying	0	-0.48	-0.48	-0.10	0.00	0	0.33	0.58	2.54	3.38
3	Industrial Production: Manufacturing	0	-1.75	-1.05	0.13	0.29	0	0.24	0.44	2.45	4.34
4	Industrial Production: Food, Beverage and Tobacco	0	-0.26	-0.13	0.03	0.29	0	0.12	0.17	1.14	3.30
5	Industrial Production: Textiles and Wearing Apparel	0	-0.69	-0.61	-0.61	0.17	0	0.41	0.68	1.93	4.72
6	Industrial Production: Leather and Related Products	0	-0.27	-0.45	0.27	0.46	0	0.04	0.07	1.28	3.57
7	Industrial Production: Wood Products Ex Furniture	0	-1.17	-1.39	0.23	0.15	0	0.40	0.94	2.83	3.85
8	Industrial Production: Paper, Printing and Reproduction Recreational Media	0	-0.11	0.20	0.35	0.43	0	0.05	0.06	0.19	1.58
9	Industrial Production: Chemicals, Basic Pharmaceutical Products	0	-1.24	-1.02	-0.17	0.06	0	0.71	1.23	1.20	2.85
10	Industrial Production: Rubber and Plastic Products	0	-0.90	-0.94	-0.29	0.03	0	0.45	0.88	1.97	2.70
11	Industrial Production: Other Non-Metallic Mineral Products	0	-0.38	-0.31	0.16	0.12	0	0.10	1.13	3.11	3.19
12	Industrial Production: Basic Metals/Metal Products,Ex Machinery/Equipment	0	-0.81	-1.30	-0.83	0.13	0	0.41	0.99	1.46	2.94
13	Industrial Production: Computer, Electronic and Optical Equipment	0	-1.14	-0.24	0.66	0.69	0	0.81	1.03	3.21	4.04
14	Industrial Production: Machinery and Equipment n.e.c.	0	-1.34	-0.92	0.14	0.48	0	0.06	1.07	3.06	4.22
15	Industrial Production: MV, Trailers and Other Transp Equipment	0	-0.78	-1.17	-0.67	-0.15	0	0.15	0.47	1.78	3.42
16	Industrial Production: Furniture; Other Manufacturing	0	-0.31	-0.05	-0.01	1.02	0	0.16	0.12	1.08	2.54
17	Industrial Production: Repairand Installation Machinery and Equipment	0	0.62	0.18	0.14	-0.05	0	0.10	0.78	1.07	3.10
18	Construction Output	0	-1.25	-0.93	-0.45	0.15	0	0.45	0.85	2.56	4.16
19	Building Permits: Residential Ex. Community Residen.	0	0.21	-0.31	-0.64	0.64	0	0.08	0.79	2.26	3.34
20	Building Permits: Office Buildings	0	-0.23	-0.71	-0.54	-0.05	0	0.10	0.81	2.11	4.12
21	Building Permits: Non-Residential Ex Office Buildings	0	-0.71	-1.30	-0.43	0.09	0	0.06	1.19	2.32	3.55
22	Retail Sales Volume Index: Adjusted for Cal. Effects	0	-3.37	-1.22	0.03	0.01	0	0.02	1.02	3.04	5.17
23	Retail Trade: Non-Food Products Incl Fuel	0	-3.14	-1.14	-0.13	0.22	0	0.21	1.45	2.55	4.53
24	Retail Trade Excluding Autos and Motorcycles	0	-0.11	-0.14	-0.15	0.18	0	0.16	0.50	2.84	3.68
25	Retail Trade: Food, Beverages and Tobacco	0	-0.06	-0.13	-0.14	0.08	0	0.06	2.36	3.88	4.70
26	Retail Trade: Automotive Fuel at Gas Stations	0	-2.04	-1.01	-0.57	-0.02	0	0.01	1.01	4.01	3.04
27	Retail Trade: Clothing and Footwear	0	-1.71	-1.05	-0.08	0.12	0	0.09	2.08	3.09	5.10
28	Retail Trade: Pharmaceutical and Cosmetic Goods	0	-2.48	-1.13	-0.52	0.17	0	0.00	1.02	2.22	4.27

29	Retail Trade: Computers/Software, Telecom Equipment	0	-3.46	-2.16	-0.51	0.04	0	0.02	1.06	3.09	4.12
30	Retail Trade: AV Equipment, Hardware and Households Appliances	0	-3.26	-1.35	-0.20	0.09	0	0.12	1.30	3.45	4.39
31	Unemployment Rate	0	0.42	0.64	0.66	-0.01	0	0.33	1.08	2.64	4.80
32	Wages and Salaries: Industry Excl Construction	0	-0.07	-0.36	-0.14	0.44	0	0.03	0.31	0.88	2.25
33	Wages and Salaries: Industry Excluding Energy	0	-0.06	-0.11	-0.05	0.26	0	0.01	0.75	2.09	2.33
34	Wages and Salaries: Mining, Mfg and Energy	0	-0.04	-0.13	-0.10	0.21	0	0.01	0.64	1.13	1.24
35	Wages and Salaries: Intermediate and Capital Goods	0	-0.05	-0.16	-0.09	0.30	0	0.01	0.56	1.15	2.43
36	Wages and Salaries: Consumer Goods	0	0.13	0.13	0.10	0.13	0	0.02	0.35	0.67	1.15
37	Wages and Salaries: Energy	0	-0.13	-0.23	-0.23	0.04	0	0.01	0.33	1.09	1.51
38	Wages and Salaries: Mining and Manufacturing	0	-0.09	-0.21	-0.18	0.12	0	0.02	0.71	2.28	3.21
39	Wages and Salaries: Mining and Quarrying	0	-0.59	-0.76	-0.84	0.60	0	0.08	0.19	1.42	1.34
40	Wages and Salaries: Manufacturing	0	-0.12	-0.42	-0.20	0.52	0	0.02	0.48	1.23	2.18
41	Hours Worked: Industry Excluding Construction	0	-0.37	-0.42	-0.06	0.21	0	0.33	1.65	1.80	3.97
42	Hours Worked: Industry Excluding Energy	0	-0.38	-0.32	0.05	0.21	0	0.62	1.72	2.89	4.05
43	Hours Worked: Mining, Manufacturing and Energy	0	-0.38	-0.20	-0.06	0.32	0	0.25	0.53	2.70	3.90
44	Hours Worked: Intermediate and Capital Goods	0	-0.32	-0.26	-0.11	0.27	0	0.23	1.51	2.71	2.83
45	Hours Worked: Consumer Goods	0	-0.15	-0.12	0.02	0.12	0	0.20	0.34	0.38	2.67
46	Hours Worked: Energy	0	-0.12	-0.09	0.01	0.06	0	0.13	1.24	2.23	3.23
47	Hours Worked: Mining and Manufacturing	0	-0.18	-0.21	-0.06	0.22	0	0.24	1.50	1.66	2.86
48	Hours Worked: Mining and Quarrying	0	0.03	-0.04	-0.18	0.08	0	0.02	1.02	1.15	3.22
49	Hours Worked: Manufacturing	0	-0.38	-0.40	-0.06	0.22	0	0.24	1.50	3.65	3.86
50	Hours Worked: Electricity/Gas/Steam and Water/Waste	0	-0.12	-0.09	0.01	0.05	0	0.69	2.17	3.17	4.16
51	IFO climate	0	-0.52	-0.73	-0.06	0.07	0	0.26	0.66	0.62	0.51
52	IFO situation	0	-1.88	-0.54	1.13	1.17	0	0.18	0.74	1.01	0.72
53	IFO expectations	0	-0.51	-0.55	0.58	0.49	0	0.19	0.35	0.33	0.42
54	EABCI	0	-0.53	-0.94	-0.31	0.37	0	0.20	0.53	0.50	0.48
55	Economic Sentiment Indicator	0	-0.31	-0.63	-0.10	0.01	0	0.03	0.11	0.38	0.86
56	Industrial Confidence Indicator, Percent Balance	0	-0.22	-0.43	-0.08	0.04	0	0.05	0.23	0.34	0.75
57	Consumer Confidence Indicator, Percent Balance	0	-0.19	-0.26	-0.10	0.12	0	0.02	0.24	0.47	0.56
58	Retail Trade Confidence Indicator, Percent Balance	0	-0.05	-0.28	-0.08	0.22	0	0.04	0.16	0.67	0.75
59	Construction Confidence Indicator, Percent Balance	0	-0.24	-0.39	-0.11	0.44	0	0.09	0.17	0.30	0.70
60	Consumer Price Index (CPI)	0	-0.10	-0.12	-0.03	-0.15	0	0.00	0.14	0.25	0.50
61	CPI-Food	0	-0.10	-0.16	-0.17	-0.24	0	0.06	0.16	0.27	1.05
62	CPI-Alcoholic Beverages and Tobacco	0	-0.08	-0.09	-0.03	-0.09	0	0.11	0.30	0.44	0.62
63	CPI-Clothing and Footwear	0	-0.34	-0.13	-0.06	0.03	0	0.19	0.33	0.34	0.52
64	CPI-Consumer Durable Goods	0	-0.06	-0.08	-0.12	-0.03	0	0.10	0.26	0.59	0.65
65	CPI-Electricity, Gas and Other Fuels	0	-0.31	-0.30	-0.09	-0.13	0	0.10	0.24	0.32	0.85
66	CPI-Other Goods Including Motor Fuels and Lubricants	0	-0.12	-0.13	-0.08	-0.10	0	0.11	0.19	0.27	0.35
67	CPI-Services	0	-0.10	-0.10	-0.08	-0.19	0	0.15	0.32	0.37	0.56
68	Core CPI	0	-0.08	-0.12	-0.08	-0.06	0	0.06	0.25	0.56	0.89
69	Core CPI net of indirect taxes	0	-0.10	-0.17	-0.09	-0.01	0	0.36	0.45	0.69	0.77
70	Producer price index	0	-0.37	-0.12	0.03	0.14	0	0.14	0.30	0.57	0.78
71	M1	0	-0.50	-0.14	-0.05	0.27	0	0.23	0.43	1.42	2.48

72	M2	0	-0.46	-0.14	0.01	0.10	0	0.16	0.18	1.01	2.05
73	M3	0	-0.19	-0.03	0.09	0.03	0	0.26	0.49	1.04	2.05
74	MFI Loans to Non-Financial Corporations	0	-0.46	-0.15	-0.21	-0.07	0	0.25	1.24	0.88	0.97
75	MFI Loans to Other Financial Intermediary and Financial Corporations	0	-0.60	-0.32	-0.28	0.36	0	0.38	1.34	1.25	0.92
76	MFI Loans to General Government	0	0.00	0.65	0.44	-0.23	0	0.00	0.32	0.56	0.10
77	MFI Loans to Households	0	-0.46	0.09	0.10	0.40	0	0.27	1.23	1.21	0.73
78	Loans to Non-Financial Corporations, Transactions, HUF	0	-2.59	9.15	2.87	7.31	0	1.42	2.48	2.37	2.75
79	Loans to Non-Financial Corporations: Transactions, FX	0	-9.67	-15.89	9.01	-0.57	0	0.35	1.75	2.45	1.03
80	Loans to Households, Transactions, HUF	0	-5.14	-0.47	1.60	-0.41	0	1.13	3.63	1.43	1.63
81	Loans to Households, Transactions, FX	0	-5.16	3.32	4.47	2.29	0	0.65	2.54	1.43	0.54
82	Loans to Non-Financial Corporations, Stock, HUF	0	-0.32	0.21	0.09	0.10	0	0.22	1.13	1.17	0.82
83	Loans to Non-Financial Corporations, Stock, FX	0	-0.77	-0.18	-0.29	-0.18	0	0.37	1.09	1.10	0.51
84	Loans to Households, Stock, HUF	0	-0.53	-0.67	-0.07	0.89	0	0.11	1.16	1.13	1.06
85	Loans to Households, Stock, FX	0	-0.65	0.09	0.08	0.45	0	0.43	1.01	1.03	0.95
85	Monetary Policy Interest Rate	1.00	0.19	-0.18	-0.23	0.03	20.82	20.61	19.72	18.30	15.00
87	Yield on 10 Year Government Debt securities	0.15	-0.32	-0.15	-0.08	0.09	0.06	1.04	2.60	3.94	4.86
88	Yield on 3-Month Government Debt Securities	0.74	-0.06	-0.18	-0.17	-0.05	11.85	10.41	9.13	8.06	7.23
89	Lending Rate to Nonfinancial Corporations: Short-term	0.23	0.51	0.37	-0.05	-0.17	4.07	3.43	3.04	2.78	2.64
90	Lending Rate to Nonfinancial Corporations: Long-term	-0.03	0.51	0.30	-0.09	-0.05	0.09	0.69	0.93	1.93	2.87
91	Lending Rate to Households - Loans for consumption	0.21	0.32	0.01	-0.14	-0.06	6.06	4.10	4.48	3.47	3.32
92	Lending Rates to Households - Loans for house purchase	0.14	0.04	0.06	-0.03	0.00	0.25	1.03	2.06	4.08	5.07
93	JPM EMBI Global Hungary - blended spread	22.54	7.59	5.67	-8.08	1.16	6.42	6.07	5.71	5.40	5.21
94	JPM EMBI Global Hungary - blended yield to maturity	0.37	0.16	0.12	-0.02	0.02	10.99	10.25	9.50	8.86	8.46
95	BSE: Market Index: Budapest Stock Index (BUX)	-4.23	-0.37	0.45	4.27	-2.76	4.40	4.14	3.86	3.64	3.45
96	Nominal effective exchange rate, all countries	0.02	-0.83	0.46	0.10	-0.28	0.00	0.11	0.45	0.68	0.70
97	Real effective exchange rate, CPI based, all countries	-0.04	-0.86	0.56	0.13	-0.07	0.02	0.15	0.55	0.85	0.92
98	Forint/Euro exchange rate	-0.04	-0.97	-0.13	0.14	0.29	0.27	0.53	1.02	1.32	1.38

Table 2. Full Model Impulse Response and Variance Decomposition—Risk-Premium Shock

		Impulse Response					Variance Decomposition				
	Horizon (months)	0	3	6	12	24	0	3	6	12	24
1	Industrial Production: Industry Including Construction	0	-1.95	-1.98	-0.47	1.92	0	1.88	3.55	5.63	6.54
2	Industrial Production: Mining and Quarrying	0	-2.59	-2.57	-0.30	2.28	0	1.34	2.54	4.55	6.52
3	Industrial Production: Manufacturing	0	-2.09	-2.15	-0.27	2.39	0	2.23	4.38	5.41	7.38
4	Industrial Production: Food, Beverage and Tobacco	0	-2.36	-2.48	-0.46	2.75	0	2.13	0.35	0.58	0.60
5	Industrial Production: Textiles and Wearing Apparel	0	-1.97	-2.20	-1.21	-0.18	0	2.50	1.02	1.60	1.67
6	Industrial Production: Leather and Related Products	0	-1.29	-1.30	-1.09	-1.15	0	1.02	0.03	0.03	0.03
7	Industrial Production: Wood Products Ex Furniture	0	-2.05	-2.66	-1.32	-0.41	0	1.89	2.01	2.31	2.25
8	Industrial Production: Paper, Printing and Reproduction Recreational Media	0	-0.77	-0.40	0.76	1.03	0	2.02	0.08	0.34	0.40
9	Industrial Production: Chemicals, Basic Pharmaceutical Products	0	-2.71	-2.63	-0.66	0.17	0	1.84	1.47	1.64	1.60
10	Industrial Production: Rubber and Plastic Products	0	-0.84	-0.82	-0.24	0.20	0	2.27	0.45	0.44	0.42
11	Industrial Production: Other Non-Metallic Mineral Products	0	-0.20	-0.10	0.25	-0.27	0	2.03	0.02	0.02	0.02
12	Industrial Production: Basic Metals/Metal Products,Ex Machinery/Equipment	0	-2.56	-1.90	-0.50	0.12	0	2.11	0.28	0.40	0.38
13	Industrial Production: Computer, Electronic and Optical Equipment	0	-1.63	-0.42	-0.30	-0.47	0	2.15	0.19	0.21	0.20
14	Industrial Production: Machinery and Equipment n.e.c.	0	-2.19	-1.38	-0.58	0.45	0	2.02	0.05	0.11	0.13
15	Industrial Production: MV, Trailers and Other Transportation Equipment	0	-2.65	-1.82	-0.25	0.17	0	2.07	0.17	0.23	0.22
16	Industrial Production: Furniture; Other Manufacturing	0	-1.15	-1.22	-0.55	0.79	0	1.58	0.84	1.22	1.32
17	Industrial Production: Repairand Installation Machinery and Equipment	0	-2.26	-1.74	-1.16	0.02	0	2.30	4.06	5.16	7.19
18	Construction Output	0	-2.61	-2.67	-1.40	0.22	0	2.07	3.16	4.19	6.20
19	Building Permits: Residential Ex. Community Residen.	0	-2.58	-2.85	-1.12	-0.18	0	2.08	3.23	5.60	7.68
20	Building Permits: Office Buildings	0	-1.47	-1.39	-0.20	0.22	0	1.23	2.22	4.25	6.25
21	Building Permits: Non-Residential Ex Office Buildings	0	-2.28	-2.44	-1.09	0.19	0	2.05	2.05	5.06	7.06
22	Retail Sales Volume Index: Adjusted for Cal. Effects	0	-3.34	-1.59	-0.43	-0.41	0	2.02	3.04	6.15	8.18
23	Retail Trade: Non-Food Products Incl Fuel	0	-3.19	-0.22	-0.26	0.03	0	2.26	3.50	6.68	7.71
24	Retail Trade Excluding Autos and Motorcycles	0	-3.05	-0.05	-0.04	0.21	0	1.02	2.04	4.04	5.04
25	Retail Trade: Food, Beverages and Tobacco	0	-2.05	-1.05	-0.05	0.18	0	1.06	2.06	3.05	5.05
26	Retail Trade: Automotive Fuel at Gas Stations	0	-3.19	-2.22	-1.26	0.32	0	1.16	2.32	4.47	5.50
27	Retail Trade: Clothing and Footwear	0	-2.11	-1.17	-1.11	-0.03	0	0.52	2.07	3.15	6.15
28	Retail Trade: Pharmaceutical and Cosmetic Goods	0	-2.28	-2.26	-1.33	-0.20	0	1.45	3.33	4.24	7.22
29	Retail Trade: Computers/Software, Telecom Equipment	0	-2.06	-1.21	-0.43	-0.22	0	2.00	3.03	5.19	8.23
30	Retail Trade: AV Equipment, Hardware and HouseholdsAppliances	0	-2.11	-1.19	-0.42	0.05	0	2.01	4.03	5.08	7.09
31	Unemployment Rate	0	0.87	1.06	1.13	-0.18	0	2.46	3.47	6.76	6.88
32	Wages and Salaries: Industry Excl	0	-0.62	-0.95	-0.71	0.19	0	0.22	1.49	2.72	4.71

	Construction										
33	Wages and Salaries: Industry Excluding Energy	0	-0.29	-0.38	-0.31	-0.01	0	0.19	1.41	2.59	4.59
34	Wages and Salaries: Mining, Manufacturing and Energy	0	-0.74	-0.72	-0.24	0.06	0	1.11	2.24	3.36	5.35
35	Wages and Salaries: Intermediate and Capital Goods	0	-0.23	-0.32	-0.19	0.20	0	0.10	1.21	2.28	4.27
36	Wages and Salaries: Consumer Goods	0	-0.50	-0.44	-0.31	-0.12	0	1.02	2.05	4.10	5.11
37	Wages and Salaries: Energy	0	-0.24	-0.16	-0.12	0.42	0	0.43	1.04	2.43	5.30
38	Wages and Salaries: Mining and Manufacturing	0	-0.59	-0.97	-0.29	0.04	0	0.13	1.29	2.42	3.42
39	Wages and Salaries: Mining and Quarrying	0	-1.32	-1.73	-1.53	0.71	0	1.25	2.56	3.99	4.02
40	Wages and Salaries: Manufacturing	0	-0.66	-1.05	-0.87	0.19	0	0.11	2.24	3.35	5.35
41	Hours Worked: Industry Excluding Construction	0	-0.47	-0.50	-0.38	0.40	0	0.56	1.99	4.27	5.24
42	Hours Worked: Industry Excluding Energy	0	-0.53	-0.33	-0.21	0.06	0	0.67	1.96	3.35	6.45
43	Hours Worked: Mining, Manufacturing and Energy	0	-0.77	-0.53	-0.47	0.30	0	1.41	1.79	3.09	5.07
44	Hours Worked: Intermediate and Capital Goods	0	-0.36	-0.37	-0.22	0.13	0	0.39	2.75	4.01	4.98
45	Hours Worked: Consumer Goods	0	-0.24	-0.24	-0.12	0.01	0	0.43	1.63	4.85	5.86
46	Hours Worked: Energy	0	-0.62	-0.51	-0.31	0.24	0	0.06	1.14	3.24	6.25
47	Hours Worked: Mining and Manufacturing	0	-0.28	-0.32	-0.18	0.08	0	1.39	2.77	4.05	5.03
48	Hours Worked: Mining and Quarrying	0	-0.42	-0.43	-0.37	-0.13	0	0.77	1.23	3.76	5.86
49	Hours Worked: Manufacturing	0	-0.28	-0.32	-0.18	0.09	0	0.79	1.76	2.03	4.01
50	Hours Worked: Electricity/Gas/Steam and Water/Waste	0	-0.54	-0.47	-0.30	0.34	0	1.06	2.14	3.27	4.29
51	IFO climate	0	-0.74	-1.01	-0.31	0.32	0	0.24	0.66	0.76	1.72
52	IFO situation	0	-1.78	-1.67	-0.04	1.64	0	0.18	0.69	1.09	2.07
53	IFO expectations	0	-0.70	-0.75	-0.46	0.25	0	0.19	0.39	0.73	1.31
54	EABCI	0	-0.07	-0.09	-0.03	0.02	0	0.35	0.81	0.90	1.84
55	Economic Sentiment Indicator	0	-0.46	-0.80	-0.18	0.22	0	0.04	0.62	0.98	1.17
56	Industrial Confidence Indicator, Percent Balance	0	-0.47	-0.66	-0.16	0.16	0	0.18	0.48	1.63	1.60
57	Consumer Confidence Indicator, Percent Balance	0	-0.50	-0.72	-0.13	0.02	0	0.14	0.83	1.46	2.43
58	Retail Trade Confidence Indicator, Percent Balance	0	-0.61	-0.80	-0.03	0.32	0	0.09	0.73	1.31	2.30
59	Construction Confidence Indicator, Percent Balance	0	-0.10	-0.44	-0.17	0.07	0	0.02	0.97	1.20	2.20
60	Consumer Price Index (CPI)	0	-0.16	-0.26	-0.46	-0.30	0	0.09	0.10	0.11	2.11
61	CPI-Food	0	-0.24	-0.36	-0.51	-0.28	0	0.06	0.51	1.13	2.14
62	CPI-Alcoholic Beverages and Tobacco	0	-0.25	-0.03	-0.02	-0.08	0	0.02	0.71	0.02	1.02
63	CPI-Clothing and Footwear	0	-0.15	-0.54	-0.49	-0.09	0	0.24	0.58	0.75	1.76
64	CPI-Consumer Durable Goods	0	-0.11	-0.18	-0.31	-0.30	0	0.25	0.67	2.41	3.53
65	CPI-Electricity, Gas and Other Fuels	0	-0.04	-0.35	-0.37	-0.56	0	0.01	0.56	2.04	3.06
66	CPI-Other Goods Including Motor Fuels and Lubricants	0	-0.18	-0.21	0.37	-0.13	0	0.15	0.23	1.19	2.18
67	CPI-Services	0	-0.17	-0.36	0.57	-0.35	0	0.04	0.38	1.06	1.86
68	Core CPI	0	-0.18	-0.25	-0.40	-0.37	0	0.01	0.72	1.04	2.05
69	Core CPI net of indirect taxes	0	-0.13	-0.23	-0.24	0.09	0	0.06	0.75	1.39	2.38
70	Producer price index	0	-0.56	-0.18	-0.08	-0.02	0	0.10	0.63	1.27	2.25
71	M1	0	-1.35	-0.79	-0.20	0.07	0	0.06	0.11	0.12	1.12
72	M2	0	-0.93	-0.82	-0.28	0.15	0	0.01	0.01	0.03	1.03
73	M3	0	-0.83	-0.73	-0.12	0.03	0	0.01	0.04	0.07	2.07
74	MFI Loans to Non-Financial Corporations	0	-1.30	-1.24	-0.79	-0.53	0	0.58	1.19	1.25	2.28
75	MFI Loans to Other Financial Intermediary and Financial Corporations	0	-1.90	-1.83	-1.20	-0.63	0	0.44	0.61	0.88	1.95
76	MFI Loans to General Government	0	-0.35	-1.18	-0.90	-0.53	0	1.30	2.04	2.10	1.91
77	MFI Loans to Households	0	-0.64	-0.93	-0.87	-0.61	0	0.47	1.66	1.94	2.01

78	Loans to Non-Financial Corporations:Transactions, HUF	0	3.34	-9.16	1.23	4.49	0	1.08	3.09	3.49	4.09
79	Loans to Non-Financial Corporations:Transactions, FX	0	-14.40	-2.14	-8.45	1.74	0	2.14	3.74	4.84	5.15
80	Loans to Households, Transactions, HUF	0	-7.34	-2.65	-0.55	1.39	0	1.12	3.19	4.32	4.34
81	Loans to Households, Transactions, FX	0	-7.45	-10.34	-2.65	-2.23	0	2.21	3.33	4.47	5.46
82	Loans to Non-Financial Corporations, Stock, HUF	0	-0.04	-0.25	-0.36	-0.03	0	0.13	0.50	1.28	1.30
83	Loans to Non-Financial Corporations, Stock, FX	0	1.33	1.05	-0.14	1.39	0	0.14	0.51	1.43	2.69
84	Loans to Households, Stock, HUF	0	-0.27	-0.34	0.21	0.26	0	0.07	0.44	1.25	1.58
85	Loans to Households, Stock, FX	0	1.16	0.16	1.46	0.53	0	0.07	1.41	2.55	3.62
85	Monetary Policy Interest Rate	0.68	0.02	-0.23	-0.65	-0.04	8.57	6.55	4.13	2.73	1.68
87	Yield on 10 Year Government Debt securities	0.21	-0.16	-0.12	-0.24	-0.05	0.23	1.39	1.52	1.79	2.59
88	Yield on 3-Month Government Debt Securities	0.48	-0.12	-0.28	-0.64	-0.02	3.63	3.30	2.25	1.28	0.29
89	Lending Rate to Nonfinancial Corporations: Short-term	0.01	0.68	0.19	-0.44	-0.23	4.02	3.27	4.31	2.30	1.30
90	Lending Rate to Nonfinancial Corporations: Long-term	0.19	0.02	-0.03	-0.52	-0.36	2.01	3.19	2.78	2.49	2.46
91	Lending Rate to Households-Loans for consumption	-0.21	0.41	0.17	0.02	-0.54	3.58	2.71	2.44	1.21	0.18
92	Lending Rates to Households-Loans for house purchase	0.12	0.02	-0.03	-0.08	-0.32	2.28	2.20	1.16	0.93	0.22
93	JPM EMBI Global Hungary - blended spread	100	42.33	24.68	-33.65	-28.64	22.85	26.05	27.10	25.17	24.5
94	JPM EMBI Global Hungary - blended yield to maturity	0.67	0.29	0.12	-0.12	-0.16	9.78	7.58	6.68	5.80	6.72
95	BSE: Market Index: Budapest Stock Index (BUX)	-4.06	-4.16	-3.79	0.12	0.96	6.18	7.01	5.97	3.72	1.68
96	Nominal effective exchange rate, all countries	1.83	1.68	1.64	-0.22	-0.77	0.76	1.14	1.37	1.56	2.13
97	Real effective exchange rate, CPI based, all countries	1.85	1.72	1.66	-0.38	0.88	0.58	1.13	1.54	2.51	3.11
98	Forint/Euro exchange rate	1.79	1.83	1.85	0.28	0.51	1.06	2.27	1.26	2.34	3.24

REFERENCES

Allard, C., 2009, *Competitiveness in Central Europe: What Has Happened Since EU Accession,* IMF Working Paper 09/121.

Banbura, M., D. Gianonne, and L. Reichlin, 2010, "Large Bayesian VARs," *Journal of Applied Econometrics*, Vol. 25(1), pp. 71–92.

Benk, S., Z. M. Jakab, M. A. Kovács, B. Párkányi, Z. Reppa, and G. Vadas, 2006, *The Hungarian Quarterly Projection Model (NEM),* MNB Occasional Papers 2006/60, Magyar Nemzeti Bank.

Bloor, C. and T. Matheson, T., 2008, *Analysing Shock Transmission in a Data-Rich Environment: A Large BVAR for New Zealand,* Reserve Bank of New Zealand, DP2008/09.

Bernanke, B., J. Boivin, and P. Eliasz, 2005, "Measuring Monetary Policy: A Factor Augmented Autoregressive (FAVAR) Approach," *Quarterly Journal of Economics*, 120, pp. 387–422.

Calvo, G.A. and C. M. Reinhart, 2002, "Fear Of Floating," *The Quarterly Journal of Economics*, MIT Press, Vol. 117(2), May, pp. 379–408.

Carriero, A., G. Kapetanios, and M. Marcellino, 2009, "Forecasting Exchange Rates with a Large Bayesian VAR," *International Journal of Forecasting*, 25(2), pp. 400–417.

Chang, R. and A. Velasco, 2001, "Monetary Policy in a Dollarized Economy where Balance Sheets Matter," *Journal of Development Economics*, Elsevier, Vol. 66(2), December, pp. 445–464.

Christiano, L. J., M. Eichenbaum, and C. L. Evans, 1999, *Monetary Policy Shocks: What Have We Learned and to What End?*, in Handbook of Macroeconomics, ed. by J. B. Taylor, and M. Woodford, Vol. 1, chap. 2, Elsevier, pp. 65–148.

Csermely, Á. and B. Vonnák, 2002, *The Role of the Exchange Rate in the Transmission Mechanism in Hungary,* presented at the ECB conference "Monetary Policy Transmission in the Euro Area and in Accession Countries" October.

De Mol, C, D Gianonne, and L Reichlin, 2008, "Forecasting Using a Large Number of Predictors: Is Bayesian Regression a Valid Alternative to Principal Components?," *Journal of Econometrics*, Vol. 146, No. 2, October, pp. 318–328.

Doan, T. and R. Litterman and C. Sims, 1984, "Forecasting and Conditional Projection Using Realistic Prior Distributions," *Econometric Reviews*, Taylor and Francis Journals, Vol. 3(1), pp. 1–100.

Forni, M., D. Giannone, M. Lippi, and L. Reichlin, 2009, "Opening the Black Box: Structural Factor Modelswith Large Cross Sections," *Econometric Theory*, 25 (5), pp. 1319–1347.

Giannone, D., and L. Reichlin, 2006, "Does Information Help Recovering Structural Shocks from Past Observations?," *Journal of the European Economic Association*, 4(2-3), pp. 455–465.

Jakab, Z. and B. Világi, 2008, *An Estimated DSGE Model of the Hungarian Economy,* MNB Working Papers No. 2008/9, Magyar Nemzeti Bank.

Koop, G., 2010, *Forecasting with Medium and Large Bayesian VARs*, Manuscript, University of Strathclyde.

Leeper, E. M., C. Sims, and T. Zha, 1996, "What Does Monetary Policy Do?," *Brookings Papaers on Economic Activity*, 1996(2), pp. 1–78.

Litterman, R., 1986, "Forecasting with Bayesian Vector Autoregressions - Five Years of Experience," *Journal of Business and Economic Statistics*, vol 4(1), pp. 25–38.

LLosa, G., Tuesta V. and M. Vega, 2005, *A BVAR Forecasting Model for Peruvian Inflation*, Central Bank of Peru.

Kadiyala, K. Rao and S. Karlsson, 1997, "Numerical Methods for Estimation and Inference in Bayesian VAR-models," *Journal of Applied Econometrics*, Vol. 12(2), March–April, pp. 99–132.

Rezessy, A., 2005, *Estimating the Immediate Impact of Monetary Policy Shocks on the Exchange Rate,* MNB Occasional Papers No. 38, Magyar Nemzeti Bank.

Sims, C. A., 1992, *Bayesian Inference for Multivariate Time Series with Trend*, Mimeo.

Sims, C. A. and T. Zha, 1998, "Bayesian Methods for Dynamic Multivariate Analysis," *International Economic Review*, 39(4), pp. 949–68.

Stock J.H. and M.W. Watson, 2002, "Forecasting Using Principal Components From a Large Number of Predictors," *Journal of the American Statistical Association*, American Statistical Association, Vol. 97, December, pp. 1167–1179.

Stock J.H. and M.W. Watson, 2005, *An Empirical Comparison of Methods for Forecasting Using Many Predictors*, Manuscript, Princeton University.

Vonnák, B., 2005, *Estimating the Effect of Hungarian Monetary Policy within a Structural VAR Framework,* MNB Working Papers 2005/1, Magyar Nemzeti Bank.

Vonnák, B., 2007, *The Hungarian Monetary Transmission Mechanism: an Assessment*, MNB Working Papers 2007/3, Magyar Nemzeti Bank.

Vonnák, B., 2010, *Risk Premium Shocks, Monetary Policy and Exchange Rate Pass-Through in the Czech Republic, Hungary and Poland*, MNB Working Papers 2010/1, Magyar Nemzeti Bank.