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The Sectoral Effects of Monetary Policy in Hungary: A Structural Factor Analysis*

(A monetáris politika ágazati hatásai Magyarországon: elemzés strukturális faktormodellel)

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Contents

Abstract

This paper uses a structural factor model to analyze sectoral heterogeneity in the impact of monetary policy in Hungary. Monetary shocks are identified with sign restrictions. The impulse responses of aggregate variables are similar to the findings of previous VAR based studies. The sectoral responses reveal considerable heterogeneity. In particular, sectors more reliant on external finance show larger output responses, while healthier corporate balance sheets imply weaker price responses. These results suggest that the credit channel of monetary transmission is operating in Hungary as well. In addition, there appears some role for the interest sensitivity of demand and price rigidities in explaining the heterogeneity of sectoral responses.

JEL: C32, E32, E52.
Keywords: structural factor model, monetary policy, credit channel, sectoral heterogeneity.

Összefoglalás

A tanulmány strukturális faktormodell segítségével elemzi a monetáris transzmisszió ágazati heterogenitását Magyarországon. A monetáris sokkokat előjel-megkötések útján identifikálom. Az aggregált változók impulzusválaszai hasonlóak a korábbi, VAR alapú tanulmányok eredményeihez. Az ágazati reakciók jelentős heterogenitást mutatnak. A több külső finanszírozást igénylő szektorok kibocsátása erősebben reagál, míg egészségesebb vállalati mérleghelyzet mellett az árak reakciója mérsekeltebb. Ezek az eredmények arra utalnak, hogy a monetáris transzmisszió hitelcsatornája Magyarországon is működik. Emellett a kereslet kamatérzékenysége és az ármerevségek is szerepet játszanak az ágazati reakciók különbségeinek magyarázatában.

1 Introduction

Central bankers cannot make everyone equally happy. Monetary policy affects each sector differently. This heterogeneity is important for the design of monetary policy, because its distributional effects can alter the transmission mechanism. A simple example can illustrate this point. Consider an economy of two sectors. A monetary tightening has a strong negative impact on sector A, and a weak effect on sector B. To reach equilibrium, the relative prices of the two sectors should change: the price of product A should fall relative to that of product B. Relative wages should also change in favour of sector B. However, real and nominal rigidities can slow down the adjustment of relative prices and wages. If the prices of sector A are rigid, the aggregate price level may not fall as quickly as the central bank intends.

A number of authors have analyzed the sectoral differences in the impact of monetary policy. Leading explanations include sectoral differences in the degree nominal rigidities; input-output linkages across sectors; and the broad credit channel of monetary transmission. Model-based studies include Bouakez et al. (2009), who find a significant role for price stickiness and input-output linkages in a multi-sector dynamic stochastic general equilibrium model with sticky prices. Empirical analyses can employ firm-level data, e.g. Gaiotti and Secchi (2006); or VAR models with sectoral data, for example Barth and Ramey (2002), Dedola and Lippi (2005), Ganley and Salmon (1997), Hayo and Uhlenbrock (1999). In a related approach, Peersman and Smets (2005) construct a monetary shock variable in a VAR and use it to explain output fluctuations in a country/industry panel. The general conclusion from this literature is that heterogeneity across sectors is much larger than across countries. In particular, the sensitivity of demand to interest rates, and the working capital requirement of production are important determinants of the sectoral impact of monetary policy. The latter finding lends support to the cost channel of monetary policy: higher interest rates increase the financing costs of firms, driving up their sales prices in the short term. In addition, there is some evidence for the financial accelerator mechanism of Bernanke et al. (1996): more vulnerable corporate balance sheets can amplify the effects of monetary policy, especially in recessions.

All the above approaches have their limitations. DSGE models impose a tight theoretic structure on data, which might be excessively restrictive. Firm-level data are difficult to obtain and are usually available only low frequency. Finally, VAR studies are prone to identification issues, and do not allow the simultaneous estimation of all sectors' impulse responses.

The structural factor model of Forni et al. (2009) can overcome some of these difficulties. This tool is essentially data-driven, and can generate "stylized facts" without too many theoretic restrictions. It uses a large cross-section of easily available macroeconomic time series; and all impulse responses are estimated jointly. Such models have already been used to analyze the heterogeneous effects of aggregate shocks. Eickmeier (2009) and Eickmeier and Breitung (2006) investigate business cycle synchronization in the euro area and between old and new EU members, respectively. Barigozzi et al. (2011) assess the cross-country heterogeneity of common monetary policy, while Cimadomo (2008) analyzes the sectoral effects of systematic monetary policy in the U.S.

This paper explores the sectoral heterogeneity of monetary transmission in Hungary, using a structural factor model, where aggregate shocks are identified using sign restrictions. The study has two novelties. It is the first estimated structural factor model for Hungary (or indeed, any small, open, emerging economy). It is also the first paper to analyze the sectoral impacts of unanticipated monetary shocks in a structural factor model framework. I find that a single large structural factor model can replicate the results of many previous VAR based studies on various topics. Monetary policy has a heterogeneous effect across sectors; industry and construction are particularly sensitive, consistent with the high dependence of these sectors on bank finance. Within manufacturing subsectors, the interest sensitivity of demand and short-term financing requirements appear to matter most, consistently with previous findings in the literature.

The remainder of the paper is organized into six sections. The structural factor model and the identification method is described in Section 2, while the data are presented in Section 3. Section 4 validates the structural factor model by comparing its impulse responses of key macroeconomic variables with available VAR evidence. The sectoral heterogeneity of monetary shocks is analyzed in detail in Section 5. Section 6 discusses the robustness of the results, and Section 7 concludes.

2 Methodology

I estimate a structural factor model of Forni et al. (2009) to assess the impact of aggregate shocks on a large panel of macroeconomic and sectoral variables. The model is a special case of the generalized dynamic factor model by Forni et al. (2000) and Forni and Lippi (2001), and belongs to the more general class of approximate dynamic factor models, introduced by Chamberlain and Rothschild (1984). The following section describes the intuition behind the model and the estimation method, and discusses the identification of aggregate shocks. For details of the methodology see Forni et al. (2009). Some practical details of the estimation and identification are discussed in Appendix A.

2.1 THE STRUCTURAL FACTOR MODEL

Structural factor models are based on the idea that the behaviour of a large number of observable economic variables can be described by a relatively small number of unobserved factors. These factors are, in turn, influenced by a few shocks, which can be interpreted as macroeconomic disturbances.

Consider x_t, a large panel of n observed, stationary variables. Each variable can be decomposed into a common and an idiosyncratic component, so that

$$x_t = \chi_t + \xi_t \tag{1}$$

The common components are represented by r ($<< n$) unobserved factors (these are also called static factors in the literature):

$$\chi_t = a_1 f_{1t} + \ldots + a_r f_{rt} = A\mathbf{f}_t \tag{2}$$

Statistical tests exist to determine the optimal number of factors, for example Bai and Ng (2002) or Onatski (2010). The factors need not have economic interpretation; their only purpose is to summarize the information content of observed variables. Still, it is usually possible to attribute some economic meaning to the first few factors.

The idiosyncratic components (ξ_t) capture the effects of micro shocks and measurement errors. These can be weakly correlated across variables; for example, sector-specific shocks can propagate across industries through input-output linkages. However, the common and idiosyncratic components are orthogonal for each variable.

The dynamic relations among the factors are described by the following VAR:

$$\begin{aligned} D(L)\mathbf{f}_t &= \varepsilon_t \\ \varepsilon_t &= Ru_t \end{aligned} \tag{3}$$

The vector u_t contains the economically meaningful aggregate shocks (these are also called dynamic factors or primitive shocks). The shocks are orthogonal to each other, and can be interpreted in the same way as the identified shocks of a structural VAR. However, the number of shocks (q) need not equal the number of variables in the VAR (r), as in the SVAR case: generally, $q < r$. Indeed, the optimal number of shocks can be tested; see for example the tests proposed by Amengual and Watson (2007), Bai and Ng (2007), Hallin and Liska (2007) or Onatski (2009).

The structural factor model can thus be written in the following dynamic form:

$$\begin{aligned} x_t &= B(L)u_t + \xi_t \\ B(L) &= AD(L)^{-1}R \end{aligned} \tag{4}$$

This representation is unique only up to orthogonal transformations: for any orthogonal $(q \times q)$ matrix H, the following relationship holds: $Ru_t = Sv_t$, where $S = RH'$ and $v_t = Hu_t$ and $Cov(v_t) = I$. Thus, impulse responses are also unique only up to orthogonal rotations. The identification of u_t, the economically meaningful shocks, amounts to finding a specific H rotation matrix. This requires theory-based restrictions on the structural impulse responses of observed variables (without loss of generality, the first m elements of $B(L)$, labelled $B_m(L)$). Given a set of non-structural shocks v_t and their associated impulse responses $C(L)$, H can be calculated from:

$$\begin{aligned} \chi_{mt} &= C_m(L)v_t \\ B_m(L) &= C_m(L)H \end{aligned} \tag{5}$$

VAR models with only sign restrictions are not exactly identified: many H matrices can yield impulse responses which satisfy the restrictions (Rubio-Ramirez et al. (2010)). To find the set of acceptable H matrices, one needs to draw random orthogonal matrices, check whether $C(L)H'$ satisfies the restrictions for each draw of H, and store the successful draws.

The structural factor model can be estimated in a straightforward way. In the first step, static factors are estimated using principal component analysis. In the second step, a VAR is estimated on the static factors.[1] The VAR estimation should incorporate the restriction that the number of shocks is different from the number of variables. Alternatively, one can estimate the VAR without this restriction, and extract the first q principal components of the VAR residuals: if the "true" number of shocks (q) is known, then the remaining $r-q$ residuals will asymptotically reduce to linear combinations of these shocks (see also Stock and Watson (2005), p. 16). Thus, a set of mutually orthogonal, fundamental shocks (v_t) and their associated impulse responses (elements of $C(L)$) can be obtained as:

$$\chi_t = C(L)v_t = AD(L)^{-1}KMv_t \tag{6}$$

where A is the $(n \times r)$ matrix of factor loadings; M is a $(q \times q)$ diagonal matrix whose diagonal elements are the square roots of the eigenvalues of the covariance matrix of the VAR residuals (ε), in decreasing order; and K is the $(r \times q)$ matrix of the associated normalized eigenvectors.

Finally, v_t and $C(L)$ are rotated by a suitable matrix H to identify economically meaningful shocks (u_t) and their associated structural impulse responses ($B(L)$).

2.2 DISCUSSION

It is instructive to compare the structural factor model with three similar approaches: the well-known structural VAR, the large scale Bayesian VAR by Banbura et al. (2010) and the factor-augmented VAR (FAVAR) developed by Bernanke et al. (2005).

The main difference from a traditional VAR is the larger variable set of the structural factor model. This can be a major advantage. In a SVAR, the information set of the econometrician could be smaller than the information set of economic agents. If this is the case, the relatively small number of variables in a VAR may not be sufficient to identify shocks. In other words, structural shocks are not fundamental: they cannot be recovered from the past end present values of the VAR variables; see Alessi et al. (2011) for a detailed review. For example, identified monetary shocks in a VAR may not be truly exogenous, because they may also capture instances when the central bank endogenously reacts to changing inflation expectations. Forni and Gambetti (2010) demonstrate that non-fundamentalness can account for well-known VAR puzzles such as the price puzzle and the delayed overshooting puzzle. As the static factors incorporate information from a large number of economic variables, the information set of the structural factor model is far greater than that of a standard VAR. Thus, it becomes unlikely that the information set of economic agents will be superior to the information set of the econometrician.

[1] Alternatively, the factors and their VAR could be estimated jointly in a state space framework via maximum likelihood, as in Doz et al. (2006).

Another difference is that the number of macroeconomic shocks can be explicitly tested, while the SVAR implicitly assumes that the number of shocks is equal to the number of variables. Thus, the specification of a structural factor model can be tested in ways which are not possible for a standard VAR.

The large Bayesian VAR use a large variable set, similar to the structural factor model. Therefore it can overcome the problem of non-fundamentalness. Both approaches face the problem that the number of parameters is large relative to available sample sizes. The structural factor model reduces the number of parameters by assuming that the observed variables admit a factor structure; i.e. they can be represented by the linear combination of a small number of latent factors. The large BVAR achieves a similar result by imposing priors on the parameters and by shrinking more and more parameters towards zero as the size of the model increases.

Finally, the FAVAR is a special case of the structural factor model, where some static factors are observable. However, the FAVAR approach also assumes that the number of factors equals the number of shocks, which is not supported by existing tests. Finally, identification is less flexible. In the structural factor model, identifying restrictions are applied directly on observed variables. In the FAVAR, restrictions must be applied on the static factors - therefore these factors must have economic interpretation. The solution proposed by Bernanke et al. (2005) is to create "real" and "nominal" factors, and assume that monetary shocks have no contemporaneous impact on real factors. This strategy is more restrictive in the economic sense, and the separation of real and nominal factors may also lead to loss of information.

2.3 IDENTIFICATION

I use sign restrictions to identify the impact of four types of macroeconomic disturbances: monetary, risk premium, supply and demand shocks. The cumulative impulse response of eight observed variables is restricted for the first three quarters (that is, the restrictions are applied on the levels of the variables). Identifying restrictions can be derived from economic theory using formal models or economic intuition. The identification scheme in this paper is consistent with the predictions of theoretical and applied dynamic stochastic general equilibrium models. All restrictions are summarized in Table 1.

A monetary shock lowers interest rates and depreciates the currency. In addition, it increases value added and prices. The responses of real activity and prices to monetary shocks are left unrestricted on impact and in the first quarter, because there is no consensus on the short-run response of these variables - the cost channel of monetary policy is a potential explanation for the short-term price puzzle.

Risk premium shocks raise interest rates, depreciate the currency and increase the EMBI bond spread, a measure of sovereign risk. The depreciation leads to higher prices in the short term, but the weaker currency also helps exports. However, the response of aggregate output is not restricted, because depreciations can be either expansionary or contractionary.

Additional zero restrictions are placed on the instantaneous response of foreign interest rates and real activity to domestic monetary and risk premium shocks. This helps disentangle domestic monetary and risk shocks from foreign disturbances.

Supply shocks raise private sector output and exports, and reduces prices. Demand shocks raise output and prices; this triggers a systematic reaction by the central bank, leading to higher interest rates and real appreciation.

I generate impulse responses with the algorithm of Rubio-Ramirez et al. (2010). The zero restrictions on impact responses are implemented using the method of Reppa (2009). This procedure is efficient because it rules out rotation matrices that do not satisfy the zero restrictions before checking the remaining (sign) restrictions.

3 Data

3.1 DESCRIPTION OF THE DATA

I use a panel of 198 quarterly macroeconomic and sectoral time series over the period 2000:II-2010:IV. Most series describe the Hungarian economy and its main sectors; I also include 10 key foreign variables because Hungary is a small, open economy, and is strongly affected by external developments. The domestic series cover the real economy, prices, financial and monetary variables and survey indicators. Value added, employment and nominal wage data are available for 10 sectors of the economy, while production, price, employment and nominal wage data are included for 13 industrial subsectors. These disaggregated variables can be used for intersectoral comparisons.[2]

The data are seasonally adjusted where necessary; they are usually transformed into logs. Finally, they are differenced - if necessary - to achieve stationarity.[3] Most variables are I(1); interest rates, and some survey indicators are I(0). Data definitions and transformations are available upon request.

3.2 MODEL SPECIFICATION

The Onatski (2009) test suggests five aggregate shocks while the Bai and Ng (2007) criteria recommend four to six shocks. I choose a five-shock specification, which is close to other authors' choices. Conveniently, I can identify my four preferred shocks - supply, demand, monetary and risk premium - while leaving one shock to capture unspecified aggregate disturbances.

The available information criteria recommend a small number of static factors: the Onatski (2010) test suggests four while the IC_2 criterion of Bai and Ng (2002) suggests even less factors. However, the VAR representation requires at least as many factors as shocks. Thus, I follow the recommendation of Stock and Watson (2005) and choose as many factors as necessary to explain a sufficient share of variance of key observed variables. Eight static factors appear a reasonable choice (Table 2).

One possible concern is the relatively large fraction of unexplained variation in interest rates: the idiosyncratic component accounts for over 20 per cent of the variation of the short term rate even with 12 static factors. This idiosyncratic term could also capture monetary policy shocks, which could lead to the underestimation of the role of monetary policy. To alleviate these concerns, I perform Granger causality tests between the idiosyncratic component of the short term interest rate, and key macroeconomic variables (Table 3). The tests provide no evidence that the omitted component of the interest rate influences output, inflation or the exchange rate. Furthermore, the idiosyncratic term of the interest rates is uncorrelated with identified monetary shocks. Finally, visual inspection of the idiosyncratic term reveals that most of the unexplained variation occurs in 2003-2004 (Figure 1). If this period is omitted from the sample, eight static factors can explain over 90 per cent of the variance of the short term interest rate. The identified monetary shock and its associated impulse responses are qualitatively similar in the benchmark specification and with the truncated sample.

The VAR of the static factors is of order one; this choice is based on the inspection of the autocorrelation of VAR residuals.

[2] As all industry-level studies, this analysis is limited by the fact that the heterogeneity of companies within industries is greater than the heterogeneity between sectors; see e.g. Altomonte et al. (2011) and the references therein. Thus, sectoral aggregation leads to loss of information. Nevertheless, there remains some heterogeneity across sectors which can be used for inference.

[3] Seasonal adjustment might introduce measurement error into the variables, but this error should turn up in the idiosyncratic variables. The factor model could also be estimated on unadjusted data. In this case, however, higher order differencing is necessary to achieve stationarity. This increases the autocorrelation of the data, which might distort the estimation of factors; see Uhlig (2005a).

4 Aggregate results

I first discuss aggregate results: the impact of identified shocks on macroeconomic variables. The purpose of this is to validate the identification procedure and provide information on the overall performance of the model. The following section analyses impulse responses and discusses the contribution of aggregate shocks to the dynamic behaviour of key macro variables.

The key take-away of this section is that the model can reasonably explain the reaction of the economy to macroeconomic disturbances; impulse responses are qualitatively in line with previous VAR based studies on Hungary and other emerging economies, for example Carare and Popescu (2011), Jakab et al. (2006), Jarocinski (2010) or Vonnák (2010).

4.1 THE MACROECONOMIC IMPACT OF AGGREGATE SHOCKS

The median impulse responses of selected variables and their 16th and 84th percentile confidence intervals are presented in Figures 2, 3 and 4. Shocks are the size of one standard deviation. The horizontal axis shows the quarters following the shock (which occurs in the first quarter). The impulse responses are scaled to percentage points of observed variables (basis points in the case of the EMBI spread). They typically refer to level changes; in the case of prices and wages they refer to annualized quarterly growth rates.

4.1.1 Monetary shocks

The impulse responses of selected variables to a monetary expansion are shown on Figures 2 and 3. A typical monetary expansion reduces short term interest rates by almost 50 basis points. Long term rates fall by 30 basis points, thus the yield curve becomes somewhat steeper, consistent with the finding of Reppa (2009). The response of interest rates is negative in the first year then becomes somewhat positive in the second year.

Monetary expansion leads to an immediate depreciation of the home currency; there is little evidence for delayed overshooting. The response of the exchange rate is stronger than in previous VAR models. It is also quite persistent; this is a typical result when this variable is differenced. Nevertheless, the response of the exchange rate becomes insignificant after the second year.

The real effects of a monetary expansion are temporary but significant. GDP increases by 0.2-0.3 per cent in the year following the shock. This is mostly due to the improvement of net exports and a – barely significant – rise of consumption. On the other hand, investments do not change significantly. This is in contrast with Jakab et al. (2006) who find that investments respond significantly, but report mixed results for consumption and net exports. The muted response of consumption and investments suggests that the interest rate channel of monetary transmission could be relatively weak. This could be explained by the relatively low level of financial development, and the large share of foreign currency-denominated debt within private sector liabilities. The current account balance is unaffected by the monetary shock: although the export sector benefits from real depreciation, import demand also rises, while the rising profitability of foreign-owned companies worsens the income balance.

Monetary expansion boosts employment temporarily, corroborating the findings of Jakab and Kaponya (2010). However, real wages also increase immediately and significantly. This could suggest that wages are flexible in Hungary.

Inflation rises for two years following a monetary expansion. There is little evidence of a price puzzle. The peak effect occurs in the third quarter, when quarterly inflation is 0.1 percentage points higher. The response of inflation similar to other Central and Eastern European countries, as reported by Jarocinski (2010), but higher than previous results for Hungary, e.g. Jakab et al. (2006) or Vonnák (2010). In terms of core inflation (CORE VAI) the effect is somewhat smaller but more protracted. This could be due to the persistent rise in non-traded inflation - which, in turn, can be explained by rising real wages in the services sector. Inflation expectations respond significantly and quite persistently to monetary shocks.

4.1.2 The remaining shocks

The impulse responses of main macroeconomic variables to the remaining identified shocks are summarized on Figure 4. The impact of these shocks is generally plausible. However, some interesting results merit further discussion.

Risk premium shocks are contractionary: GDP falls for two consecutive years as the rise of exports is offset by falling consumption. Unemployment increases and household consumption drops considerably. The rising servicing costs of households' foreign currency denominated debt may also contribute to the response of consumption. The external balance improves persistently on account of improving trade and income balances.

Prices respond rapidly to risk premium shocks: the peak response of consumer price inflation occurs in the first half year. However, weak domestic demand results in a slight disinflation in the longer term.

Positive demand shocks reduce the country risk premium in line with the experience of emerging economies; supply shocks have a similar - although not significant - effect. Lower risk premia can amplify the effects of favourable real shocks on domestic demand, and contribute to the strong countercyclical behaviour of the external balance, as in Neumeyer and Perri (2005).

Finally, a typical (one standard deviation) demand shock appears to have stronger effects on the exchange rate than any other shock.

4.2 THE CONTRIBUTION OF AGGREGATE SHOCKS TO THE BEHAVIOUR OF OBSERVED VARIABLES

Table 4 summarizes the contribution of identified shocks to the variance of key variables. The shocks are presented on Figure 5, while their contributions to the historical evolution to key macroeconomic variables is shown on Figure 6.

Demand shocks explain the largest share of the variance of output and inflation. Monetary policy explains 7 percent of output variance and around 10 percent of inflation variability. Demand shocks appear to have a prominent role in long-term exchange rate movements, but risk premium shocks are the key source of short-term fluctuations. Interest rates are affected primarily by monetary shocks in the short term. In the longer term, the contribution of real shocks increases, due to the systematic behaviour of monetary policy.

According to the model, monetary policy was restrictive for much of 2002-2004, contributing to falling inflation around 2005-2006. A slightly expansionary phase followed from 2005 to 2008. During the global crisis and recession monetary policy was procyclical, although its impact faded in 2010.

Three well-defined episodes of risk premium shocks are observable. The first begins in 2003 and coincides with the shifting of the flotation band of the currency. This shock appears to be a major reason behind the surge of inflation in 2004. The second episode is the escalation of the budget deficit in 2006 and the announcement of a drastic fiscal adjustment: the latter appears as a large, favourable risk premium shock. This may point to the presence of strong non-Keynesian effects of fiscal adjustment; a possibility contemplated by Horváth et al. (2006a) at the time. Finally, the global financial crisis brought three peaks in the risk premium: around the fall of Bear Stearns (March 2008), after the Lehman collapse (September 2008) and most recently, during the Greek sovereign crisis (Spring 2010).

Supply shocks generally appear less straightforward to interpret, but the rise and fall of commodity prices is a plausible explanation for the large shocks around 2008-2009. They had a marked impact on price developments, and contributed significantly to the drop of output during the recession.

Expansionary fiscal policy might explain the positive demand shock in 2002 and the subsequent acceleration of output growth and inflation. Large negative demand shocks appear during international recessions (2001 and 2008-2009). The global financial crisis was followed by a succession of positive demand shocks, which could capture the effect of monetary and fiscal stimulus in major trade partners. However, the overall impact of demand shocks on prices has been negative since 2008.

5 Sectoral results

The main focus of this paper is on sectoral differences in the effects of monetary policy. The following section provides an overview of sectoral impulse responses. It then discusses possible sources of heterogeneity and their relevance in Hungary.

5.1 IMPULSE RESPONSES

5.1.1 Main economic sectors

Figure 7 presents the impulse responses of value added, employment and wages for industry, construction and three branches of market services. An expansionary monetary shock raises output, employment and wages in all sectors. The peak response of output and employment occurs around the end of the first year following the shock, while wage growth accelerates instantaneously.

Two groups of sectors emerge based on the response of value added. Industry, construction and trade are affected more strongly than the remaining service sectors. The comparatively strong response of industry and trade is consistent with the findings of Bouakez et al. (2009) and Ganley and Salmon (1997), as well as Cimadomo (2008) for systematic monetary policy.

The labour market responds positively in every sector. Labour productivity (value added per employment) rises in most sectors due to the temporary nature of monetary stimulus. Employment and wages rise the most in construction, reflecting the large response of output. Industrial wages do not appear to respond to monetary shocks, somewhat counter-intuitively. This result could reflect the fact that industrial firms tend to hire low-skilled workers to cover temporary increases in labour demand. The rising number of these workers could reduce average wages in the sector through a composition effect.

5.1.2 Manufacturing subsectors

Impulse responses of industrial production, employment, prices and wages for 13 subsectors to a monetary shock are presented in Figure 8. Some sectors respond vigorously to a monetary expansion, for example those producing intermediate goods (rubber, plastics, metals) or various types of machinery and equipment. On the other hand, the chemical and pharmaceutical industries even show slightly negative responses.

Prices increase immediately following the shock. This could be explained by the depreciation of the currency, because industrial exports and imports are typically priced in foreign currency (euro, or in some cases U.S. dollar). However, the price increase is often larger than the change in the exchange rate (which is estimated at 1 per cent following a typical monetary shock, see Figure 3). This might reflect a price response to increasing domestic demand in the wake of monetary stimulus.

Finally, the response of wages is mixed, and generally insignificant. This could simply mean that the model cannot adequately capture the determinants of wages.

As a cross-check I aggregated sectoral impulse responses to manufacturing-level responses, using average production weights for the 2000-2010 period for output, and employment weights for employment and wages. Reassuringly, the aggregated sectoral responses are very similar to manufacturing-wide impulse responses (results are available upon request).

5.2 EXPLAINING THE DIFFERENCES BETWEEN SECTORAL RESPONSES

5.2.1 Possible sources of heterogeneity

The monetary transmission mechanism describes how monetary policy affects the real economy and inflation. The transmission mechanism has several channels; many of these can be sources of heterogeneity across sectors. This section discusses how sector-specific characteristics may affect the strength of transmission channels (the proxies for these characteristics are described in more detail in Appendix B).

The *interest rate channel* of monetary policy affects the demand for goods and services. The purchases of some high-value goods (especially durables) are typically financed from credit. Thus, sectors producing these items could experience a larger increase in demand following a monetary expansion. The durability of products is typically proxied with a dummy variable for certain sectors, or the capital intensity of production.

The *exchange rate channel* of monetary transmission can also play a role. Some sectors are more export-oriented than others, while the share of imported inputs can also differ. Thus, the depreciation of the currency depreciation following a monetary expansion can affect competitiveness and output differently across sectors. However, more export-oriented sectors also benefit less from the interest rate channel. Thus, the expected sign of correlation between openness and output effects is theoretically unclear. The share of export sales and the net trade exposure indicator of Campa and Goldberg (1995) are possible measures of international openness.

The *credit channel* describes the effect of monetary policy on real activity through the financial sector. On the one hand, interest payable is a cost item for firms. A monetary expansion lowers these costs, which may allow companies to reduce prices in the short term - this *cost channel* is a potential explanation for the price puzzle often found in monetary VARs; see for example Barth and Ramey (2002). In addition, lower interest rates increase firms' demand for credit and allow them to raise output (*bank lending channel*). On the other hand, the financial accelerator model of Bernanke et al. (1996) states that monetary policy can also affect the external financing premium of firms, depending on the strength of their balance sheets: a lower interest burden allows firms to borrow more, which can boost their investments and output even further (*balance sheet channel*). The sensitivity to interest costs can be proxied by measures of short-term external financing needs; for example, the ratio of working capital to total assets, or the share of short-term debt in total debt. The quality of balance sheets can be assessed for example by the leverage ratio and the interest coverage.

In the case of Hungary, the large stock of foreign currency debt could also influence the impact of monetary shocks, especially through the credit channel. The financing costs of sectors with large foreign currency debt stocks are less affected by interest rate changes, but they are more exposed to exchange rate movements.

The literature suggests that price rigidities and input-output linkages also matter for sectoral heterogeneity. Price stickiness affects the speed of price adjustment; more limited price responses can also lead to larger changes in quantities. Meanwhile, production linkages can amplify output responses, regardless of their source.

5.2.2 Results

Due to the limited number of observations, I focus on manufacturing subsectors, and only report rank correlations between the responsiveness of output, prices, nominal sales and sectoral variables. Nominal sales are defined as the sum of price and output volume changes. Table 5 summarizes Spearman rank correlations across variables and their associated probability values.

Sectors producing durable goods appear to respond more strongly to monetary expansion. This finding is common in the literature, although the rank correlation is not statistically significant in my set of impulse responses. On the other hand, capital intensity as a proxy does not perform well. There is weak evidence that the interest rate channel could operate differently across sectors.

Openness does not seem to matter for the transmission of monetary shocks, consistent with the findings of Peersman and Smets (2005). In the case of more export-oriented sectors, a relatively weaker interest rate channel might offset the positive effects of competitiveness gains.

Higher short-term financing requirements are associated with a stronger output response and a more muted price response; the associated probability values of rank correlations are reasonably low given the small sample size. Sectors which are more reliant on short-term external finance can raise output more following a drop in interest rates; they are also less inclined to raise prices, thanks to falling financing costs.[4] This evidence for the credit channel is supported by Dedola and Lippi (2005) and Peersman and Smets (2005).

The latter authors also find that borrower quality affects the transmission of monetary policy during recessions, consistent with the financial accelerator hypothesis. I find no differences in output reaction by balance sheet variables. However, sectors with stronger balance sheets increase prices significantly less after monetary expansion. To explain this result, consider that firms' borrowing costs consist of a refinancing cost and a risk premium. If a firm has a stronger balance sheet, its risk premium is lower, and the share of refinancing costs is larger within the total borrowing cost. If monetary policy only affects refinancing costs, then sectors with stronger balance sheets will experience a larger reduction in borrowing costs following a monetary expansion. This cost saving will reduce the need to increase their prices.

The elasticity of output and prices to monetary shocks is negatively correlated as in Hahn (2007), although not significantly. This finding is in line with economic intuition, and can be motivated by different degree of price rigidity across sectors. The largest price responses appear in petroleum refining, pharmaceutical, food and metal industries - sectors where the pass-through of raw material costs might be rather quick.

The role of foreign currency debt remains unclear in this rudimentary analysis. It appears that a high share of foreign currency debt is associated with stronger balance sheets and a higher export share. Indeed, the share of foreign currency debt is the highest in the chemical and machinery industries, which are dominated by large, export-oriented firms.

Finally, results remain intact if nominal sales are considered instead of output volume. Nominal sales are less affected by price rigidities than real output. Thus, the above findings are not only driven by sectoral differences in nominal rigidities: other industry-level characteristics are indeed relevant.

Certainly, the sectoral explanatory variables are sometimes correlated with each other. However, Dedola and Lippi (2005) and Peersman and Smets (2005) show that these sectoral variables remain significant if the are used jointly to explain the heterogeneity of impulse responses. My analysis did not intend to reconsider these relationships; it merely illustrated that earlier results (for different countries) may be relevant for Hungary as well.

[4] At a higher level of aggregation, the strong output reaction of industry and construction relative to services could also reflect the impact of the credit channel. At the end of 2010, the ratio of outstanding bank credit to annual value added was 0.25 for industry, 0.65 for construction but as low as 0.02 for market services.

6 Robustness

This section discusses the robustness of the results. I check the sensitivity of impulse responses to different model specifications, and reestimate the model on a shorter sample.

6.1 ALTERNATIVE SPECIFICATIONS

Specification tests for the structural factor model typically give widely differing results regarding the number of shocks and factors. In particular, the number of shocks is unique (Forni et al. (2009)); the estimation may be inconsistent if the model is misspecified.

Figure 9 presents the impulse responses of key macroeconomic variables when the number of factors, shocks or VAR lags is modified. The shape of the impulse responses is unaffected. The responses of output and the exchange rate are somewhat sensitive to the number of factors. On the other hand, the reaction of the interest rate and prices do not appear sensitive to changes in model specification.

The ranking of sectoral output and price responses is not particularly sensitive to specification. The rank correlation between sectoral responses in the baseline estimation and various alternative specifications is typically around 0.8-0.9.

6.2 SHORTER SAMPLE

A possible concern is that the global financial crisis and the following recession in 2008-2009 might drive some of the results. The crisis brought a rise in Hungarian interest rates and a sharp drop in output. The model might interpret this episode as a monetary tightening with particularly large output effects. To check the effect of the crisis period on the impulse response of output, I reestimate a model on a shorter sample, ending in 2008:II.

Indeed, the response of GDP is halved in the shorter sample. The reaction of consumption is no longer significant, although employment and wages still respond positively. There are several potential explanations for the stronger reaction of output in recent years. First, the debt stock of the private sector has increased, making consumers and firms more sensitive to interest and exchange rate movements. Second, the financial accelerator mechanism of Bernanke et al. (1996) can cause nonlinearities in the impact of monetary shocks during recessions.

The rank correlation between sectoral responses is 0.60 for output and 0.52 for prices. Thus, sectoral results are somewhat sensitive to sample choice. This could reflect that some sectoral characteristics - for example balance sheet quality - changed after the crisis. However, the short sample includes just 33 quarterly observations, thus the estimates might be less precise.

7 Conclusion

Monetary policy can affect each economic sector differently. This sectoral heterogeneity is important: the literature suggests that it may be a more important driver of cross-country differences in monetary transmission than country-specific factors. Therefore, understanding the size and the sources of heterogeneity is important for the design of monetary policy.

This paper used a structural factor model to analyze the sectoral impact of monetary policy in Hungary. Structural factor models are a useful tool to assess heterogeneity. They use a large set of easily available macroeconomic and sectoral data. They allow the researcher to use familiar VAR techniques while escaping the problem of non-fundamentalness, which arises from the limited information set of small-scale VAR models. I used sign restrictions, which can identify macroeconomic shocks with a minimum set of theory-consistent restrictions.

The estimated model provides a reasonable description of monetary transmission, and the role of aggregate disturbances in the Hungarian economy. It strongly suggests that each sector reacts differently to monetary shocks. The output response of industry, construction and trade are particularly strong. Within manufacturing, subsectors producing durable goods respond more to a monetary expansion. This suggests that the interest sensitivity of demand can differ across sectors. Furthermore, industries with a stronger reliance on external financing also benefit more from a monetary expansion. Prices increase less in sectors using more credit and with stronger balance sheets, thanks to their falling borrowing costs. This ”cost channel” works against other transmission channels of monetary policy because it reduces prices after a monetary expansion (making it a plausible explanation for the ”price puzzle” of monetary VARs). Finally, the response of sectoral output and prices is negatively correlated, which hints at different degrees of price rigidity across industries.

A number of policy-relevant conclusions emerge from the analysis. First, it shows that the credit channel of monetary policy is operating in Hungary as well, corroborating the findings of Horváth et al. (2006b). The credit channel is particularly strong for construction and some manufacturing subsectors.

Second, changes in the production structure can affect monetary transmission. The comparatively strong impact on the construction sector also suggests that ”conventional” monetary policy could be used to contain real estate bubbles with milder effect on the rest of the economy.

Third, the quality of corporate balance sheets also affects monetary policy. The financial crisis could have brought a significant deterioration in borrower quality. This increases the share of risk premium within total borrowing cost, making it less responsive to monetary policy. Thus, monetary shocks can have a somewhat stronger effect on prices because the cost channel could be weaker in the years following the financial crisis.

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Appendix A Details of the estimation and identification procedure

Estimation is based on the Matlab code of Forni and Gambetti (2010) with a few modifications. The authors use a block bootstrap procedure to generate confidence intervals to impulse responses. This bootstrap also takes into account the uncertainty of factor estimation, because it is based on the resampling of blocks of the original data. I do not use block bootstrap because my sample size is short, thus the number of available blocks would be too small. Instead, I ignore the uncertainty in the estimation of static factors. Bai and Ng (2006) show that this uncertainty becomes irrelevant if the number of observed variables is large relative to the length of the series.

Due to the presence of generated regressors, estimated standard errors may not be consistent in the second stage of estimation. Also, estimated VAR parameters can be biased in small samples. I use the bootstrap-after-bootstrap methodology of Kilian (1998) to address these concerns. The procedure involves a first bootstrap to estimate the bias of the initial VAR parameters, and a second bootstrap using the bias-corrected VAR parameters to create impulse responses and their confidence bands.

For each draw in the second bootstrap loop I draw random orthogonal rotation matrices from the Haar distribution until one of them satisfies the sign and zero restrictions; the identified set of shocks and impulse responses are then stored. I draw a maximum of 100 rotation matrices for each bootstrap iteration; if none satisfies the restrictions, I move on to the next bootstrap draw. A similar procedure was applied by Uhlig (2005b).

I generate a total of 500 impulse responses and report their medians as well as their 16th and 84th percentiles. Variance decompositions and historical shock decompositions are performed for each of the 500 draws; I then report their respective medians.

Appendix B The definitions of sector-specific variables

The following sector-specific variables are considered to explain the heterogeneous impact of monetary policy:

- **Durability** refers to the output of the sector. Its value is 1 for Metals, Electronics, Electronic equipment, Machinery and Transport; 0 for Food, Textile and leather, Wood and paper, Petroleum, Chemicals, Pharmaceuticals; and 0.5 for Rubber and plastics and Other manufacturing (these aggregates contain some subsectors producing durables).
- **Capital intensity** is the ratio of sectoral capital to value added.
- **Export share** is the ratio of exports to total sales.
- **Net trade exposure** is the index of effective exposure proposed by Campa and Goldberg (1995):

$$IEE_i = \chi_i - \left(\sum_{j \neq i} m_{ij} x_{ij}\right) \Big/ \left(\sum_j x_{ij} + w_i\right)$$

  where χ_i is the sectoral export share; x_{ij} is total new supply from sector j to sector i (i.e. the value of products by sector j used in the production of sector i as intermediate input); m_{ij} is the import share in new supply from sector j to sector i; and w_i is total wage cost of sector i.

- **Working capital ratio** is the sum of inventory, accounts receivable, marketable securities, cash and cash equivalents relative to total assets.
- **Short-term debt ratio** is the share of short-term liabilities within total liabilities.
- **Leverage** is the ratio of liabilities to capital stock (including provisions and deferred payments).
- **Interest coverage** is operating profits relative to interest payable.
- **Share of foreign currency debt** is the ratio of foreign currency debt to total debt stock.

Export share and net trade exposure are derived from the 2005 input-output table for Hungary. Foreign currency debt figures are collected by Magyar Nemzeti Bank; data refer to December 2010. The remaining variables are calculated from firm-level data of the National Tax and Customs Administration, taking the sectoral averages for 2000-2008.

Appendix C Tables and Figures

Table 1
Overview of the identifying restrictions

	Monetary	Risk premium	Supply	Demand
Private sector value added	(+)	?	+	+
Exports	?	+	+	?
Core price index	(+)	+	-	+
Short-term interest rate	-	+	?	+
Real exchange rate	+	+	?	-
Foreign interest rate	0	0	?	?
External demand	0	0	?	?
EMBI bond spread	?	+	?	?

Note: Zero restrictions apply to impact responses. Sign restrictions apply to first three quarters; parentheses indicate restrictions which apply only to the third quarter. Sign restrictions are imposed so as to allow zero responses.

Table 2
Explained variances by the number of static factors

	4 factors	8 factors	12 factors
Value added, private sector	0.682	0.830	0.860
Value added, average of sectors	0.447	0.655	0.757
Production, average of manufacturing subsectors	0.307	0.482	0.600
Household consumption	0.659	0.746	0.847
Investments	0.298	0.601	0.674
Exports	0.548	0.659	0.834
Imports	0.558	0.709	0.819
GDP	0.863	0.884	0.893
Employment, private sector	0.441	0.735	0.844
Employment, average of sectors	0.220	0.418	0.620
Employment, average of manufacturing subsectors	0.337	0.512	0.644
Unemployment rate, labour force survey	0.542	0.586	0.724
Gross wages, private sector	0.817	0.880	0.906
Gross wages, average of sectors	0.520	0.592	0.729
Gross wages, average of manufacturing subsectors	0.313	0.498	0.599
Core price index excl. VAT	0.828	0.838	0.917
Consumer prices	0.367	0.656	0.680
Producer prices, average of manufacturing subsectors	0.699	0.771	0.831
Nominal effective exchange rate	0.916	0.962	0.967
Real exchange rate, CPI based	0.919	0.944	0.946
Long term interest rate (5 year)	0.720	0.780	0.810
Short term interest rate (3 month)	0.688	0.777	0.780
EMBI spread	0.615	0.782	0.874
Government debt per GDP	0.467	0.657	0.738
Net foreign liabilities per GDP	0.215	0.420	0.548
Credit stock, private sector	0.524	0.659	0.774
External financing capacity	0.462	0.718	0.739
Equity prices (BUX)	0.612	0.698	0.766

Table 3
Granger causality between the idiosyncratic component of the short term interest rate and main macroeconomic variables *(p-values)*

Idiosyncratic term does not Granger cause variable

	Horizon (quarters)			
	1	2	3	4
GDP	0.506	0.493	0.540	0.499
Core inflation	0.804	0.955	0.027	0.018
3M interest rate	0.722	0.231	0.276	0.404
Exchange rate	0.246	0.308	0.563	0.679

Variable does not Granger cause idiosyncratic term

	Horizon (quarters)			
	1	2	3	4
GDP	0.838	0.430	0.363	0.340
Core inflation	0.103	0.153	0.226	0.393
3M interest rate	0.030	0.097	0.116	0.190
Exchange rate	0.777	0.975	0.986	0.852

Table 4
The contribution of shocks to the variance of key variables

	Monetary		Risk premium		Supply		Demand	
	1 quarter	3 years	1 quarter	3 years	1 quarter	3 years	1 quarter	3 years
Gross domestic product	0.051	0.070	0.010	0.060	0.169	0.132	0.391	0.307
Core price index	0.017	0.082	0.089	0.099	0.051	0.117	0.613	0.422
Nominal exchange rate	0.100	0.063	0.373	0.093	0.045	0.065	0.209	0.432
Short-term interest rate	0.375	0.161	0.082	0.110	0.106	0.212	0.099	0.253

Table 5
Rank correlations of impulse responses and sectoral characteristics

	Y	P	DUR	CI	XS	NXS	WCR	STD	LEV	IC
Output response (Y)	1.000									
Price level response (P)	-0.341	1.000								
	(0.255)									
Durability (DUR)	0.290	-0.329	1.000							
	(0.337)	(0.273)								
Capital intensity (CI)	-0.165	0.198	-0.397	1.000						
	(0.591)	(0.517)	(0.179)							
Export share (XS)	0.069	-0.239	0.622	-0.495	1.000					
	(0.823)	(0.431)	(0.023)	(0.085)						
Net trade exposure (NXS)	0.217	-0.289	0.218	-0.396	0.741	1.000				
	(0.476)	(0.339)	(0.474)	(0.180)	(0.004)					
Working capital ratio (WCR)	0.412	-0.341	0.624	-0.522	0.399	0.366	1.000			
	(0.162)	(0.255)	(0.023)	(0.067)	(0.177)	(0.219)				
Short term debt ratio (STD)	0.435	-0.195	0.398	-0.286	0.343	0.415	0.891	1.000		
	(0.138)	(0.523)	(0.178)	(0.343)	(0.251)	(0.159)	(0.000)			
Leverage (LEV)	-0.006	-0.582	0.302	-0.357	0.063	-0.003	0.231	0.066	1.000	
	(0.986)	(0.037)	(0.317)	(0.231)	(0.837)	(0.993)	(0.448)	(0.830)		
Interest coverage (IC)	-0.088	0.269	0.391	-0.006	0.644	0.451	0.077	0.124	-0.495	1.000
	(0.775)	(0.374)	(0.186)	(0.986)	(0.018)	(0.122)	(0.803)	(0.687)	(0.086)	
FX debt ratio (FXD)	-0.138	0.364	0.083	0.068	0.406	0.420	-0.231	-0.209	-0.589	0.727
	(0.653)	(0.222)	(0.788)	(0.826)	(0.168)	(0.153)	(0.448)	(0.494)	(0.034)	(0.005)

Note: Spearman rho values; associated p-values are in parentheses.

Figure 1
The common and idiosyncratic components of the short term interest rate (per cent)

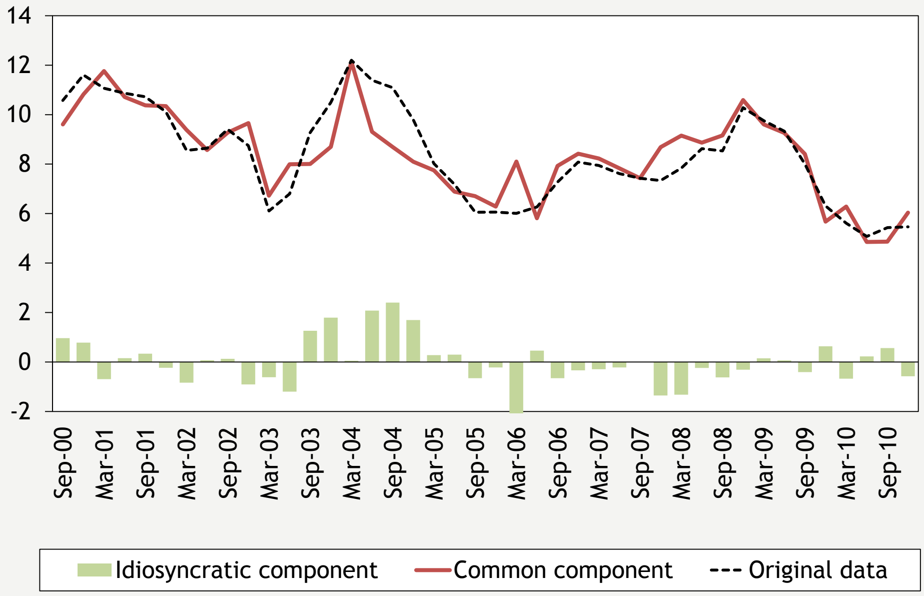


Figure 2
Impulse responses to a one standard deviation monetary shock (real economy and labour market)

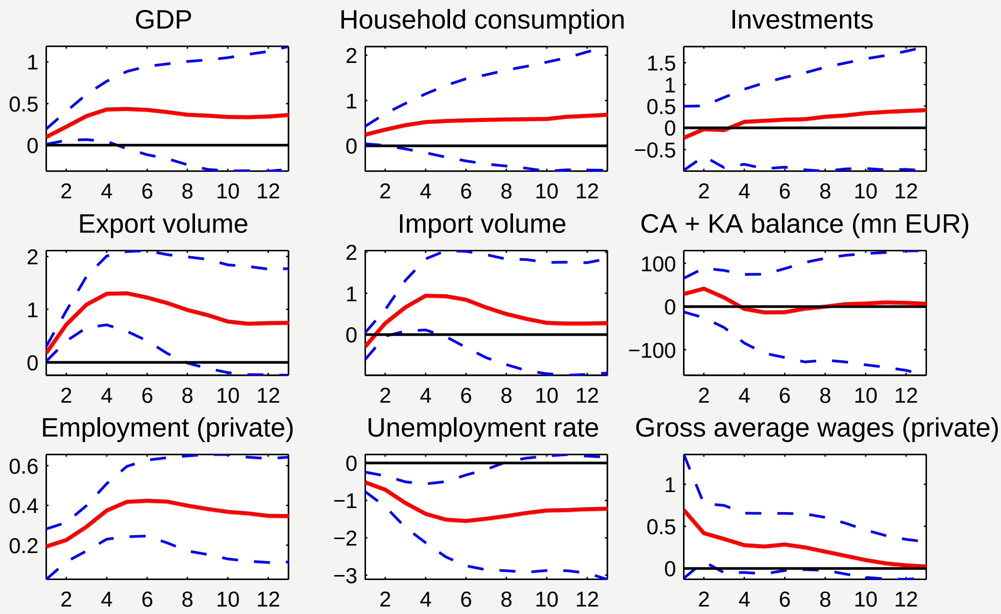


Figure 3
Impulse responses to a one standard deviation monetary shock (nominal variables)

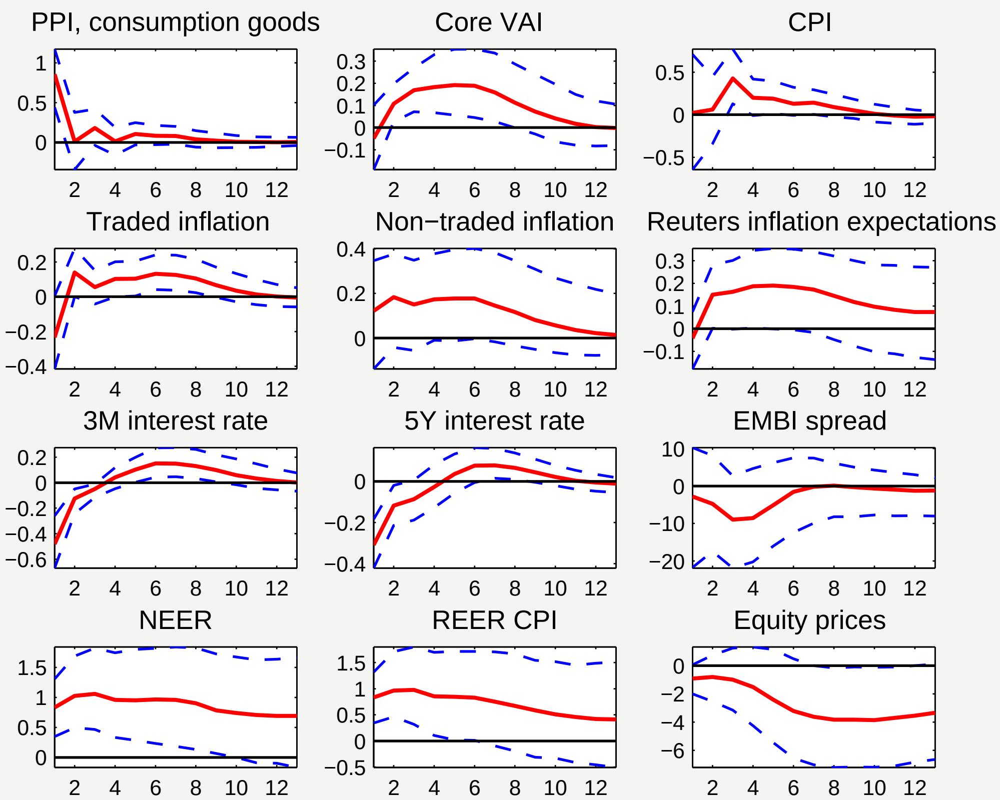


Figure 4
Impulse responses to other identified shocks

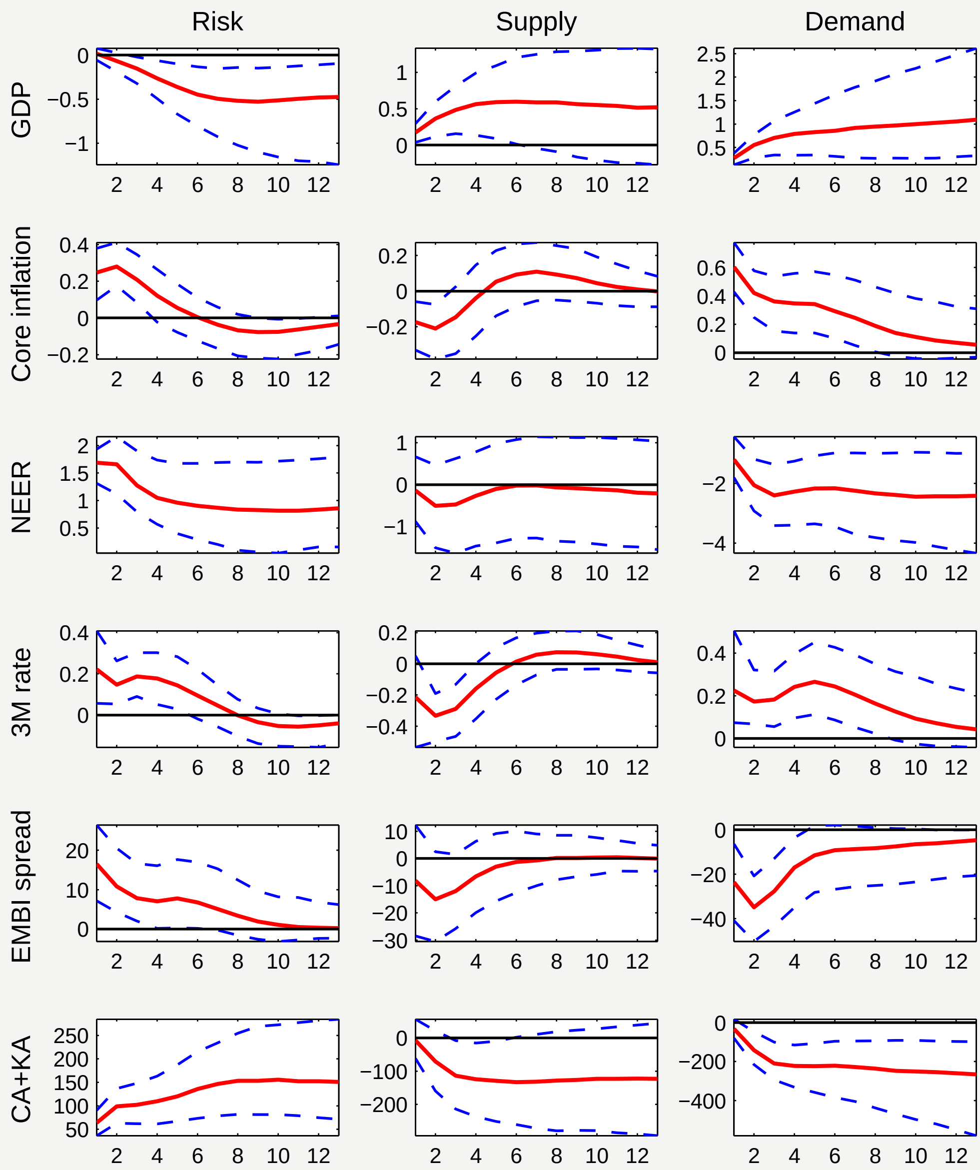


Figure 5
The identified shocks

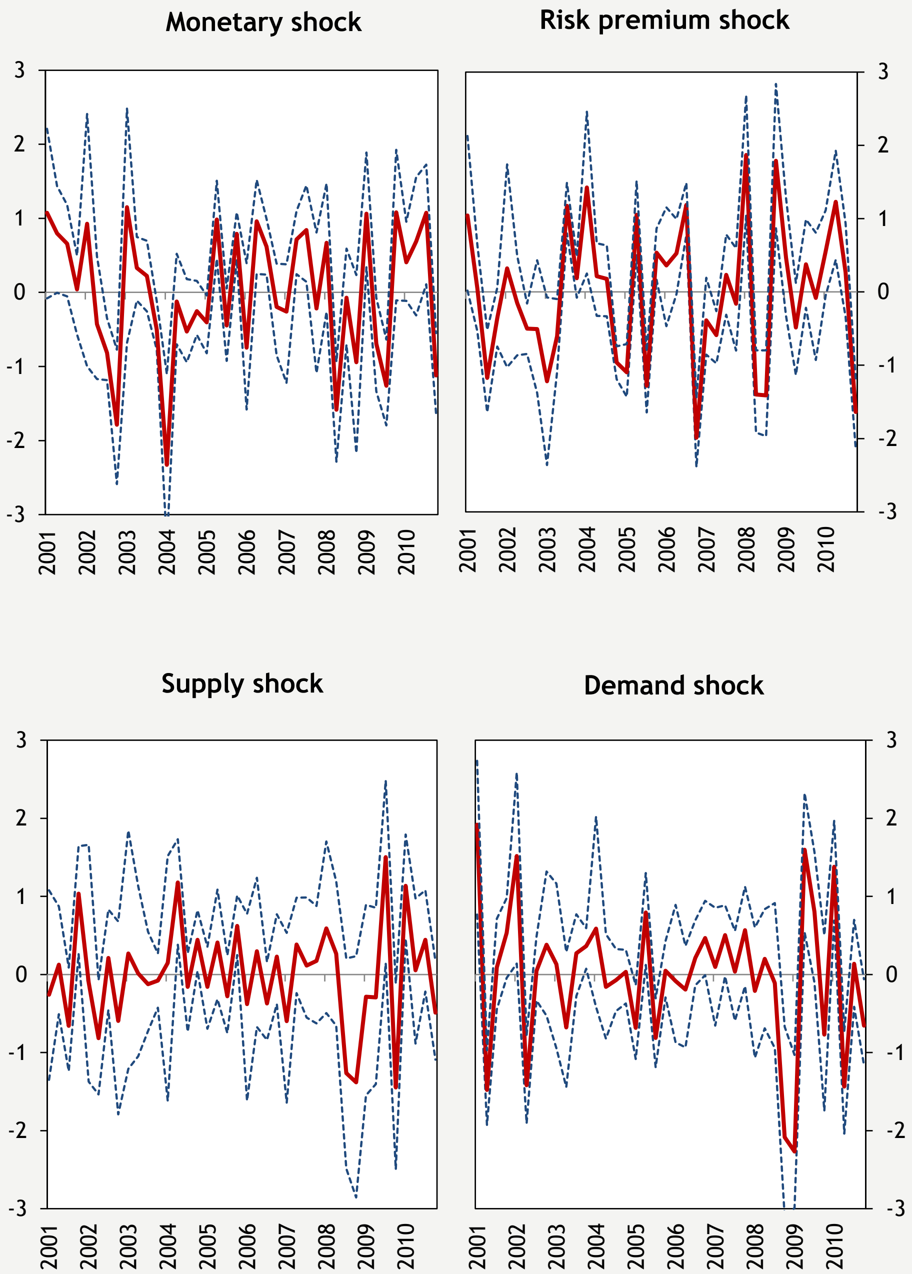


Figure 6
The contribution of shocks to the historical path of selected variables

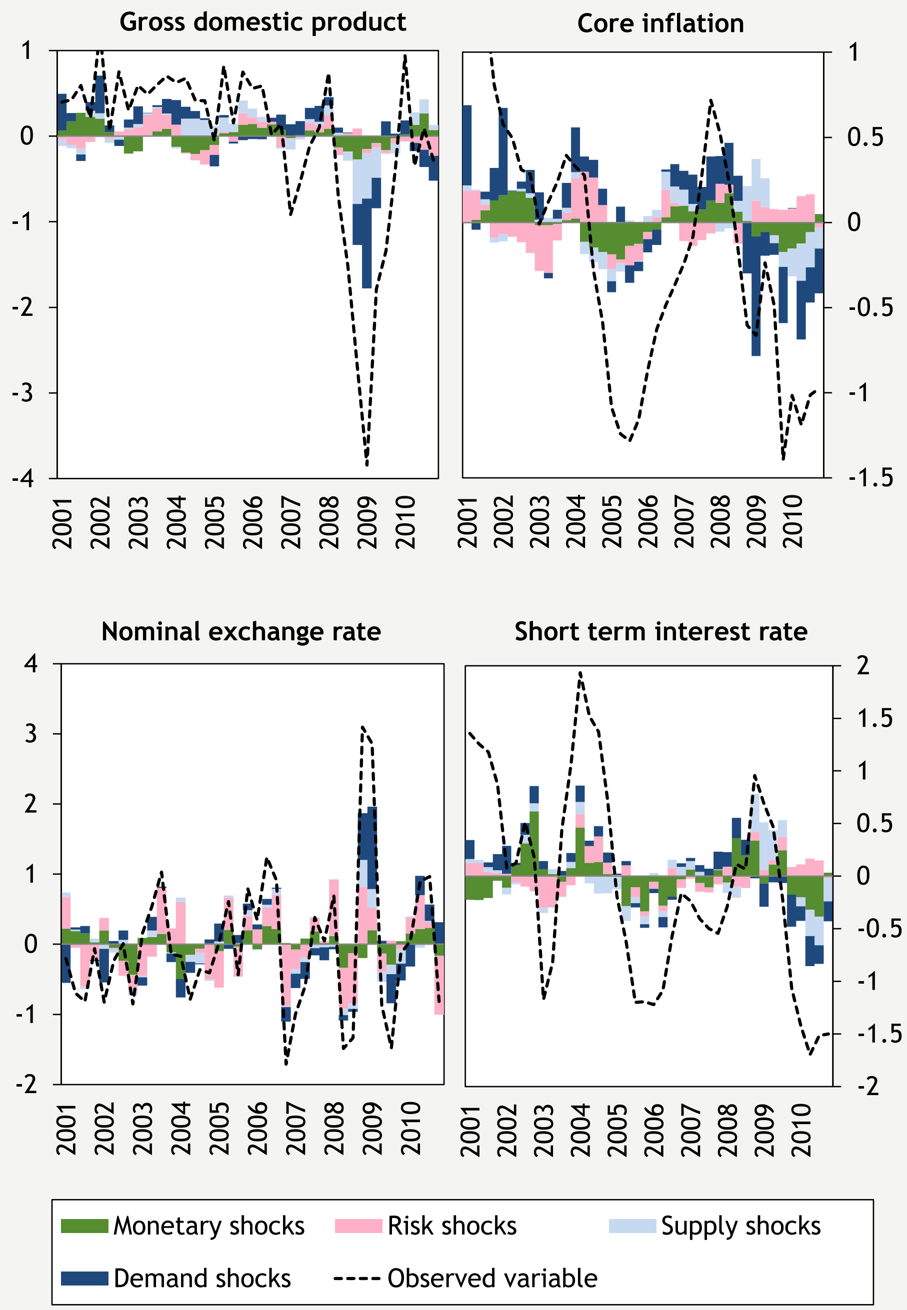


Figure 7
Sectoral impulse responses to a one standard deviation monetary shock

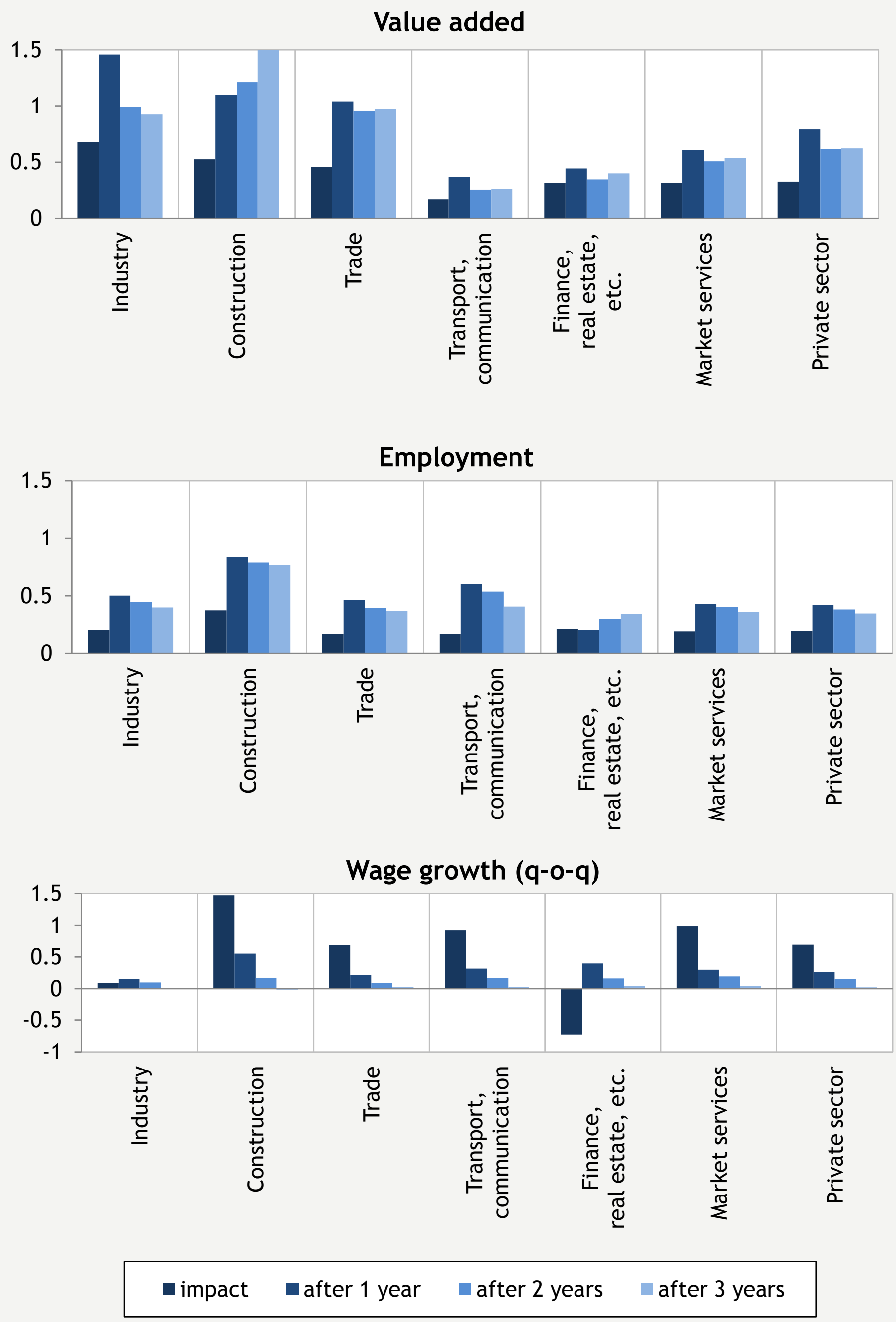
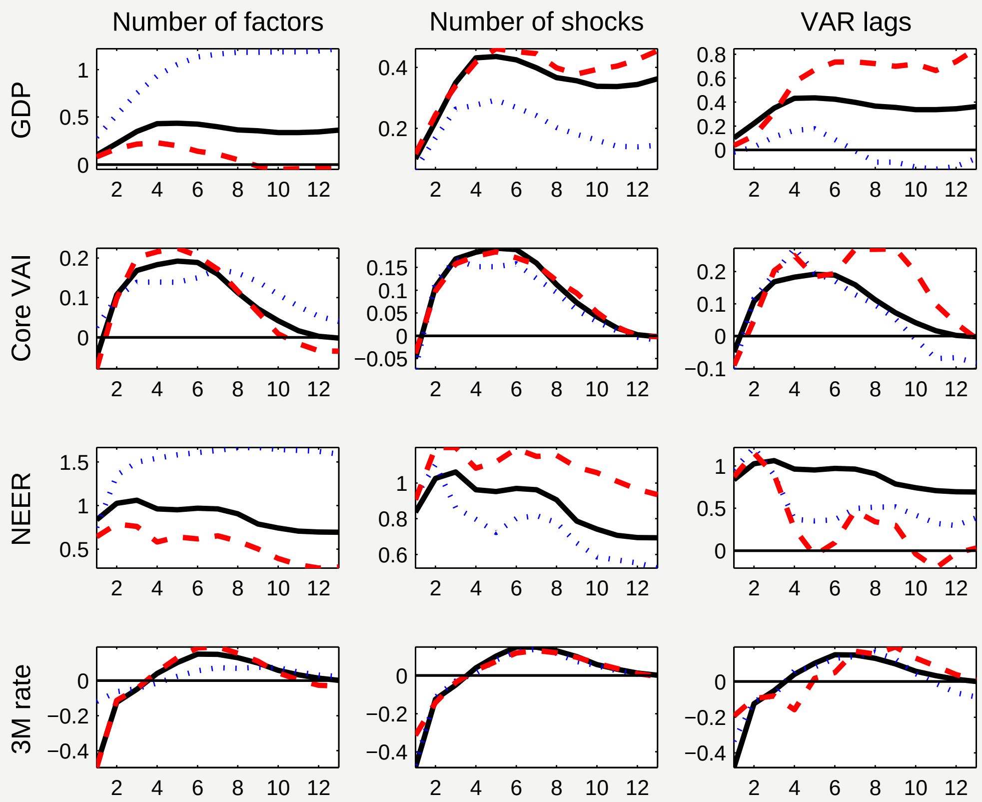


Figure 8
Sectoral impulse responses to a one standard deviation monetary shock among manufacturing subsectors

Figure 9
The robustness of impulse responses to a monetary shock



Note: impulse responses of variables' levels in percentages; the responses of prices and wages are annualized quarterly growth rates. Black lines indicate impulse responses from the baseline specification. In the first column, the number of static factors is changed (red dashed line = 5 factors, blue dotted line = 10 factors). In the second column, different VAR lag lengths are specified (red dashed line = 2 lags, blue dotted line = 3 lags). In the third column, the number of shocks is altered (red dashed line = 4 shocks, blue dotted line = 6 shocks).

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