How does monetary policy affect aggregate demand? A multimodel approach for Hungary*

Zoltán M. Jakab†
Viktor Várpalotai‡
Balázs Vonnák§

Abstract

This paper tries to estimate the effect of monetary policy on some components of the GDP and on some price variables. We use three different macromodels, all estimated on or calibrated to Hungarian data of the past 10 years. We find that after an unexpected monetary policy tightening the drop in investments dominates the output response which can be attributed to higher interest rates and the slowdown of investment goods inflation, both contributing to higher user cost of capital. On the other hand, we could not detect any significant change in consumption and net exports during the first couple of years. The former can be explained by the slow adjustment of nominal wages, which temporarily increases real wages. The weak response of net exports is due to the fact that the drop in exports is coupled with a fall in imports of almost the same magnitude.

JEL: E20, E27, E52

Keywords: Monetary transmission mechanism, macromodels, VAR, impulse responses

* The authors would like to thank Szilárd Benk for his invaluable help. We are grateful for comments from Ágnes Csermely and Mihály András Kovács. The views expressed here are those of the authors and do not necessarily reflect the official view of the Central Bank of Hungary (Magyar Nemzeti Bank). All remaining errors are our own.

† Head of Unit, Model development unit, Conjunctural Assessment and Projections Division, Economics Department, jakabz@mnb.hu

‡ Researcher, Research Division, Economics Department, varpalotaiv@mnb.hu

§ Deputy Head of Division, Monetary Strategy and Assessment Division, Economics Department, vonnakb@mnb.hu

I. Introduction

It is a widely accepted view that monetary tightening leads to lower output and lower prices in the short to medium run. Most studies in empirical monetary transmission mechanism literature confirm, or at least are unable to reject this view.[1]

The negative effect on output can come from various sectors of the economy. Higher interest rates can push the households to postpone some of their planned expenditures and save more. Higher interest rates can make investments more costly and can therefore temporarily slow down capital accumulation. Finally, more appreciated exchange rate, which is a natural consequence of monetary tightening, can make imported goods cheaper and decrease the competitiveness of domestically produced good thereby resulting in lower level of net exports[2].

The importance of the sectors in transmitting monetary policy movements can differ significantly across countries. Angeloni et al. (2003) compare the reaction of consumption and investments in the euro area and the U.S. They conclude that following an unexpected monetary tightening output components contribute to the economic slowdown to a different extent. Whereas in the U.S. the drop in private consumption dominates, the effect on investments seems to be more important in the euro area.

As for Hungary, the crucial role of the exchange rate in the monetary transmission mechanism is widely accepted. Being a small open economy with capital markets accessible for foreign investors, both the sensitivity of the exchange rate to monetary policy and that of real activity to exchange rate movements are supposed to be high. Rezessy (2005), Karádi (2005) and Vonnák (2005) estimate the impact of monetary policy to the nominal exchange rate. They all detect significant exchange rate response. Darvas (2001), Jakab and Kovács (2003), and Kovács (2005) give empirical characterisation of the exchange rate pass-through and the effect on the real economy.

Inspired by the study of Angeloni et al. (2003) and aiming at a deeper understanding of the Hungarian monetary transmission mechanism, this paper tries to estimate the effect of monetary policy on some components of the expenditure side of GDP, namely, consumption, investment, export and import. We also investigate the reaction of some price variables, such as wages, price of investment goods, traded and non-traded prices.

In order to minimise methodological uncertainties, we use three different models. All of them are somehow estimated on Hungarian data of the past 10 years, but they differ in what features of the Hungarian economy they capture. We compare the response of key variables to a monetary shock and we draw firm conclusions only when there is substantial similarity among the three models.

The paper organised as follows: in the next section the three models are described briefly. In the third section we present our estimation strategy and the results. Section IV concludes.

---

[1] See for example Christiano et al. (1998). Uhlig (2005) is a counterexample, as he could not reject the null that monetary policy is neutral even in the short run.

[2] In this paper we do not deal with public expenditures, i.e. we assume a fiscal policy that does not respond to monetary policy shocks.

II. Models used in this paper

II. 1. The Quarterly Projection Model (NEM)

The Quarterly Projection Model (NEM) developed at the Magyar Nemzeti Bank (see Jakab et al., 2004) is a neokeynesian, macroeconometric model. The key behavioural equations are estimated with some calibrated coefficients. The estimation sample generally starts in 1995. The specifications usually consist of an error correction term, describing the effect of long run relationship and some short run dynamics.

In order to understand the monetary transmission mechanism, here we focus on those mechanisms which are of importance in this respect.

Monetary transmission in the NEM model works in different channels. Higher long term interest rates lead to an increase in user cost of capital. The user cost channel is based on the capital demand equation, which is derived from profit maximizing optimality conditions of firms. Production is based on a Constant Elasticity of Substitution (CES) production function with capital and labour as inputs. Technological progress is exogenous and labour augmenting. Production function defines potential output: the one prevailing under trend (full-capacity) employment.

The key parameter in the production function (the elasticity of substitution between capital and labour) is calibrated by using microeconometric estimations (Kátay, 2003). This value is not far from the one estimated on macro data (see Reppa, 2005). This parameter has a key importance for the long run reaction of the economy to a monetary shock, as this also gives the elasticity of (private) capital demand to a real user cost of capital change. In our baseline model setup, a one percentage change in the user cost of capital would lead to around 0,4 percent drop in capital in the long run. One should note however, that according to our estimates the user cost effect on capital is very slow, after 6 years the dynamic response is less than half of the total (long term) response.

There is one important feature with regard to the treatment of real user cost: it is determined by the long term nominal yield plus an equity premium deflated by the inflation of investment goods.[3] Given the fact that investment prices respond relatively quickly to a monetary tightening (through their "almost tradable" nature), in the short run real user cost increases by more than that of long term interest rates. This gives a negative response of investment for a monetary tightening in the shorter run, as well.

Employment is also modelled through profit maximization. In the NEM model the "right-to-manage" wage-employment mechanism is built in. This means that there is a wage-bargain where employers and employees determine nominal (and real) wages, and then employees decide on labour demand which determines employment. Elasticity of employment to wage-costs in the long run has an elasticity equal to the coefficient of capital/labour substitution in the production function.

Main elements of aggregate demand are private consumption, private investments and net exports. Consumption is modelled with a standard "consumption-smoothing" equation adjusted with liquidity constrained ("rule-of-thumb") consumers, where in the long run

[3] In fact, corporate taxes, depreciation and the relative price of investment goods (compared to domestic goods) also play some role.

disposable income, financial and housing wealth determines consumption (with elasticities 0.6, 0.2 and 0.2, respectively). Liquidity constrained households' consumption amounts to around 20 percent of total consumption demand. Monetary policy can have an effect on consumption mostly through the change in real income (through the change in wages and employment). Direct real interest rate effect on consumption is not modelled, because it was not found to be empirically important.

Exports depend on relative export prices and foreign demand. However, export prices in the NEM have very high pass-through, the short term elasticity is higher than 0.9. Hence a shift in monetary policy, even if it changes the nominal exchange rate can only modify exports in a very modest way.

The exchange rate channel of monetary transmission mostly works through the change in imports. Imports depend on relative import prices (import prices to core inflation) and on a weighted average of aggregate demand components. As the pass-through of exchange rate to import prices is relatively fast (although not as much as for export prices) and the pass-through to core inflation is slower, any change in the exchange rate modifies relative import prices. Moreover, imports also depend on aggregate demand, hence any effect of monetary policy, which alters demand slows down the effect through imports: lower demand leads to lower imports and thus, the original drop in GDP will be somewhat lower, as well.

Aggregate demand changes feed into prices, wages and employment, which again alters demand and the new equilibrium develops simultaneously.

An important source of price response comes from the price equation (Phillips curve). The key price variable in the model is the GDP-deflator which describes "domestic" inflationary pressures. In the long run "domestic" prices depend on unit labour costs times a markup. This is consistent with the price decision of a monopolistically competitive representative firm assumption. Markup, however is not constant and fluctuates along business cycles: in recessions price-markup is lower than in booms. Monetary policy can affect prices through the goods market by changing aggregate demand (e.g. through the exchange rate channel via exports and imports or through consumption and through the real user cost channel on investments) and consequently the output gap. The goods market effect is captured by the short term inclusion of output gap term in the price equation. The coefficient, however is calibrated and not estimated and lies in the middle range compared to other models. The maximum effect of an increase in output gap on prices is reached within one year with an elasticity of around 0.25.

Change in prices is however not only driven through aggregate demand (output gap), nominal wages are also affected. Private wages depend on prices (with a long term elasticity of one), productivity, labour-augmenting technology and unemployment. This equation describes a wage-bargaining mechanism: employers' wage-offer depends on productivity (marginal revenues) while employees charge a markup which depends on the scarcity of the labour market (proxied by unemployment). A monetary shock which effects output and employment leads to lower wages (in the short to medium run), as well. A permanent 1 percentage point increase in unemployment leads to around 2 percent lower wage level.[4]

Wages are relatively persistent to a nominal (price) shock. The half life is more than one year. Hence, if domestic prices (e.g. GDP-deflator) are lower due to a monetary shock, real

[4] This is the semi-elasticity of unemployment to wages, the elasticity is around 0.14.

wages and thus, real income increases. This effect is quite strong relative to others, as a result of a monetary tightening a temporary increase in consumption can also be observed in the model simulations (see later). In international comparison, unemployment's effect on wages is not extreme.

The direct exchange rate channel of monetary transmission mechanism is modelled through import prices. As mentioned previously, the pass-through is relatively fast and the direct impact is more than 70 percent.

Core inflation is then calculated as a weighted average of import and domestic prices (GDP-deflator). Consumer prices are then a weighted average of core inflation, regulated, energy and food prices. Consequently, the direct price impact of a monetary tightening leads to lower consumer prices, but as wages are more persistent than prices, this also means higher real income of households, which smoothes the negative output effect of higher imports.

As the model is simultaneous, the distinction between the channels of monetary transmission mechanism in the model is far from obvious. In a birds-eye-view, the main mechanisms of a monetary policy shock (increase in interest rates) works as follows:

The exchange rate channel is quite strong, as it has a direct impact on consumer prices, and thus leads to an increase in real income. Consequently, in the very short run consumption increases. Direct effect of the hike in interest rate is not present. Exports respond rapidly and only very modestly. However, due to the temporary increase in demand for imports and the relative price effect (pass-through to import prices is faster than to consumer prices) imports are higher. At the same time, as a consequence of higher long-term interest rates real user cost is also higher, and this effect is magnified by the drop in investment prices. This lowers private investments both in the short and in the longer horizon. Overall, GDP, output gap and employment is lower which slowly feeds into lower real wages (which later tilts consumption down) and to lower domestic prices (GDP-deflator). This helps in stabilizing the system, as imports start to drop. The second-round effects of the change in demand and wage costs feeds into prices in a quite persistent manner. Nominal wages are the most persistent among nominal variables. Therefore a monetary policy shock has a short term (direct) effect and the demand-led and cost-push forces make the domestic price responses flat and relatively persistent.

One should notice that there are channels of monetary transmission mechanism which were switched off or not modelled in this paper explicitly. The reason is that some of these channels were not found to be econometrically significant for the past, but in the future they can be more important. For example housing wealth effects would modify households' behaviour, as well. Through these valuation effects, initial consumption increase (due to higher real income) might be mitigated, and thus, GDP response in the model is underestimated. Moreover, the corporate sector's behaviour is only modelled through the change in real user cost (and the accelerator in investment), no balance-sheet or credit channels are present in the model.

A second drawback of our model simulations is that the treatment of expectations was not satisfactory. Only "partial forward-lookingness" (through nominal exchange rate and long term yields) is modelled. Agents' forward looking behaviour would also change the way monetary shocks hit the economy. For example, as a consequence of a monetary tightening price and wage expectations can also be altered. In other words: Phillips-curves (the price and the wage equation) are not forward-looking. Forward-looking Phillips curves (if the policy is credible) would end up with more pronounced initial impact of monetary policy shocks. Credibility of the monetary authority is also not explicit in this setup.

A third drawback comes from the lack of fiscal reactions in our model simulations. If fiscal policy reacts to a monetary tightening by e.g. lowering taxes, GDP and thus price and wage responses might be lower even in the shorter run.

II. 2. The 5GAP model

The 5GAP model describes the evolution of inflation, several factors of excess demand, exchange rate and interest rate in a small open economy framework with floating exchange rate regime in a reduced form.[5] The model was inspired mainly by Svensson (2000) but there are other papers like Batini and Haldane (1999), Batini and Nelson (2001) and Leitemo (2000) which present a slightly modified version of original model of Svensson (2000). The model was originally designed to understand some price and real variable movements in Hungary triggered by introducing new monetary regime and some consumption boosting policy of the government.

The theoretical background of the model is neo-Keynesian with rational expectations. It assumes a Calvo-type pricing where current inflation depends on expected future and past inflation, output gap[6] and real exchange rate. The exchange rate is determined by uncovered interest rate parity condition, where the domestic short term interest rate is modelled by a Taylor rule. The main strength of this model is that it presents a structure broadly based on micro foundation with rational expectation in a compact form.

The theoretical novelty of 5GAP model is the decomposition of aggregate excess demand variable (output gap) into household and government consumption, investment, export and import gaps. It has been assumed that the evolution of these disaggregated gaps[7] are determined by some of the following variables like aggregate gap, foreign demand, real exchange rate or disaggregated gaps themselves with a relatively long distributed lag structures. This decomposition and the use of long lags enable the model to deliver a more detailed picture about the size and the timing of transmission mechanism as well.

The model is quarterly and it is estimated on Hungarian data starting from 1991. Each gap variable has been defined as a Hodrick–Prescott filtered series of correspondent seasonally adjusted variable (λ=1600), except for real exchange rate which was detrended with a linear trend. However, the standard estimation process was not applicable to equations containing long lags, therefore we applied a Bayesian technique using a smoothness prior developed by Shiller (1973). This prior effectively breaks multicollinearity inherent in lagged data. The estimated distributed lag structures often report a delayed reaction to a change in explanatory variables (see Figure 1.5).

II. 3. SVAR

The third model is in fact a bunch of models, each of them is an appropriate expansion of the structural VAR introduced in Vonnák (2005). The specification consists of a VAR and an identification scheme. The former describes the systematic response of the variables to

---

[5] See Várpalotai (2003) for further details

[6] Output gap is a proxy variable for marginal cost.

[7] Except for government consumption, which was treated as exogenous.

past shocks, whereas the identification establishes connection between economic intuition and the covariance structure of reduced form residuals. This involves actually the characterization of unexpected monetary policy movements.

The VAR in that paper consisted of output, consumer prices, short term interest rate and nominal effective exchange rate. In order to analyze the behaviour of components of the output and overall price level one needs to include them in the VAR. The short time span, however, does not allow estimating too large models, hence adding all the variables that are of interest (consumption, investment etc.) is not feasible. We modified therefore the original specification by adding in each case only one more variable to the original set of output, price level, interest rate and exchange rate. In some cases, when two new variables were introduced, we omitted consumer prices. We had to select appropriate lag length in each case. We chose the minimal length that produced unautocorrelated residuals. Typically two lags were enough, sometimes three.

We experimented both with quarterly and monthly series. With monthly series of prices, interest rate and exchange rate, the output variable was the industrial output. The expenditure components of GDP were transformed to monthly frequency by the interpolation technique suggested by Chow and Lin (1971), included in version 2.1 of the Flash software developed by the European Commission. Since results obtained on different frequencies were qualitatively almost the same, we present only results from the quarterly models.

For identification we used the sign restriction approach. We assumed that after an unexpected monetary tightening the short interest rate will be higher, the nominal exchange rate will be more appreciated for one year. This is one of the identification strategies used in Vonnák (2005) and found to produce credible results. For a detailed discussion of alternative approaches the reader should refer to that paper. We also assumed that monetary policy shocks have no immediate impact on real variables, which is a restriction more arguable for monthly VARs, nonetheless, the experiences of our reference paper justify its use for quarterly data as well.

Although the VARs were the same as in the referred benchmark with an additional variable, the same identifying restrictions led sometimes to quite different impulse responses, particularly for the output. In many cases output increased, even if not significantly, after a monetary contraction. Since the results of the original VAR were found to be robust and reasonable, and our purpose here is to explore the relative behaviour of aggregate demand components and not that of GDP, we found it justifiable to add a new assumption to the restriction set. We restricted therefore the response of total output to be negative for one year after a monetary tightening.

The impulse responses of interest rate, consumer prices and exchange rate were then similar to the 4-variable benchmark case, thus we concluded that this extended identification strategy is compatible with the original. With the help of this additional constraint we obtained responses of consumption, investment, foreign trade and some price indices that are comparable to each other, since they are consistent roughly with the same output and price level path.

III. Impulse responses

We pursue to get an overall picture about the monetary transmission mechanism by investigating the responses of certain variables to a monetary policy shock, i.e. an unexpected deviation from the systematic behaviour, the so-called monetary policy rule. There is a debate in the literature whether impulse responses bear relevant information about the structure of the economy. Opponents of shock analysis argue that interest rate movements are mainly predictable, therefore unexpected changes are not of interest. They propose instead to compare the volatility of important variables under different policy rules[8]. We think, however, that for our purposes, namely to get a picture about how monetary transmission works through different components of the GDP, comparing impulse response functions (IRFs) can be informative. We expect the qualitative differences between the reaction of investments, consumption and foreign trade not to be specific only to unexpected monetary policy shocks.

In the following subsections we compare impulse responses obtained from our models. The reliability of the results depends on the estimation error. In case of NEM and 5GAP, due to computational constraints, we do not report error bands. We consider a result to be informative only if the IRFs from different models are "close to each other"', and in those cases we use error bands from SVAR for making judgements about the uncertainty.

III. 1. Definition and interpretation of the shock

In order to obtain comparable impulse responses from the three models we have to give (almost) the same impulse to them. A monetary policy shock is often thought of as an unexpected transitory deviation of the (short term) nominal interest rate from the baseline, that is from what is expected by the agents of the model. Due to the openness, the role of exchange rate is crucial in Hungarian monetary transmission mechanism. Therefore it is important that either the definition of the shock include the behaviour of the exchange rate, or the relationship between the interest rate and the exchange rate be properly modelled.

There are several sensible approaches. Perhaps the simplest way is to treat only the nominal (short term) interest rate as exogenous in all three models, and to give some initial shock to it for some periods, for example 4 quarters. In this case one has to decide how to model the exchange rate dynamics. Usually it is assumed that the uncovered interest rate parity (UIP) holds. Although there are some doubts whether UIP is a good characterisation of the relationship between interest rates and exchange rates, it is difficult to find better model that is simple enough and credible at the same time.

Our approach is slightly different. Since our purpose is to answer the question, how economic agents react to a typical monetary policy shock, it is reasonable to use a typical path of the exchange rate as an exogenous variable. Fortunately, in Vonnák (2005) the behaviour of the HUF exchange rate after a monetary policy shock is estimated. We use therefore the impulse response functions (IRF) of nominal interest rate and exchange rate to one standard deviation monetary policy shock obtained from the monthly model for the 1995-2003 period with the "sign restriction on impulse response functions" identification. The exogenous interest rate and exchange rate responses we plugged into the other two

[8] See for example McCallum (1999)

models are shown in the top panel of Figure 2.1, and can be characterised briefly as corresponding to roughly a 25 basis points interest rate increase which is followed by an almost 1 percent nominal exchange rate appreciation during the first year.

Another reason for using IRFs from SVAR as exogenous paths instead of modelling the behaviour of exchange rate is that out of the three models, only the SVAR contains (implicit) estimates of the interest rate – exchange rate relationship. By imposing UIP or any other theoretical model we would lose this information embedded in the data.

Actually, our identified monetary policy shock performs relatively well in the sense of fulfilling the UIP condition, compared to other estimates in the literature. Several studies have addressed the issue of "forward discount puzzle" or "delayed overshooting".[9] Both expressions refer to roughly the same empirical phenomenon, namely, after an unexpected interest rate hike the domestic currency appreciates only gradually, with the peak response occurring only in the second or third year. That kind of hump shaped response seems to contradict to Dornbusch's model which predicts immediate appreciation and gradual depreciation afterwards (Dornbusch, 1976).

Our SVAR estimates are close to be consistent with the UIP. The peak response occurs two quarters after the shock, and then the exchange rate depreciates in a pace which is consistent with the level of the interest rate. To assess more precisely how far our estimates are from the UIP, we calculated the predictable excess return, which is the interest rate less the rate of exchange rate depreciation in the next period.[10] If UIP holds, the predictable excess return should be zero. In fact, we can observe sizeable deviation from the UIP only in the first two quarters. The positive sign indicates that holding HUF assets after an unexpected rate hike yields excess income compared to foreign assets. However, the excess return virtually diminishes in the third quarter, and the middle two-third of the posterior contains zero from the second quarter onwards. Therefore our estimates show only a one period violation of the UIP, which can be explained by several micro approaches of financial markets.[11] The posterior distribution of peak response also suggests an almost UIP-type dynamics, and a weak evidence of delayed overshooting (Figure 2.1 bottom panel).[12]

Of course, there are also some drawbacks of our approach. Perhaps the most serious one is that we used actually not only three, but about ten models. The reason is that in order to calculate the IRFs of GDP and price level components we reestimated the original VAR by adding the relevant variable to it. We therefore ended up with several SVAR models. Although we used almost the same identifying restriction set in each case, we did not get exactly the same IRFs for nominal interest rate and exchange rate. However, those responses were close enough to each other, hence we do not think it would limit the comparability of the IRFs across models.

---

[9] See for example Eichenbaum and Evans (1995) or Scholl and Uhlig (2005).

[10] Figure 2.1 middle panel. We used the benchmark 4-variable monthly VAR modell with sign restriction identification. Median estimates as well as 68% and 95% error bands are reported.

[11] See for example Bacchetta and Wincoop (2005). They consider the consequences of costs associated with collecting information and conclude that rational inattention can explain the forward discount puzzle.

[12] Since we estimated the SVAR in a Bayesian way, we could easily calculate the posterior distribution of any parameter of interest, like the horizon at which the response of the exchange rate was maximal. In 25 percent of all cases the peak occurred in the first three months, and the first year contains the 75 percent of all outcomes.

Another problem is that using exogenous interest rate and exchange rate paths of the SVAR estimates in the NEM and the 5GAP, although technically possible, may not be theoretically model consistent. The response of interest rate in the SVAR can be interpreted as a result of the price, output and exchange rate responses and a policy rule that sets the policy instrument as a function of those variables. In the other two models the response of output and inflation is very likely different from the SVAR estimates, therefore using the same interest rate path would imply a different monetary policy rule.

Finally, it should be noted that the benchmark IRFs of interest rate and exchange rate are estimated with substantial error. The appropriate treatment would be to take into account the uncertainty surrounding the point estimates, but because of the computational constraints we treated them as if they were perfectly certain.

III. 2. Reaction of aggregate demand components

As a first step we compare the IRFs of output and consumer prices. Figure 2.2 shows the responses from the three models. After a monetary policy shock that was typical between 1995 and 2003 both the output and the price level falls by 0.1-0.2 percent, according to most of the models. The output in the SVAR is an outlier. This may be the consequence that the benchmark VAR contained industrial production instead of GDP, and the former series are more volatile.[13]

According to NEM and SVAR monetary tightening leads to around 0.1-0.2 lower consumer price level in medium term. As discussed later, this can be the consequence of the different timing of different markets' responses. In the shorter run drop in imported inflation lowers prices. As aggregate demand is also lower later on this has a negative effect on prices, as well. As wages adjust in a sluggish manner, costs accommodate to the shock smoothly. As a result, consumer price response will be flat at least in the medium run.

The response of price level is considerably larger in the 5GAP, compared to the other two models. The reason for this is the unfavourable properties of the inflation inertia in the forward looking Phillips curve when some endogenous variables are treated exogenous. Namely, in the 5GAP there is a single path of exchange rate and interest rate determined endogenously by the model that results a solution without considerable swings. As our assumed shock differs from this unique path, the fall of the non-traded prices is accelerating until output gap and exchange rate remain negative and overvalued, respectively, generating an undershooting in the price level of non-traded goods. The response of traded prices in 5GAP is very similar to that in the NEM, reflecting the similar way of modelling exchange rate pass-through in these models, however, the response of aggregate price is dominated by the fall of the non-traded prices.

The next step is to investigate how components of aggregate demand contribute to the decline in output predicted by all three models. After comparing the responses of consumption, investments, exports and imports to a typical unexpected monetary tightening the following robust statements can be formulated: each model shows a sharp and relatively quick decrease in investments by a magnitude of around 0.2 percent during the first two years. The picture of the reaction of consumption and foreign trade is more blurred. According to the NEM and 5GAP, consumption does not seem to respond

[13] In fact, using GDP data in the VAR results in output responses of the same magnitude as in the NEM and 5GAP. See Figure 2.4.

strongly to the shock. The SVAR, however, indicates a significant rise during the first three years.[14]

In the case of exports the NEM shows no reaction, the 5GAP slight, the SVAR sharp decrease. The latter two models produced IRFs for the imports with the same sign (negative), while the NEM indicates a small increase. Hence, the proper assessment of the foreign trade results would be that we could not detect significant effect of monetary policy shocks on net exports. SVAR estimates for the net exports leads to the same conclusion, the middle two-third of the posterior distribution of the response contains zero in each period (bottom right panel of Figure 2.4).

Our results are roughly in line with those of Angeloni et al. (2003) for the euro area. They found that in contrast with the U.S., where it is the decline of consumption that reduces more the GDP after unexpected monetary tightening, in the euro area the output response is driven mainly by investments. An important difference, however, is that whereas consumption falls in the euro area, in Hungary it seems rather to increase slightly after a monetary contraction.

In the following we try to explain the responses of output components more detailed mainly within the framework of NEM, in some cases using additional SVAR estimates for other macrovariables, if available.

Consumption

In the case of private consumption the sensitivity of households' savings decision to interest rates may play a crucial role in monetary transmission mechanism. In Hungary the level of households' indebtedness and financial assets has been rather low during the sample period compared to developed countries. The high concentration of the banking sector in the household branch[15] and the lack of debtors' record hindered some households from accessing credits to the extent that would be sufficient to smooth their consumption.

As a consequence of low level of indebtedness and nominal wage stickiness, the effect of current income on consumption can overshadow that of the interest rate[16]. We investigated the evolution of nominal and real wages in the NEM model as well as within the SVAR framework. Both models indicated that after a monetary policy shock real wages adjust only very smoothly. The SVAR impulse response function declines only in the second, in the NEM even later, in the third year. The delay in nominal wage reaction is longer than in consumer prices, therefore real wages rise during the first 1-2 years. This result is quite significant, as demonstrated in the last panel of Figure 2.5, which shows that one year after the shock standard error bands around the median estimates are entirely above zero.

Higher real wages increase disposable income, which can explain why consumption does not decline after the shock. An intuitive understanding would be to call it "exchange rate channel", since after an appreciation imported goods become cheaper, therefore

[14] The magnitude of the SVAR IRF partly can be attributed to the fact that the VAR model augmented with consumption produced larger interest rate and exchange rate reaction than the other VAR models (see Figure 2.4). Taking this into account, a comparable consumption response could be obtained by rescaling it by 0.5-0.7. Nonetheless, this would affect only the size, not the shape or the significance of the result.

[15] Móré and Nagy (2004)

[16] Jakab and Vadas (2001) estimated a consumption function. They found that private consumption was sensitive to wage changes, but not to real interest rate. Their finding is in accordance with our results.

households can consume more. In fact, we had difficulties in verifying this story. The NEM model does not distinguish between tradable and non-tradable inflation, but the dynamics of imported goods, which can be a plausible proxy for tradable prices, is consistent with a quick exchange rate pass-through to tradable prices. We also experienced with SVAR replacing the consumer price level with traded and non-traded prices. The result is the same: quick pass-through to the former, slow pass-through to the latter.[17] Nevertheless, due to their share in CPI (more than one-fourth), quick pass-through to tradable prices would imply an impact drop in consumer prices, but estimates for the whole CPI were not affirmative, the reaction was delayed.

Investments

For an explanation of the response of investments, understanding the user cost of capital is crucial. We decomposed the user cost according to the NEM model. In Figure 2.6 the impulse response of its most important ingredients are plotted. Basically, the user cost is determined by the long term interest rate, the growth of investment goods deflator, the relative price of investment goods and some variables that are exogenous from our point of view. The long term interest rate rises after a monetary tightening (dotted line). During the first year, however, the increase in user cost is twice as much as in long term interest rate. The difference is almost entirely attributable to the dynamics of investment deflator. Due to the exchange rate appreciation and the "almost tradable" nature of investment goods, as mentioned earlier, their price drops during the first one or two years. This is reinforced by SVAR estimates, too (bottom panel of Figure 2.6). Deflation in investment goods price index drives real cost of capital accumulation higher than nominal interest rate. Intuitively, a monetary tightening makes investment costly not only because of high interest rates, but with declining prices the opportunity cost is also high. Firms may want to postpone their purchases as long as they expect further decreasing prices.[18]

The fact that tradable prices magnify the effect of higher nominal interest rate is in some sense another aspect of "exchange rate channel". As we have seen, this exchange rate effect is comparable to the change in interest rate. On the other hand, we still cannot be sure that it is the "interest rate channel" that explains the drop in investments beyond the effect of appreciation. Since none of our models is capable to identify the bank lending or the balance sheet channel, even if they were important we could not distinguish them from the classical interest rate channel. Further research would be needed to assess the role of credit supply and corporate balance sheets.

Net exports

Finally, we try to explain the behaviour of foreign trade. The IRFs of our models show very diverse picture if we look at export and import responses, but the picture becomes sharper when we turn to the net export (Figure 2.3). The first observation is that SVAR responses for export and import are considerably larger compared to the other two models. The reason for this is not clear. It could be a failure of the identification, namely, shocks to foreign demand that are assumed to be mainly responsible for fluctuations in exports and

[17] We used price index of industrial goods and market service as proxies for tradable and nontradable prices, respectively.

[18] The figure also contains a „relative price" effect: this captures that the relative price of investment goods drops compared to domestic goods, makes investment somewhat less expensive. This effect, however, is not very large in magnitude.

imports, could have been falsely identified as unexpected movements in interest rate policy. To check this, we compared SVAR estimates of monetary policy shocks to various measures for foreign demand shocks, but we could not detect any correlation. It is difficult to imagine even theoretically that decrease in foreign demand would lead to higher interest rate and stronger exchange rate, which were our identifying assumptions.

Another source of uncertainty is the reaction of imports. Whereas the SVAR shows a sharp, and the 5GAP a minor drop in imports after a monetary contraction, the NEM produces increasing IRF. We also estimated the effect of monetary policy on net export directly within the SVAR framework using volume of exports less imports as an additional variable to the 4-variable benchmark model. We obtained a slight increase during the first year, but the zero line is well inside the middle two-third of the posterior distribution, therefore we would conclude that we could not detect any significant effect (Figure 2.4, bottom right panel).

The confidence bands of the SVAR estimates as well as sometimes contradicting impulse responses from the three models indicates that either monetary policy shocks have no effect on net export or at least we had difficulties to detect it. The theory suggests two opposite effects of monetary contraction: it reduces domestic demand improving trade balance (income-absorption effect), but at the same time appreciates the exchange rate that leads to less export and more import (expenditure-switching effect).

Kim's (2001) estimates show the dominance of expenditure-switching effect for France, Italy and the UK. Within this framework our result can be interpreted as the income-absorption effect offsetting expenditure-switching. In other words, although stronger exchange rate and worsening terms of trade would make foreign made products cheaper and home made products more expensive deteriorating the trade balance, the drop in investment purchases and exports decrease imports, too, because part of capital goods are from import and some exported products are made of imported goods with minor home value-added. In accordance with this story, 5GAP and SVAR estimates predict virtually no net export response but with both exports and imports decreasing by the same magnitude. Nevertheless, as we indicated above, NEM impulse responses somewhat contradict to the other two models questioning the validity of their results.

IV. Conclusions

In this paper we tried to answer the question: which sector of the Hungarian economy transmits monetary policy? We used three macromodels. All of them are estimated on Hungarian data of the past ten years. In order to ensure comparable results, we used (almost) the same exchange rate and interest rate path which we consider as typical after an unexpected movement by the monetary policy. We looked at the impulse responses of main output components of the expenditure side. We also tracked the behaviour of some price and wage variables that could help explain the reaction of components of aggregate demand. In some cases we used the structure of the quarterly projection model of the MNB to get a deeper insight into the particular mechanism.

We used two measures of uncertainty. We regarded a result not to be significantly different from zero if the three models produced ambiguous results and the error bands around structural VAR median estimates confirmed it.

We found that after an unexpected monetary policy tightening output and consumer prices decrease in the medium term. We also found that the price response is relatively persistent and can be explained by the different speed of adjustment in different markets: nominal wages are the more persistent, while the response of imported inflation is relatively fast.

The output response is dominated by the drop in investments. This channel works through the increase of user cost of capital, which is a consequence not only of higher nominal interest rates, exchange rate may play an important role, too. Since investment goods can be regarded as traded goods, and since exchange rate movements pass through quickly to the prices of traded goods, the appreciation that accompanies the interest rate increase leads to a lower rate of investment goods inflation. This raises the real user costs firms face when making investments decisions. They respond to higher costs by cutting investment expenditures, which results in persistently lower output. Put in other words, they postpone investments as long as they expect investment goods prices to drop further.

As for the other components, we could not detect any significant change in consumption and net exports during the first couple of years. While the insensitivity of Hungarian households' consumption to the monetary conditions is an already recorded fact, the ambiguous reaction of foreign trade is somewhat surprising. We found that the drop in exports, which met our expectation, is coupled with a fall in imports of almost the same magnitude, and therefore the change in net exports remains within the error band of our estimation methods. It can be either a failure of our estimation technique or an indication of the fact that the import content of investments and exports, that is the income-absorption effect dominates the import dynamics, or at least neutralise the expenditure-switching effect after a monetary policy shock.

Finally, it is important to note that our macromodels do not enable us to identify the contribution of each channel of monetary transmission. For example, we cannot estimate the importance of credit channel in the investment reaction if it exists at all. Relying on the structure of the NEM model, our analysis traced back the response of investment to the interest rate channel and the influence of the exchange rate, ruling out credit supply effect a priori. Nevertheless, if the credit channel were important in Hungary it would not invalidate our conclusions about the relative weight of components of aggregate demand, only the explanation of the mechanism would be affected.

V. References

Angeloni, Ignazio, Anil K. Kashyap, Benoît Mojon and Daniele Terlizzese (2003) "The output composition puzzle: a difference in the monetary transmission mechanism in the euro area and U.S.", Journal of Money Credit and Banking 35(6, Part 2)

Bacchetta, Philippe and Eric van Wincoop (2005) "Rational inattention: a solution to the forward discount puzzle", CEPR Discussion Paper No. 5261

Batini, N., A. Haldane (1999) "Forward-Looking Rules for Monetary Policy", in Monetary Policy Rules, ed Taylor, J. 157-201 pp.

Batini, N., E. Nelson (2001) "Optimal Horizons for Inflation Targeting", Journal of Economic Dynamics & Control Vol 25

Berben, R.P., R. Mestre, T. Mitrakos, J. Morgan, N. Zonzilos (2004) "Inflation Persistence in Structural Macroeconomic Models (RG10)", paper presented at Conference on Inflation Persistence, Frankfurt, Dec. 10-11. 2004

Chow, G. C., An-loh Lin (1971) "Best linear unbiased interpolation, distribution, and extrapolation of time series by related series", The Review of Economics and Statistics, Vol. 53, No. 4

Christiano, Lawrence J., Martin Eichenbaum and Charles L. Evans (1998) "Monetary Policy Shocks: What Have We Learned and to What End?", NBER Working Paper No. 6400

Darvas, Zsolt (2001) "Exchange rate pass-through and real exchange rate in EU candidate countries", Deutsche Bundesbank, Discussion paper 10/01

Eichenbaum, Mertin and Charles L. Evans (1995) "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates", The Quarterly Journal of Economics, MIT Press, vol. 110(4)

Jakab, M., Zoltán and Mihály András Kovács (2003) "Explaining the Exchange Rate Pass-Through in Hungary: Simulations with the NIGEM Model", MNB Working Paper No. 2003/5

Jakab, M. Zoltán, Mihály András Kovács, Balázs Párkányi, Zoltán Reppa and Gábor Vadas (2004) "The Hungarian Quarterly Projection Model (N.E.M.) – Non-technical summary", english.mnb.hu/Resource.aspx?ResourceID=mnbfile&resourcename=nem_summary_en

Jakab, Zoltán and Vadas Gábor (2001) "Forecasting Hungarian Household consumption with econometric methods", MNB Background Studies, 2001/1, available only in Hungarian

Karádi, Péter (2005) "Exchange rate smoothing in Hungary", MNB Working Paper, forthcoming

Kátay, Gábor (2003) "Production function estimation for Hungary", mimeo

Kim, Soyoung (2001) "Effects of monetary policy shocks on the trade balance in small open European countries", Economics Letters, Elsevier, vol. 71(2)

Kovács, Mihály András (2005) "Hogyan hat az árfolyam? - Az 1995-ös stabilizáció tanulságai és jelenlegi ismereteink", MNB Background Studies, 2005/6, available only in Hungarian

Leitemo, K. (2000) "Open-Economy Inflation Targeting", Arbeitsnotat, Norges Bank

McCallum, Bennett T. (1999) "Analysis of the Monetary Transmission Mechanism: Methodological Issues", NBER Working Paper No. 7395

Móré, Csaba and Márton Nagy (2004) "Competition in the Hungarian Banking Market ", MNB Working Paper No. 2004/9

Rezessy, András: (2005) "Estimating the immediate impact of monetary policy shocks on the exchange rate", MNB Occasional Paper No. 2005/38

Scholl, Almuth and Harald Uhlig (2005) "New Evidence on the Puzzles. Results from Agnostic Identification on Monetary Policy and Exchange Rates", mimeo

Shiller, R. (1973) "A Distributed Lag Estimator Derived From Smoothness Priors", Econometrica, Vol 41. No 4.

Svensson, Lars E. O. (2000) "Open Economy Inflation Targeting", Journal of International Economics, 50(1)

Uhlig, Harald (2005: "What Are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure", Journal of Monetary Economics 52

Várpalotai, Viktor (2003) "Disinflation Simulations with a Disaggregated Output Gap Based Model", MNB Working Paper No. 2003/3.

Vonnák, Balázs (2005) "Estimating the Effect of Hungarian Monetary Policy within a Structural VAR Framework". MNB Working Paper No. 2005/1

VI. Figures and tables

VI. 1. Main features of the models

Table 1.1: Demand effects on key price variables in selected macroeconometric models

Country/model	Effect of GAP on prices	Note
Austria, MCM	-	unemployment is feedback
Netherlands, MCM	0.23	unemployment is feedback
Spain, MCM	-	unemployment is feedback
AWM	0.03	unemployment is feedback
Denmark, NIGEM	0.17	CPI's response on capacity utilization
NIGEM (maximum/minimum)	0.05 / - 0.84	response to wholesale prices
NIGEM, Hungary	0.167	CPI's response on capacity utilization
NEM	0.15	unemployment is feedback

Table 1.2: Effect of nominal wages on unemployment in selected macroeconometric models

Country/model	Effect	Note
Austria, MCM	-0.008	effect of U-NAWRU*, semi-elasticity
Netherlands, MCM	-0.004	effect of U-NAWRU, semi-elasticity
Spain, MCM	-1.04	unemployment on the level of wages, elasticity
AWM	-0.015	effect of U-NAWRU, elasticity
NIGEM (maximum/minimum)	-0.00125 / -0.083	semi-elasticity
NIGEM, Hungary	-0.03	unemployment on the level of wages, elasticity
NEM	-0.14	unemployment on the level of wages, elasticity
NEM	-0.002	unemployment on the level of wages, semi-elasticity

* NAWRU: Non-Accelerating Wage Generating Rate of Unemployment

Figure 1.1: Elasticity of export and import prices to a 1 percent permanent depreciation of nominal exchange rate in the NEM

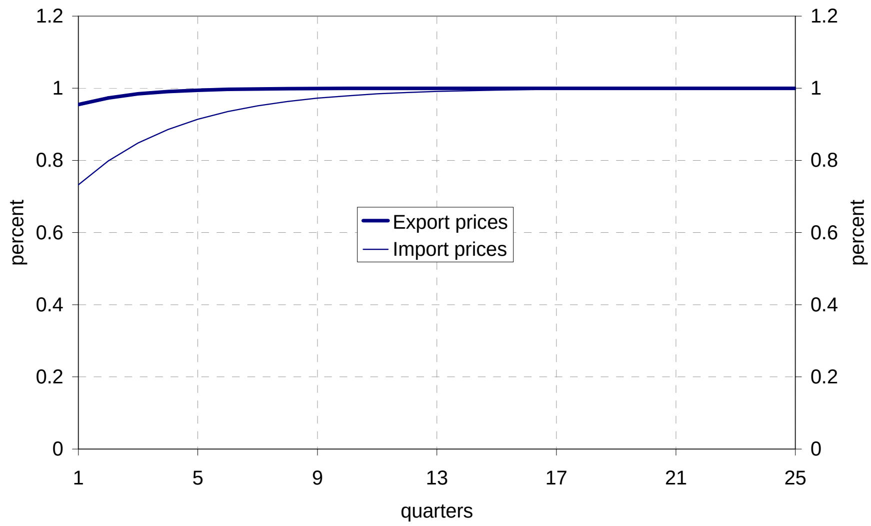


Figure 1.2: Elasticity of imports to a 1 percent permanent increase in relative import prices in the NEM

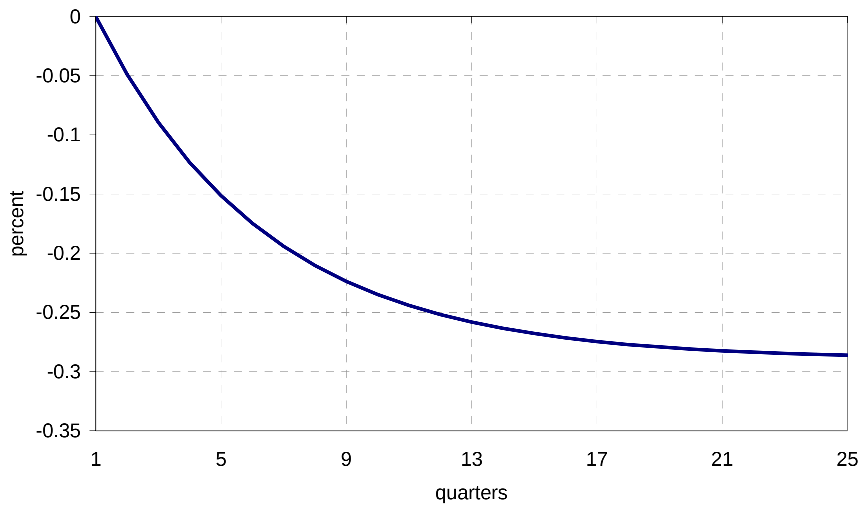


Figure 1.3: Response of GDP-deflator to an output gap shock in the NEM model

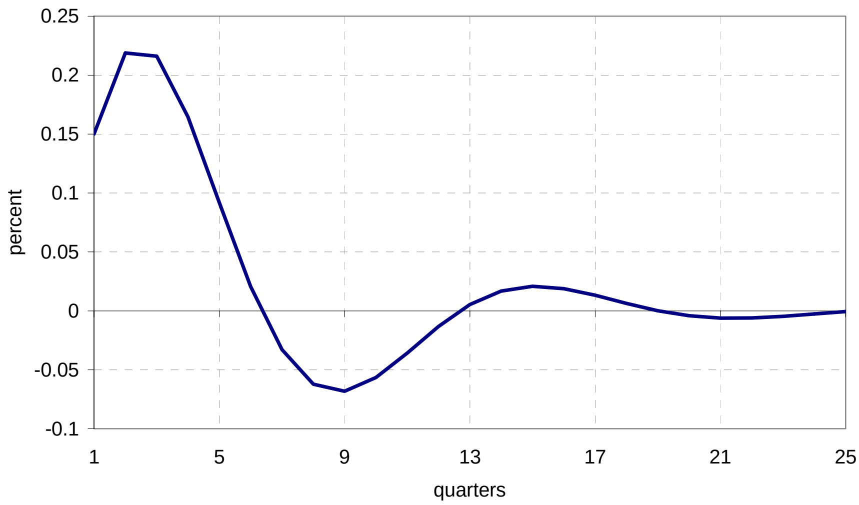


Figure 1.4: Private nominal wage responses in the NEM model

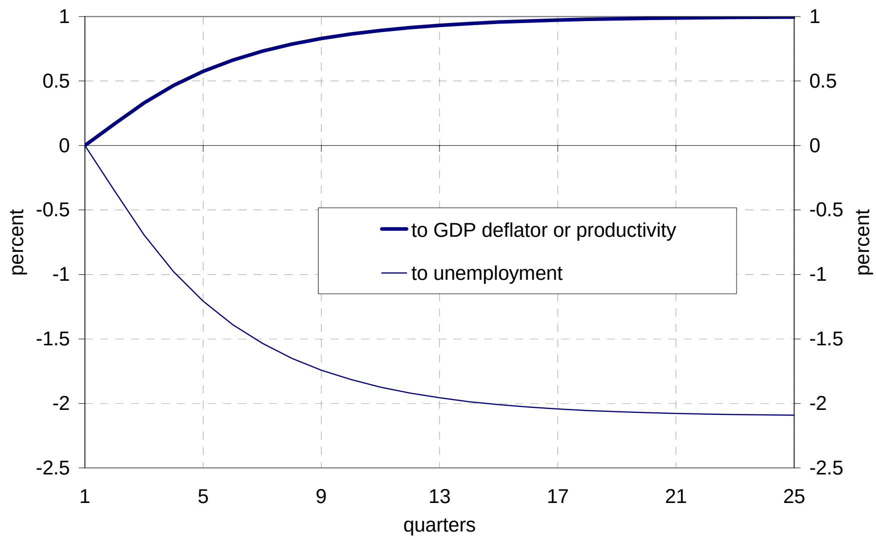
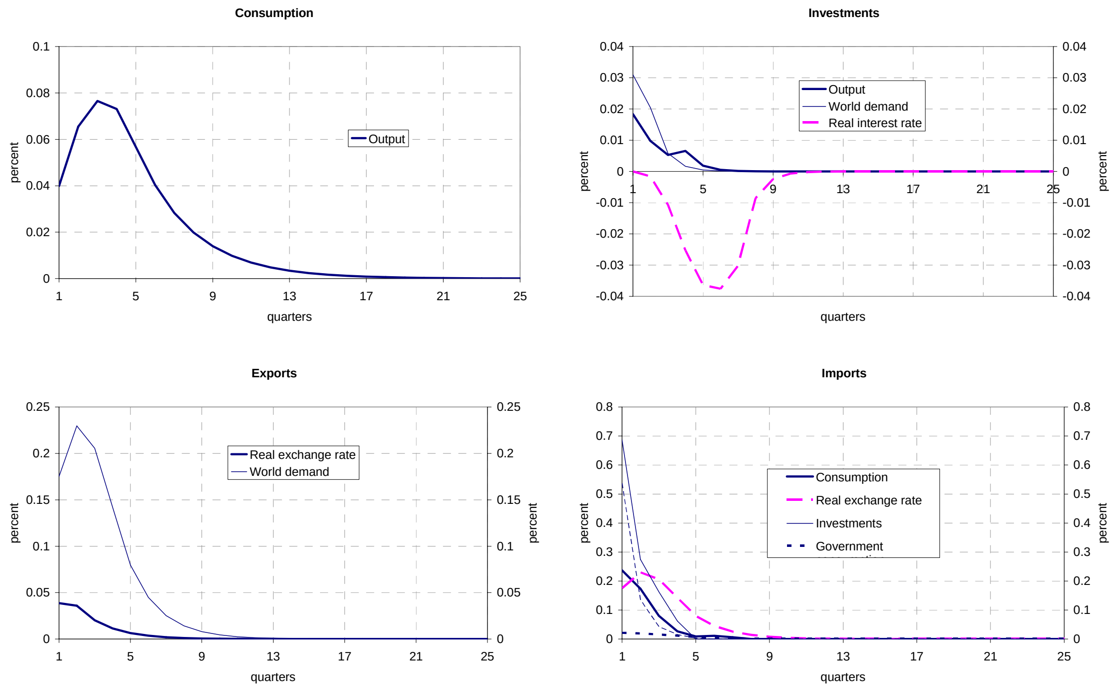


Figure 1.5: Single equation impulse responses of gaps to one percent one-off shocks in the 5GAP model



VI. 2. Impulse responses to a monetary policy shock

Figure 2.1: Characterisation of a typical unexpected monetary policy tightening: response of short term nominal interest rate and nominal exchange rate (SVAR estimates)

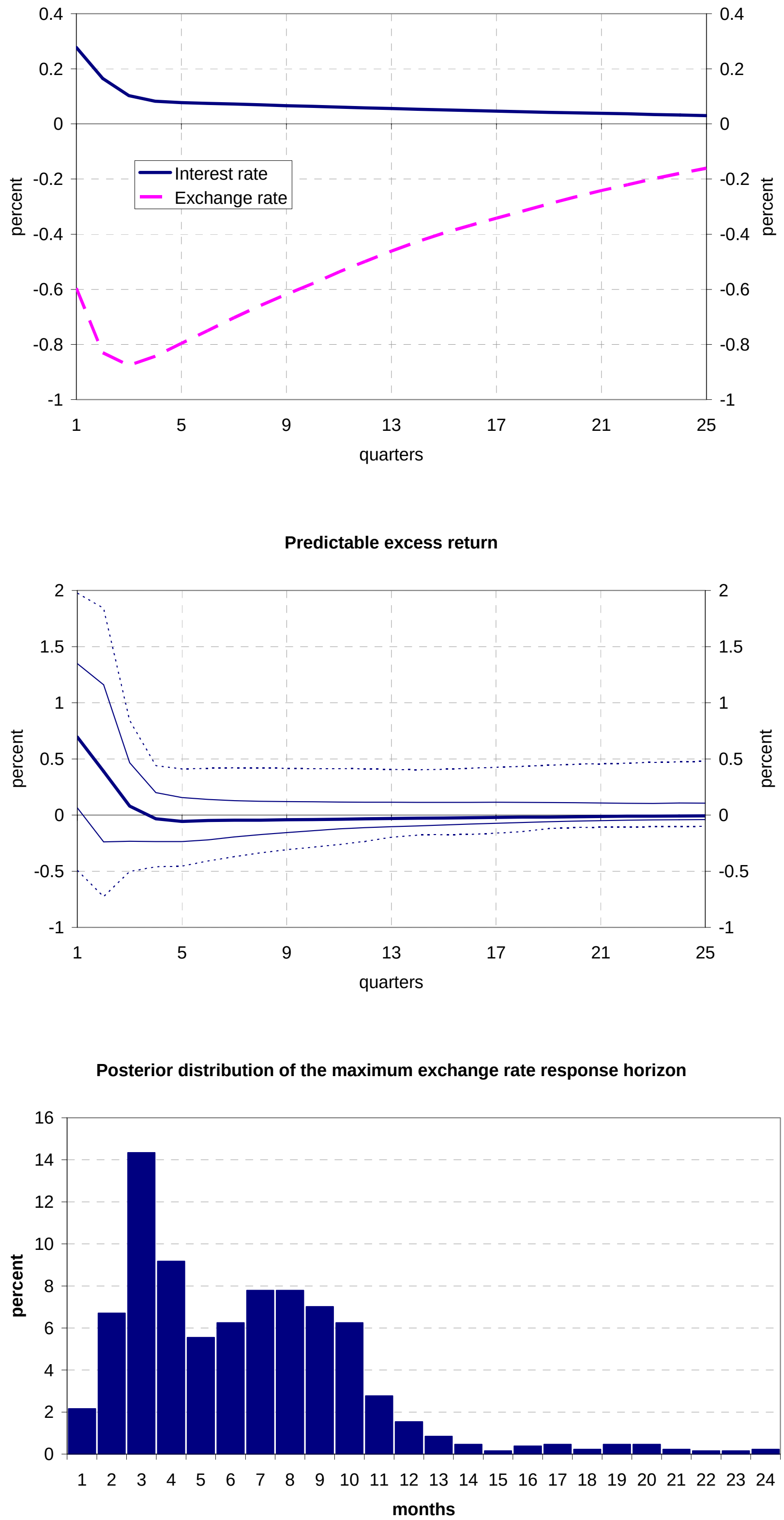
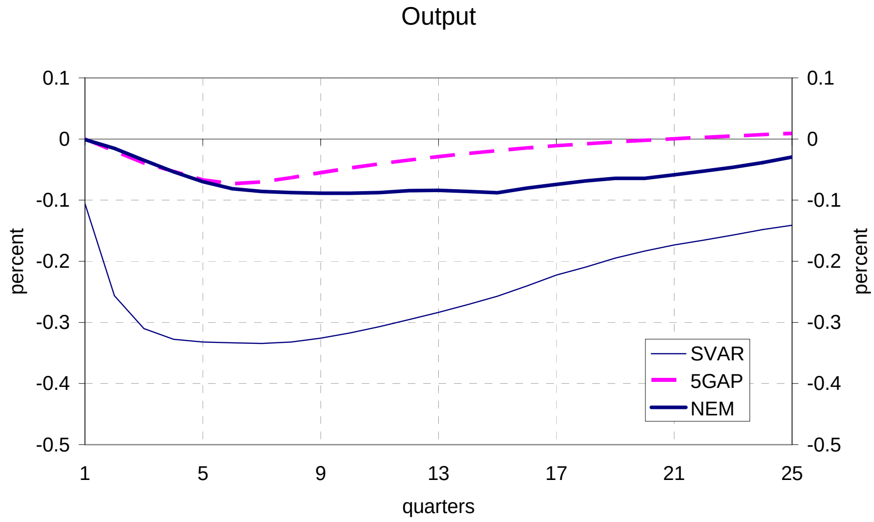


Figure 2.2: Responses of output and consumer price level to a tightening monetary policy shock (results from three models)



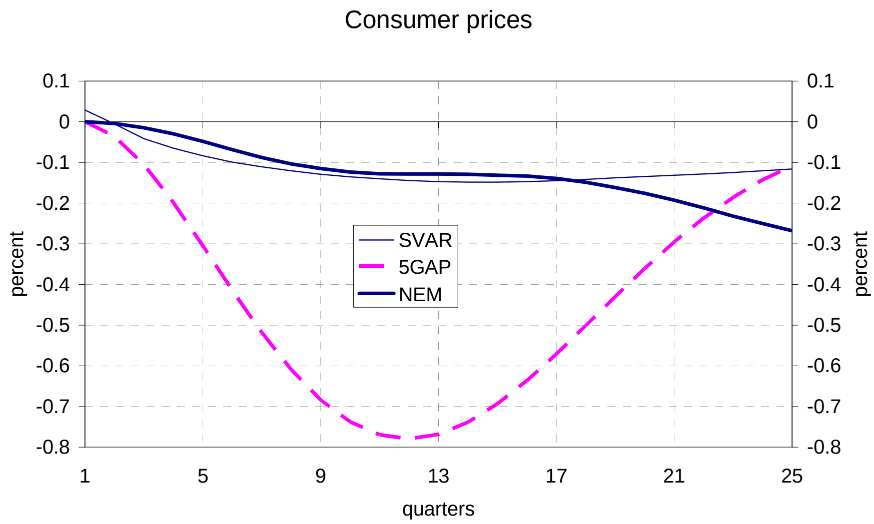


Figure 2.3: Responses of GDP components to a tightening monetary policy shock (results from three models)

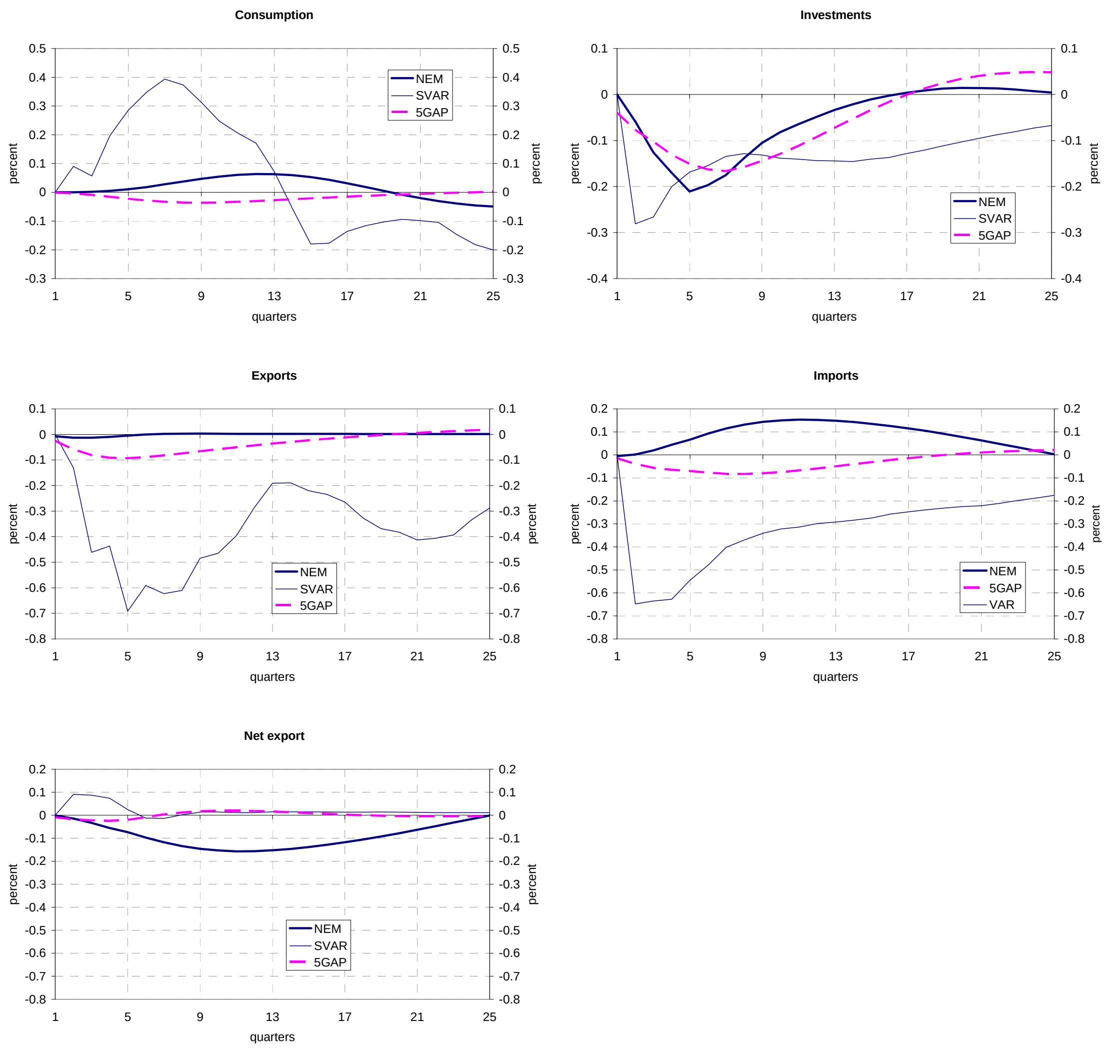


Figure 2.4: Responses to a one standard deviation tightening monetary policy shock (SVAR estimates; each row corresponds to a particular VAR model)

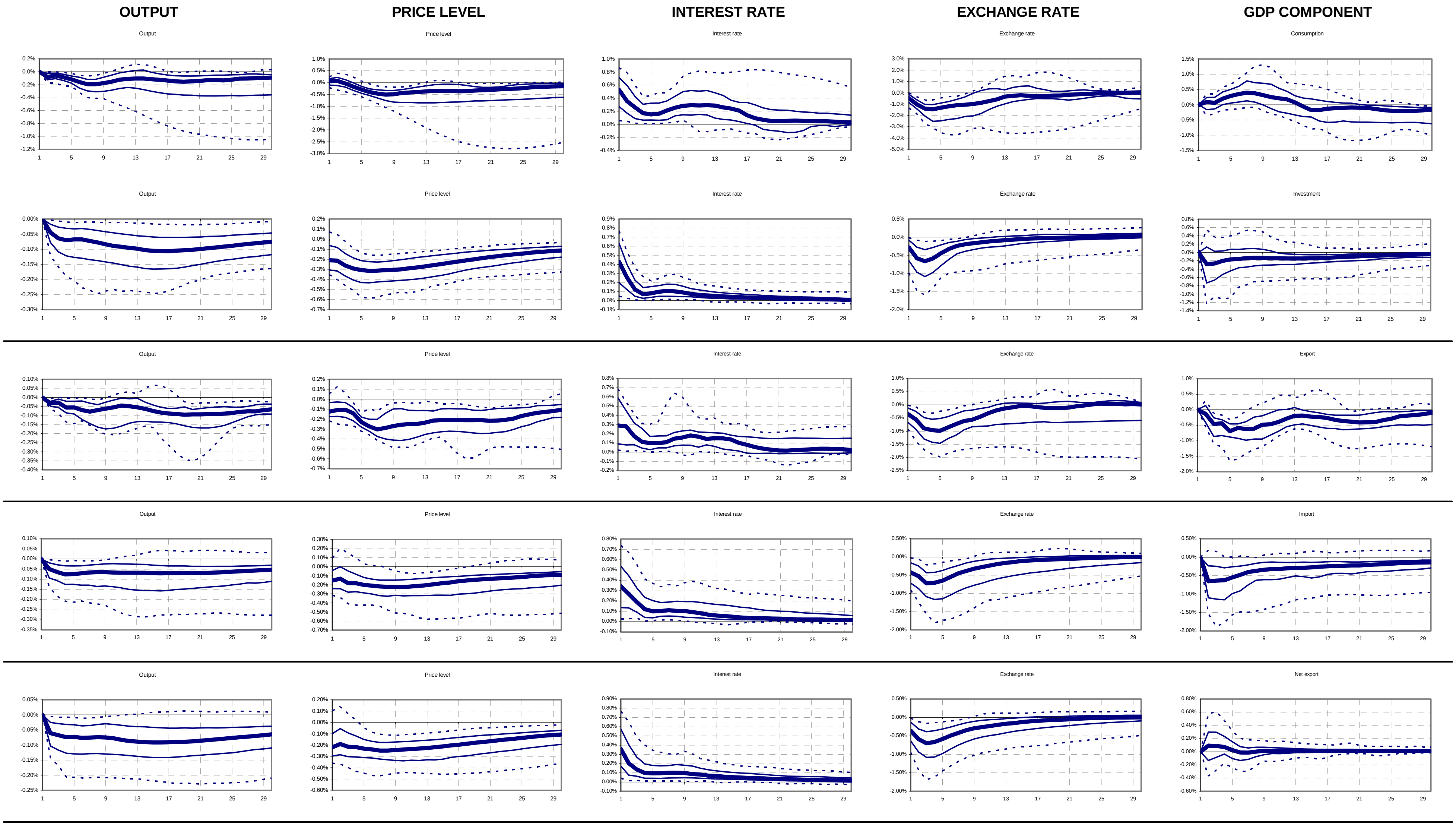
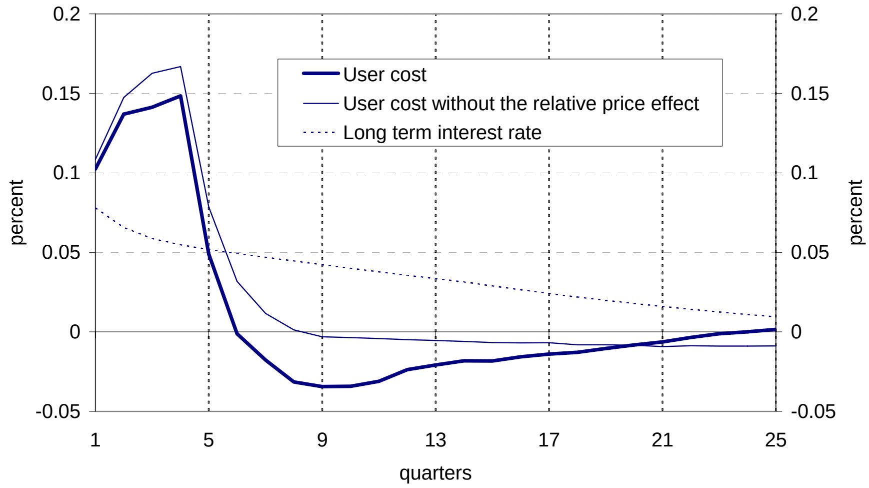


Figure 2.5: Responses of wages to a tightening monetary policy shock (results from NEM and SVAR)

Figure 2.6: Decomposition of the user cost response in the NEM model



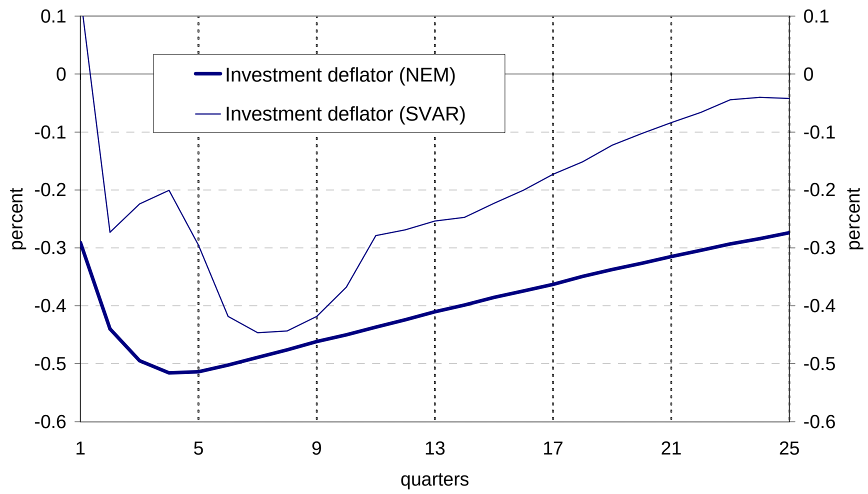


Figure 2.7: Responses of traded and non-traded goods prices to a one standard deviation tightening monetary policy shock (SVAR estimates)