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ZOLTÁN M. JAKAB–VIKTOR VÁRPALOTAI–
BALÁZS VONNÁK

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

(Hogyan hat a monetáris politika az aggregált keresletre Magyarországon? Becslések három makromodellel)

Written by: Zoltán M. Jakab**–Viktor Várpalotai***–Balázs Vonnák ****

Magyar Nemzeti Bank

Szabadság tér 8–9, H–1850 Budapest

http://www.mnb.hu

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** Principal economist, Economic Analysis and Research, jakabz@mnb.hu.
*** Researcher, Economic Analysis and Research, varpalotaiv@mnb.hu.
**** Principal economist, Economic Analysis and Research, vonnakb@mnb.hu.

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Abstract

This paper assesses the effect of monetary policy on major components of aggregate demand. We use three different macromodels, all estimated on Hungarian data of the past 10 years. All three models indicated that after an unexpected monetary policy tightening investments decrease quickly. The response of consumption is more ambiguous, but it is most likely to increase for several years, which may be explained by the slow adjustment of nominal wages. On the other hand, we could not detect any significant change in net exports during the first couple of years after the shock. The weak response of net exports can be due to the fact that the drop in exports is coupled with a fall in imports of almost the same magnitude, highlighting the relative importance of the income-absorption effect, as opposed to the expenditure-switching effect.

JEL: E20, E27, E52.
Keywords: Monetary transmission mechanism, macromodels, VAR, impulse responses.

Összefoglalás

Három különböző, az elmúlt tíz év magyar adatain becsült makromodellel megvizsgáltuk a monetáris politika hatását az aggregált kereslet legfontosabb összetevőire. Mindhárom modell a beruházások gyors visszesését jelzi előre egy váratlan monetáris szigorítás után. A fogyasztás reakciója kevésbé egyértelmű, de valószínűsíthetően a sokk után a fogyasztás néhány évig emelkedik, amit a nominális bérek lassú alkalmazkodásával magyarázunk. A nettó export számottevő változását a monetáris sokk után nem tudtuk kimutatni. Az export visszaesése ugyanis az import hasonló visszaesésével párosul, ami azt mutatja, hogy Magyarországon a monetáris politika jövedelem-visszafogó hatása erősebben érvényesül a külkereskedelemben, mint a külföldi termékek felé irányuló kereslet-átcsoportosítás.

1. 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 the literature of empirical monetary transmission mechanism confirm, or at least are unable to reject this view.[1]

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

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

Van Els et al. (2001) do simulations with country models for eurozone members. They compare the response of prices and real activity, and they find significant differences among European countries. They explain the cross-country diversity of consumption and investment responses by structural features of those economies under investigation.

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 in relation to the nominal exchange rate. They all detect a 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 above-mentioned ECB studies, and aiming at a deeper understanding of the Hungarian monetary transmission mechanism, this paper aims to estimate the effect of monetary policy on major components of the expenditure side of GDP, namely consumption, investments and net exports. We also investigate the reaction of some price variables, such as wages, the price of investment goods, traded and non-traded prices, which helps us to understand how private spending decisions are influenced by monetary policy.

In order to minimise methodological uncertainties, we use three different models. All of them are 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 is organised as follows. In the following section the three models are described briefly. In the third section we present our estimation strategy and the results. Section 4 concludes.

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

2. Models used in this paper

2.1. THE QUARTERLY PROJECTION MODEL (NEM)

The Quarterly Projection Model (NEM) developed at the Magyar Nemzeti Bank – see Jakab et al. (2004) and Benk et al. (2006) – is a neo-Keynesian, 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 the 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 long-run elasticity of (private) capital demand to a real user cost of capital change. In our baseline model set-up, a one percentage change in the user cost of capital would lead to around a 0.4 per cent 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.

The long and short-run demand for (private) capital in the NEM takes the following form:

$$\begin{aligned} k^* &= 0.717 + y^* - 0.367 user \\ \Delta k &= 0.002 - 0.002\left(k_{-1} - k^*_{-1}\right) + 0.843\Delta k_{-1} \end{aligned} \tag{1}$$

where *k, k*, y** and *user* denote the natural logarithm of private capital, long term value of private capital, potential output and user cost, respectively.

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.[2] Given the fact that investment prices respond relatively quickly to a monetary tightening (due to 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.

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

Labour demand of the private sector in the NEM is as follows:

$$
\begin{aligned}
&e^* = 4.26 + y - 0.367\left(wcr + w - p_y\right) - \left(1 - 0.367\right) latp \\
&\Delta e = 0.001 - 0.088 * \left(e_{-1} - e*_{-1}\right) + 0.49 \Delta e_{-1}
\end{aligned}
\qquad (2)
$$

where *e, e*, latp* denote the natural logarithm of private employment, its long-term value and the rate of (labour-augmenting) technological progress. *wcr, w* and p_y refer to the logarithm of wage cost rate, nominal wages in the private sector and the GDP deflator, respectively.

Major 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 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 per cent of total consumption demand.[3] Monetary policy can have an effect on consumption mostly through the change in real income (through the change in wages and employment). The 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 high pass-through, the short term elasticity being 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 also be somewhat lower.

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 mark-up. This is consistent with the price decision of a monopolistically competitive representative firm assumption. Mark-up, however, is not constant and fluctuates along business cycles – in recessions price mark-up 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.

The GDP deflator equations:

$$
\begin{aligned}
&p_y* = -11.8 + ulc \\
&\Delta p_y = 0.007 - 0.229\left(p_y - p_y*\right)_{-1} + 0.15 gap + 0.687\left(\Delta p_y\right)_{-1}
\end{aligned}
\qquad (3)
$$

where p_y, p_y* denote the natural logarithm of the GDP deflator and its long term-value. *ulc* and *gap* refer to the logarithm of unit labour costs and the output gap, respectively.

[3] The share of liquidity constrained agents' consumption is proxied by the short-term elasticity of income to consumption.

A 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: the employers' wage offer depends on productivity (marginal revenues), while employees charge a mark-up, which depends on the scarcity of the labour market (proxied by unemployment). A monetary shock which affects 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 a wage level around 2 per cent lower.[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 wages and thus real income increases. This effect is quite strong relative to others and 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, the effect of unemployment on wages is not extreme.

Nominal wages in the NEM are treated by the following:

$$\begin{aligned} w^* &= 11.47 + p_y + (y-e) - 0.021U \\ \Delta w &= 0.022 - 0.167(w_{-1} - w^*_{-1}) + 0.145\Delta w_{-1} \end{aligned} \tag{4}$$

where *U, w* and *w** denote unemployment rate, natural logarithm of private nominal wages and its long-term value, respectively.

The direct exchange rate channel of the 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 per cent.

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.[5] 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. From a birds-eye view, the main mechanisms of a monetary policy shock (increase in interest rates) work 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. The direct effect of the hike in interest rates is not present. Exports respond rapidly, though 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 are lower, which slowly feeds into lower real wages (which later tilts consumption down) and to lower domestic prices (GDP deflator). This helps in stabilising the system, as imports start to drop. The second-round effects of the change in demand and wage costs feed 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 could be more important. For example, housing wealth effects would modify households'

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

[5] For simplicity, we assumed during our simulations that regulated and food prices follow core inflation.

behaviour, as well.[6] Through these valuation effects, an 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 or user cost of capital can also change In other words, Phillips curves (the price and the wage equation) and the determination of the cost of capital are not forward-looking. Forward-looking Phillips curves (if the policy is credible) would end up with a more pronounced initial impact of monetary policy shocks. On the other hand, forward-looking investment behaviour (through forward-looking user cost) would result in a smoother investment response. Credibility of the monetary authority is also not explicit in this set-up.

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

2.2. THE 5GAP MODEL

The 5GAP model describes the evolution of inflation, components of excess demand, exchange rate and interest rate in a small open economy framework with a floating exchange rate regime in a reduced form.[7] The model was inspired mainly by Svensson (2000) but there are other papers, e.g. Batini and Haldane (1999), Batini and Nelson (2001) and Leitemo (2000), presenting models similar to that of Svensson (2000). The 5GAP model was originally designed to understand some price and real variable movements in Hungary triggered by the introduction of a new monetary regime and some consumption-boosting policies of the government after 2001.

The 5GAP model comprises a nominal block and a real block. The nominal block consists of a neo-Keynesian Hybrid Phillips Curve for determining π_t^{NTR}, the non-tradable goods inflation (5) and a simple pass-through equation for describing π_t^{TR}, the evolution of tradable goods inflation (6). The CPI index (π_t) is a weighted average of traded and non-traded inflation (7).

$$\pi_t^{NTR} = \alpha_\pi \pi_{t-1}^{NTR} + (1-\alpha_\pi) E\left[\pi_{t+1}^{NTR}\right] + \alpha_y y_t + \alpha_q q_t + \varepsilon_{\pi,t} \tag{5}$$

$$\pi_t^{TR} = \alpha_{TR} \pi_{t-1}^{TR} + \alpha_{PT} q_{t-1} + \varepsilon_{\pi^{TR},t} \tag{6}$$

$$\pi_t = \omega \pi_t^{TR} + (1-\omega) \pi_t^{NTR} \tag{7}$$

The (real) exchange rate (q_t) is determined by an uncovered interest rate parity condition:

$$Eq_{t+1} = q_t + \left(i_t - E[\pi_{t+1}]\right) - \left(i_t^* - E\left[\pi_{t+1}^*\right]\right) - \phi_t \tag{8}$$

The domestic short-term interest rate (i_t) is modelled by a Taylor-type rule:

$$i_t = \gamma_{i^*} i_{t-i} + \left(1-\gamma_{i^*}\right)\left[f_y y_t + f_\pi \pi_t\right] + \varepsilon_{i^*,t}, \tag{9}$$

The real side of the 5GAP model decomposes aggregate excess demand or output gap variable (y_t) into consumption (c_t), investment (i_t), exogenous government consumption (g_t), export (x_t) and import (m_t) gaps. Among these disaggregated gaps the standard accounting identity holds:

$$y_t = c_t + i_t + g_t + x_t - m_t \tag{10}$$

[6] During our simulations the equation for housing investments was switched off.

[7] See Várpalotai (2003) for further details.

It has been assumed that the evolution of these disaggregated gaps[8] are determined by some of the following variables: aggregate gap, foreign demand *(y_t^*)*, real exchange rate or disaggregated gaps themselves with relatively long distributed lag structures. This disaggregation enables the model to deliver a more detailed picture about both the size and the timing of transmission mechanism:

$$c_t = f_1(c_{t-1}, B_1(L)y_t) \tag{11}$$

$$i_t = f_2\left(i_{t-1}, B_2(L)y_t^*, B_3(L)q_t\right) \tag{12}$$

$$x_t = f_3\left(x_{t-1}, B_4(L)y_t^*, B_5(L)q_t\right) \tag{13}$$

$$m_t = f_4(B_6(L)c_t, B_7(L)i_t, B_8(L)g_t, B_9(L)x_t, B_{10}(L)q_t) \tag{14}$$

where $f_i(.)$ are linear function of the listed variables and $B_i(L)$ are lag polinoms. As it follows from (11)-(14), we assumed that the excess consumption depends on excess aggregate output and an inertial term. Similarly, excess investment depends on the foreign excess demand and the real exchange rate, where the latter term captures the competitiveness of the domestic investment relative to rest of the world. The excess export is modelled via the same way. The excess import need is determined from the other component of the aggregate demand and the relative prices.

The 5GAP model is estimated on Hungarian quarterly data using samples 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 approach effectively breaks multicollinearity inherent in lagged data. The estimated distributed lag structures often reported a delayed reaction to a change in explanatory variables (see Figure 1.5).[9]

2.3. THE STRUCTURAL VAR (SVAR)

The third approach is based on the structural VAR introduced in Vonnák (2005). The specification consists of a VAR and an identification scheme. The former captures the systematic behaviour of variables, whereas the identification establishes a connection between economic theory and the covariance structure of reduced form residuals. In our case this involves the characterisation of unexpected monetary policy shocks.

First, we estimated a 6-variable quarterly VAR including interest rate, exchange rate and CPI as in Vonnák (2005), but instead of GDP or industrial production we put private consumption, private investments and net exports into the VAR. In this way we can also obtain implicit estimates for GDP response if we assume that all the remaining components, including government spending react neutrally. Our sample ranged from Q1:1995 to Q4:2004. We included two lags as this eliminated the bulk of autocorrelation from the residuals.

For identification we used the sign restriction approach. We assumed that after an unexpected monetary tightening the short interest rate will be higher and the nominal exchange rate will be more appreciated for two years. This is one of the identification strategies used in Vonnák (2005) and is found to produce credible results. A slight deviation from the 4-variable VAR strategy of the reference paper is that we lengthened the sign restriction period from one year to two years. We had to do that in order to obtain a plausible interest rate path that is comparable to our benchmark. In addition to the sign restriction on exchange rate and interest rate, we also assumed that monetary policy shocks have no immediate impact on real consumption, investments and net exports. Although the zero restriction on real demand responses is more arguable for monthly VARs, the experiences of our reference paper justify its use for quarterly data as well.

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

[9] For further details, e.g. specification and parameter estimates, see Várpalotai (2003).

Unfortunately, the short time span does not allow extending our VAR further by including more variables. Therefore, estimation of all the other variables was carried out by augmenting the GDP, CPI, interest rate and exchange rate set to a 5-variable VAR by adding one more variable. In the case of tradable and non-tradable goods inflation, both price indices were put into the same VAR instead of the CPI. In the case of investment deflator we omitted CPI and included private investments. Within this strategy we ended up with several VARs. We had to select appropriate lag length in each case. We chose the minimal length that produced unautocorrelated residuals. Typically two or three lags were enough.

We report estimates for demand components from the 6-variable set-up. SVAR estimates for other variables, such as wages, prices, etc. were obtained from 5-variable VARs. Table 1.1 in the appendix summarises the VAR models used in this paper.

3. Impulse responses

We pursue getting 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 as to 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 comparing the volatility of important variables under different policy rules.[10] 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 the case of NEM and 5GAP we do not report error bands, due to computational constraints. 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.[11]

3.1. 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 the 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. Van Els et al. (2001) chose this option. 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 a better model that is simple enough and credible at the same time.

We opted for a different approach. Since our purpose is to answer the question as to 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 the SVAR model the behaviour of the HUF exchange rate after a monetary policy shock is estimated. Therefore, we used in the NEM simulation the impulse response functions (IRF) of nominal interest rate and exchange rate to one standard deviation monetary policy shock obtained from the 6-variable SVAR.

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'.[12] 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 Dornbusch's model, which predicts immediate appreciation and gradual depreciation afterwards (Dornbusch, 1976).

[10] See, for example, McCallum (1999).

[11] We calculated confidence intervals for SVAR estimates following the Bayeisan approach of Kadiyala and Karlsson (1997) and Sims and Zha (1999), which has advantageous properties in a small sample.

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

Our SVAR estimates are close to being consistent with the UIP. The peak response occurs three 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.[13] 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-thirds 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.[14] The posterior distribution of peak response also suggests an almost UIP-type dynamics, and weak evidence of delayed overshooting (Figure 2.1 bottom panel).[15]

Despite the minor deviation from the UIP, due to its forward-looking nature, the 5GAP model proved to be sensitive to the interest rate and exchange rate path. With the exchange rate path generated by the SVAR the model produced implausible price responses. Therefore, we used slightly modified paths, namely, we adjusted the exchange rate response to fulfil the UIP. It should be stressed that consumption, investments and foreign trade, the variables of major interest, were not affected by the modification, only consumer prices. The exogenous interest rate and exchange rate responses we plugged into the other two models are shown in the top panel of Figure 2.1, and can be characterised briefly as corresponding to an almost 40 basis points interest rate increase, which is followed by a 0.6-0.8 per cent nominal exchange rate appreciation during the first year.

However, there are some drawbacks of our approach. 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 different from the SVAR estimates; therefore, using the same interest rate path would imply a different monetary policy rule.

It should also 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.

3.2. REACTION OF AGGREGATE DEMAND COMPONENTS

As a first step we assess our results from a bird's-eye perspective by comparing the IRFs of output and consumer prices (see Figure 2.2). We found that after a monetary policy shock that can be considered as typical in size and shape for the period between 1995 and 2003, the price level falls by 0.1-0.2 per cent persistently.

The behaviour of output is not that clear-cut. The NEM and the 5GAP predict slightly lower GDP after the contraction. On the other hand, the SVAR estimates as well as the behaviour of individual components suggest the response of GDP to be slightly positive but insignificant.

Looking at the impulse responses of investments a robust finding emerges - each model shows a sharp and relatively quick decrease in investments by a magnitude of around 0.2 per cent during the first two years.

On the other hand, the picture of the reaction of consumption and foreign trade is more blurred. In the 5GAP, consumption does not respond strongly. However, both the SVAR and NEM indicate a sizable rise during the first three years,

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[13] Figure 2.1 middle panel. We used the benchmark 6-variable VAR. Median estimates as well as 68% and 95% error bands are reported.

[14] 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.

[15] 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 30 per cent of all cases the peak occurred in the first two quarters, and the first year contains 95 per cent of all outcomes.

although the timing of the reactions differ. Hence, we cannot rule out an 'adverse' reaction of private consumption, although the evidence is rather mixed. Van Els et al. (2001) had similar results for some eurozone countries.

In the case of net exports our results are rather inconclusive. NEM shows a slow decrease, while in the 5GAP the response is very mild. The SVAR indicates a temporary increase followed by a drop.

Our results are in some sense in line with those of Angeloni et al. (2003) for the euro area. They found that in contrast with the US, 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. Although we are not certain about the reaction of GDP, we could detect a significant contractionary effect in investments. The main 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 behaviour of output components in a more detailed manner.

Consumption

In the case of private consumption the sensitivity of households' savings decision in relation to interest rates may play a crucial role in the monetary transmission mechanism. In Hungary the level of households' indebtedness and financial assets was rather low during the sample period compared to developed countries. The high concentration of the banking sector in the household branch[16] 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 indebtedness and nominal wage stickiness, the effect of current income on consumption can overshadow that of the interest rate. Jakab and Vadas (2001) estimated a consumption function for Hungary. They found that private consumption was sensitive to wage changes, but not to real interest rates. Their finding is in accordance with our results, as we could not detect any contractionary effect of a higher interest rate.

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 slowly. The SVAR impulse response function declines only in the second year, during which time in the NEM it remains positive. As demonstrated in the first panel of Figure 2.5, nominal wage reaction is slower than that of consumer prices. Therefore, real wages rise during the first 1-2 years which is supported by the last panel of the same figure (standard error bands around the median estimates are above zero).

Higher real wages increase disposable income, which explains the lack of fall in consumption. A real wage increase may be the result of relatively quick exchange rate pass-through to tradable prices. In the NEM model tradable and non-tradable inflation are not modelled explicitly, but the dynamics of imported good prices can be a plausible proxy for tradable prices. The pass-through to imported prices is relatively quick. We also experienced this with SVAR, replacing the consumer price level with traded and non-traded prices.[17] We found quick pass-through to the former, slow pass-through to the latter. Quick pass-through to tradable prices would imply an immediate jump in households' real income, as nominal wages adjust only with delay.

Intuitively these responses might be identified as an 'exchange rate channel effect', since after an appreciation the relative price of imported goods decreases, implying both substitution and income effects in consumption. In Van Els et al. (2001) this feature is in fact referred to as exchange rate channel.

Investments

All models predicted a drop in investment after a monetary tightening. This is consistent with theory; however, this might be a new finding for Hungary, as this feature was not yet detected on macro data. The micro-estimates of Kátay and Wolf (2005) showed similar responses, though the comparability with ours is limited.

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[16] See Móré and Nagy (2004).

[17] We used the price index of industrial goods and market services as proxies for tradable and non-tradable prices, respectively.

In the NEM model investment behaviour works mostly through the change in the user cost of capital. As shown in Figure 2.6, the user cost increases after the monetary shock. The rise in the cost of capital is higher than that of long-term interest rates. As shown later, this feature, however, is merely the result of the assumptions built in the NEM model. In the basic set-up, the user cost is determined by the long-term interest rate, the growth of investment goods deflator, the relative price of investment goods and other variables (e.g. corporate taxes) that are exogenous from our point of view. The key assumption here is that price terms are treated in a backward-looking way. The mechanism in the NEM model is as follows. 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 the 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 also reinforced by SVAR estimates (bottom panel of Figure 2.6). In the backward-looking user cost specification, the past drop in investment prices raises the user cost above the long-term rates. Deflation in the investment goods price index drives the real cost of capital accumulation higher than the 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.[18]

In order to show the effect of the assumption on the backward and forward-looking treatment of investment prices, we also simulated the effect of monetary policy in NEM assuming that agents calculate user cost in a forward-looking manner, that is they consider expected rather than realised changes in investment goods prices. The results are shown in Figure 2.8.[19] In this case, the response of real user cost is much milder, as agents expect a future inflation of investment prices after an initial drop in prices. A smaller investment response, however, also leads to a less sharp response of imports. As a consequence, the drop in GDP is slightly smaller in the forward-looking case than in the backward-looking one. In contrast, price response is roughly the same. As a consequence, the drop in investment in the NEM model is mostly due to the assumption of backward-looking treatment of investment prices.

In the 5GAP model investment depends on the real exchange rate and the real interest rate. As in our simulations both point to the same direction (appreciation of real exchange rate, higher real interest rate), the negative reaction of investment is straightforward.

Both the 5GAP and the NEM simulations show the appearance of an 'exchange rate channel' in investments. In the 5GAP, the real exchange rate channel is explicitly modelled. In the NEM, lower tradable prices due to exchange rate appreciation magnify the effect of higher nominal interest rates on real user cost of capital.

In the 5GAP and the NEM the 'interest rate channel' explaining the drop in investments beyond the effect of appreciation might comprise non-explicitly modelled channels. As an example, none of our models are capable of identifying the bank lending or the balance sheet channel. Hence, we are not able to distinguish them from the classical interest rate channel. Nevertheless, if the credit channel were important in Hungary it would not invalidate our conclusions, only the explanation of the mechanism would be affected. Further research is 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 reveal a very diverse picture. According to the NEM, net exports fall gradually, reaching a bottom at nearly -0.2 per cent of GDP. The 5GAP predicts almost zero response. Although the median estimates from the SVAR are positive in the first year, the zero line is within the confidence band. Considering the lack of consensus among the three models, we were not able to detect any significant non-zero reaction of net exports.

Taking a closer look into the components of net exports, the main difference between models arises from the treatment of imports and exports. All three models forecast lower exports, albeit the size of the fall in the NEM is significantly small-

[18] The figure also contains a 'relative price' effect. This captures the fact that the relative price of investment goods drops compared to domestic goods, making investment somewhat less expensive. This effect, however, is not very large in its magnitude.

[19] In the forward-looking user cost we replaced past inflation of investment goods by expected inflation four quarters ahead.

er than in the other two models. There is, however, a marked difference in the behaviour of imports. The NEM simulation shows increasing, 5GAP and SVARs[20] point to decreasing imports.

According to Kim (2001), there are two main mechanisms through which monetary policy can affect foreign trade. A monetary contraction can reduce domestic demand thereby improving the trade balance (income-absorption effect), but at the same time an appreciating exchange rate can lead to less export and more import (expenditure-switching effect). Kim's (2001) SVAR results for France, Italy and the UK suggested the dominance of the expenditure-switching affect, similarly to the NEM simulation results. On the other hand, in the 5GAP and in SVAR the drop in investment and exports (both with relatively high import content in Hungary) leads to decreasing import demand and generates virtually no net export reactions. In these two models the income-absorption effect offsets the expenditure-switching effect.

[20] We obtained SVAR estimates for imports and exports using 5-variable specifications.

4. Conclusions

In this paper we posed the question: which sector of the Hungarian economy transmits monetary policy? The answer was based on impulse response analysis of three different models (NEM, 5GAP and SVAR) estimated on Hungarian data for the past ten years.

First we identified a typical unexpected monetary shock with SVAR, calculating the impulse responses of exchange rate and interest rate after an unexpected tightening monetary shock. Then we inserted these exchange rate and interest rate responses into the NEM model and the interest rate into the 5GAP model as a monetary shock. Finally, we compared the impulse responses of main output components of the expenditure side across the three models. We also tracked the behaviour of some price and wage variables that helped in explaining the reaction of components of aggregate demand.

We used two measures of uncertainty for assessing the significance of our findings. We checked whether the impulse responses of all models pointed to the same direction and whether the error bands of SVAR estimates contained zero.

We found that after an unexpected monetary policy tightening consumer prices decrease in the medium term. This evidence is common in all three models. In contrast, output responses were inconclusive. However, taking a closer look at the components of aggregate demand, an interesting picture emerged - clearly lower investment, arguably neutral net export and possibly higher consumption follow a monetary tightening.

A robust result across models was the drop in investments. This finding might originate from the increase of real user cost of capital, which is not only a consequence of higher nominal interest rates but also the appreciated exchange rate through investment price deflation. We also showed, however, that the magnitude of the drop in investment might be very sensitive to the assumptions about the extent to which firms are forward-looking.

As for the other components, we could not detect any significant fall either in consumption or in net exports during the first couple of years. Two of our models predicted higher consumption after the monetary contraction, which again suggests the presence of the exchange rate channel working through households' income. While the insensitivity of Hungarian households' consumption to the interest rate is an already recorded fact, the ambiguous reaction of foreign trade to exchange rate movements is somewhat surprising. Exports dropped in all models. However, in two of the three models this was coupled with a fall in imports of almost the same magnitude, and therefore the change in net exports remained minimal. It is the income-absorption and not the expenditure-switching effect that seems to dominate.

5. 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. AND A. HALDANE (1999), "Forward-Looking Rules for Monetary Policy", in Monetary Policy Rules, ed Taylor, J. 157-201 pp.

BATINI, N. AND E. NELSON (2001), "Optimal Horizons for Inflation Targeting", *Journal of Economic Dynamics & Control,* Vol 25.

BERBEN, R.P., R. MESTRE, T. MITRAKOS, J. MORGAN AND N. ZONZILOS (2004), "Inflation Persistence in Structural Macroeconomic Models (RG10)", paper presented at the Conference on Inflation Persistence, Frankfurt, Dec. 10-11. 2004.

BENK, SZ., JAKAB, M. Z., KOVÁCS, M. A., PÁRKÁNYI, B., REPPA, Z. AND VADAS, G. (2006), "The Hungarian Quarterly Projection Model (NEM)", *MNB Working Paper*, forthcoming.

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).

VAN ELS, PETER J. A., ALBERTO LOCARNO, JULIAN MORGAN AND JEAN-PIERRE VILLETELLE (2003), "Monetary policy transmission in the euro area: What do aggregate and national structural models tell us?", *ECB Working Paper* No. 94.

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*, No. 2005/6.

KÁTAY, GÁBOR (2003), "Production function estimation for Hungary", mimeo.

KÁTAY, GÁBOR AND ZOLTÁN WOLF (2004), "Investment behaviour, user cost and monetary policy transmission - the case of Hungary", *MNB Working Paper*, No. 2004/12.

KADIYALA, K. RAO AND SUNE KARLSSON (1997), "Numerical methods for estimation and inference in Bayesian VAR-models", *Journal of Applied Econometrics*, Vol. 12, No. 2.

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.

SIMS, CHRISTOPHER A. (1996), "Comment on Glenn Rudebusch's 'Do Measures of Monetary Policy in a VAR Make Sense?'" Yale University http://sims.princeton.edu/yftp/GRComm/GRComm.pdf.

SIMS, CHRISTOPHER A. AND TAO ZHA (1999), "Error Bands for Impulse Responses", *Econometrica,* Econometric Society, vol. 67(5).

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 Papers* No. 2003/3.

VONNÁK, BALÁZS (2005), "Estimating the Effect of Hungarian Monetary Policy within a Structural VAR Framework", *MNB Working Papers* No. 2005/1.

6. Figures

6.1. MAIN FEATURES OF THE MODELS

Figure 1.1

Elasticity of export and import prices to a 1 per cent permanent depreciation of nominal exchange rate in the NEM

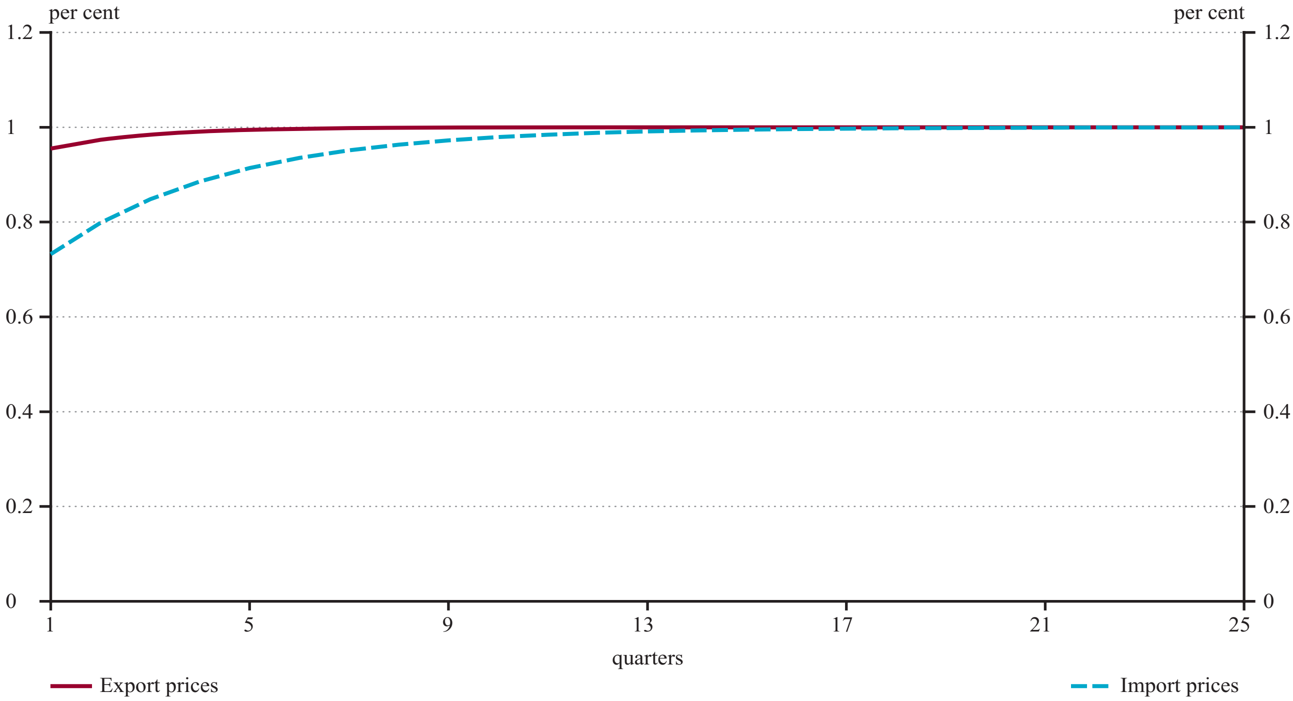


Figure 1.2

Elasticity of imports to a 1 per cent permanent increase in relative import prices in the NEM

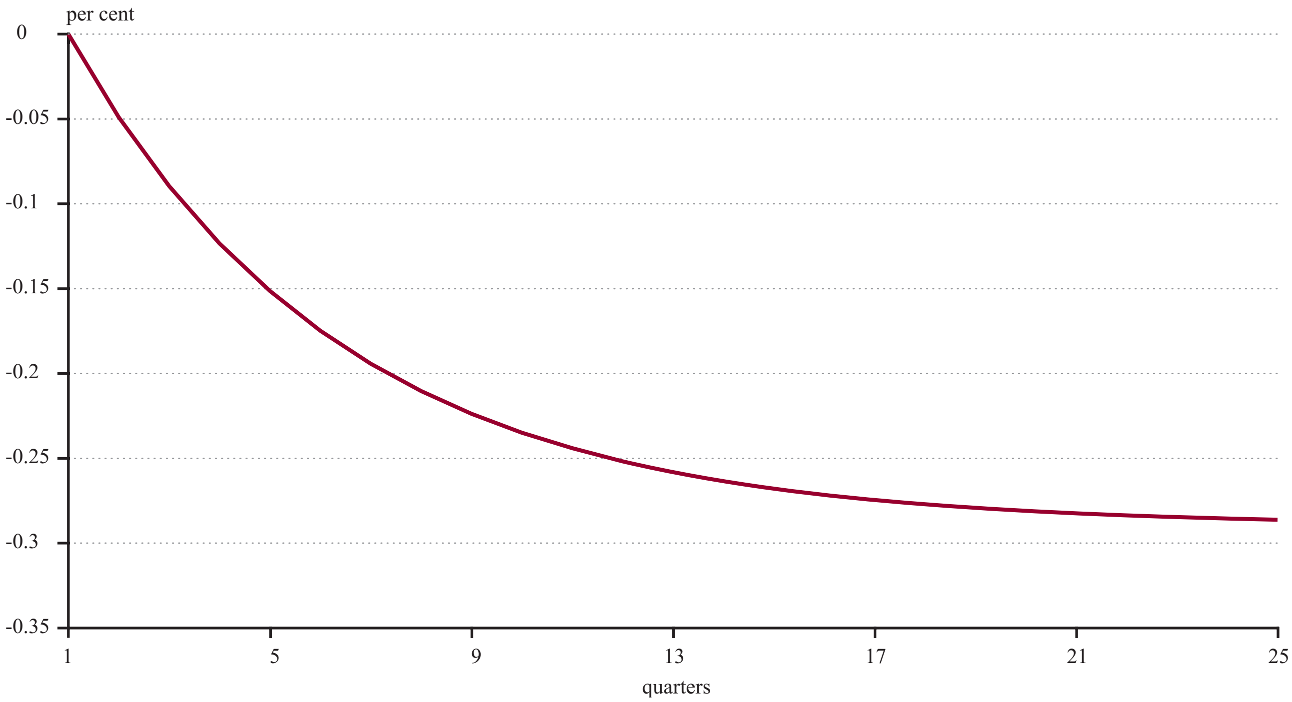


Figure 1.3

Response of GDP deflator to an output gap shock in the NEM model

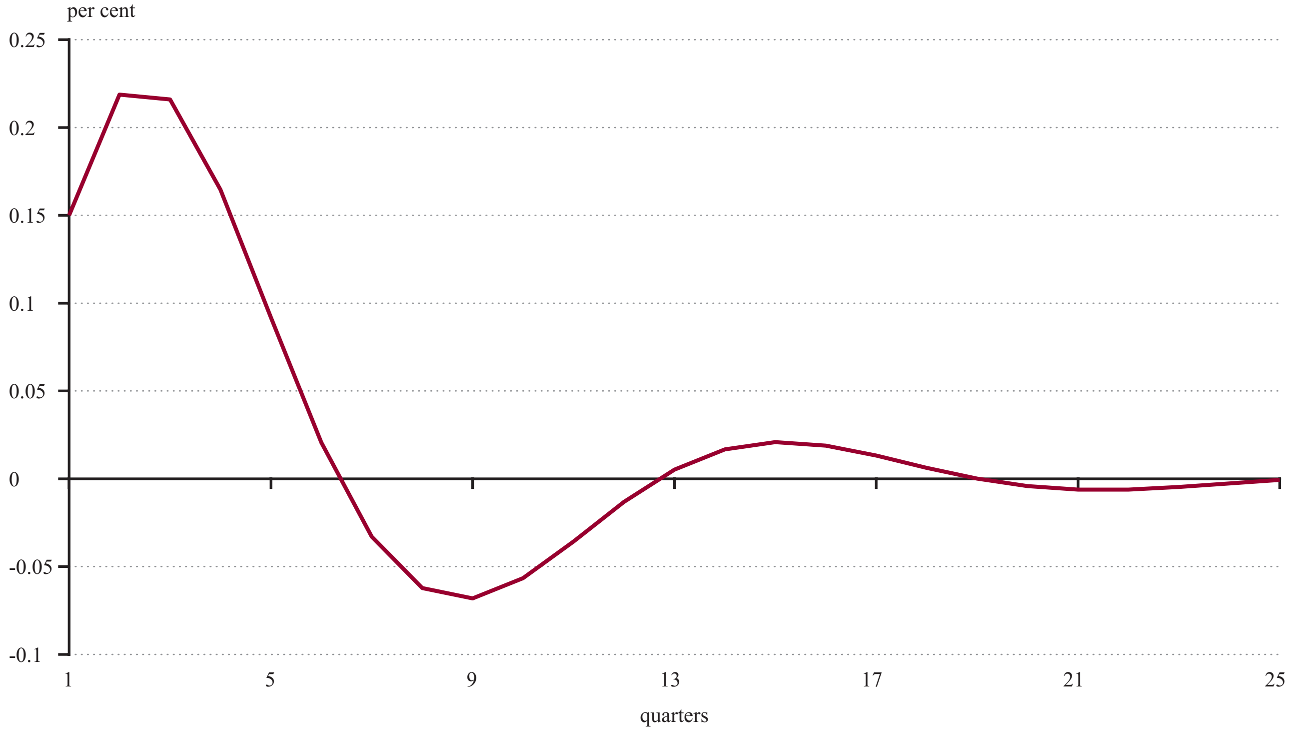


Figure 1.4

Private nominal wage responses in the NEM model

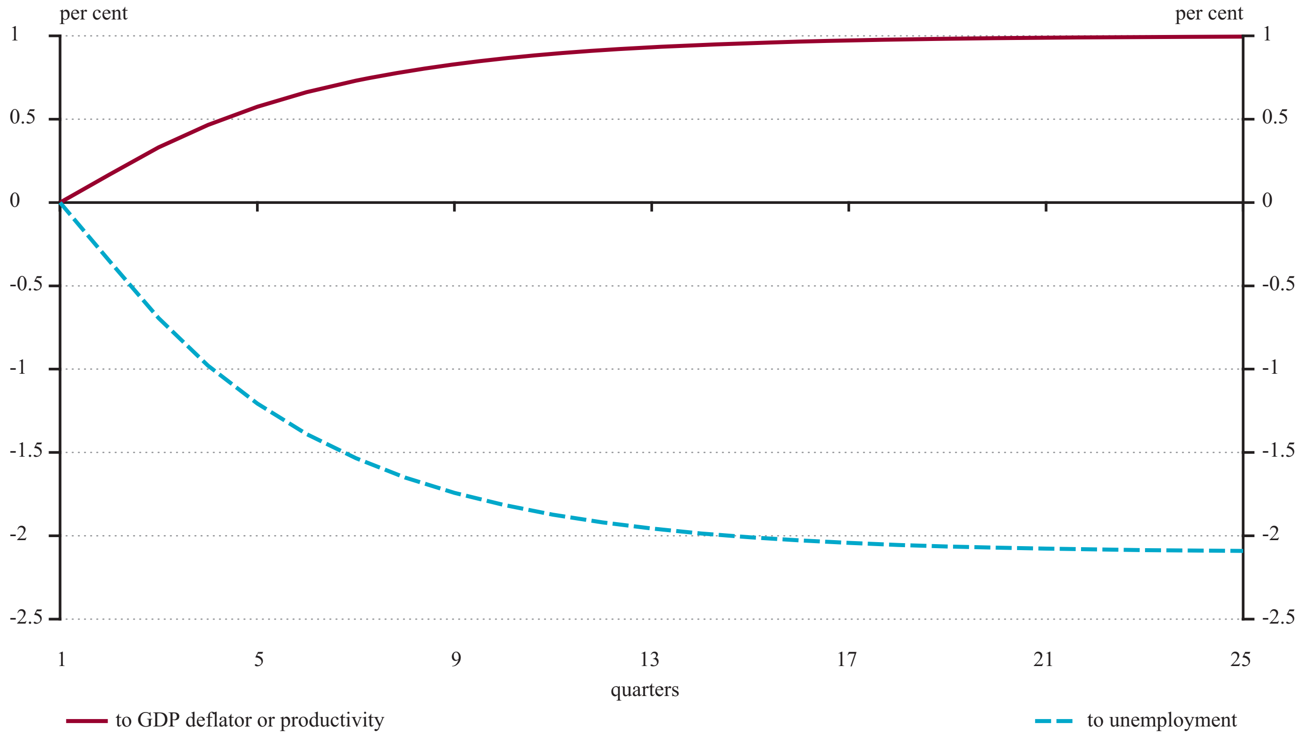


Figure 1.5

Single equation impulse responses of gaps to one per cent one-off shocks in the 5GAP model

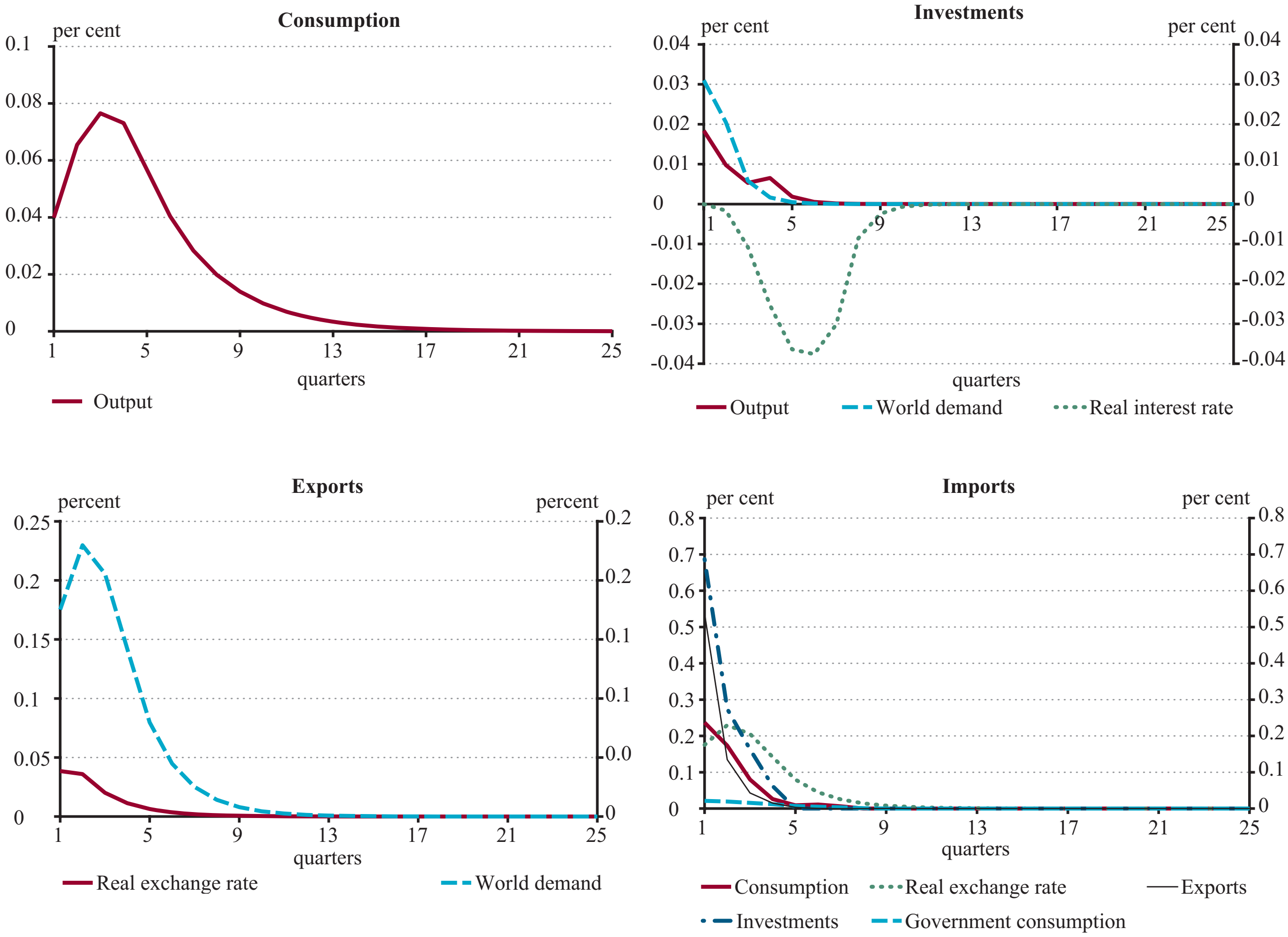


Table 1.1

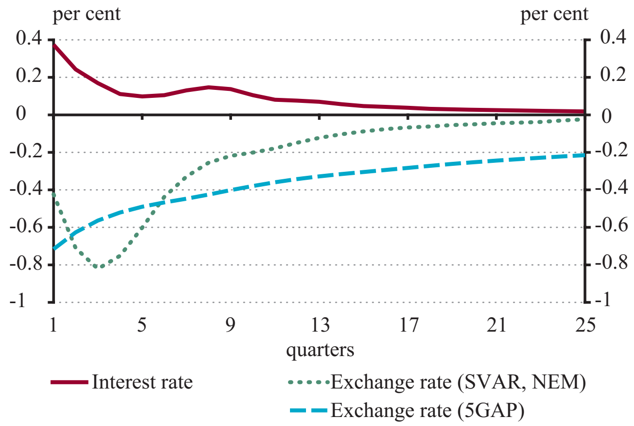
List of VARs and identification strategies used for calculating impulse responses

Number of variables	List of variables	Number of lags	Identifying restrictions	Impulse responses for:
6	– Nominal interest rate – Nominal exchange rate – CPI – Private consumption – Private investments – Net exports	2	– 2 years sign restriction on interest on rate and exchange rate – No immediate impact on GDP components	– Nominal interest rate – Nominal exchange rate – CPI – Private consumption – Private investments – Net exports
5	– Nominal interest rate – Nominal exchange rate – CPI – GDP – Nominal wages in private sector	3	– 2 years sign restriction on interest rate and exchange rate – No immediate impact on GDP and wages	– Wages
5	– Nominal interest rate – Nominal exchange rate – Investment deflator – GDP – Investments	3	– 2 years sign restriction on interest rate, exchange rate and GDP – No immediate impact on GDP and investments	– Investment deflator
5	– Nominal interest rate – Nominal exchange rate – GDP – Non–traded goods price level – Traded goods price level	2	– 2 years sign restriction on interest rate, exchange rate and GDP – No immediate impact on GDP and non–traded prices	– Non–traded goods price level – Traded goods price level

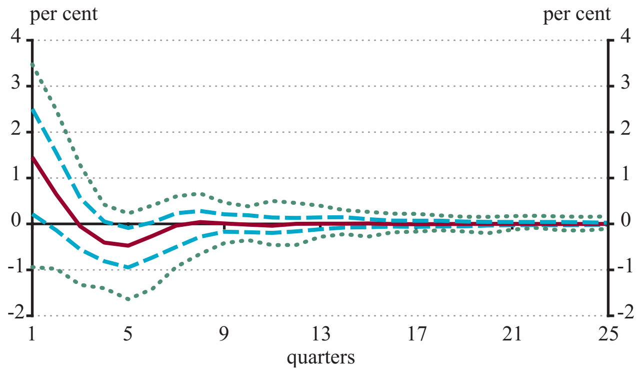
6.2. IMPULSE RESPONSES TO A MONETARY POLICY SHOCK

Figure 2.1

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



Predictable excess return (annualized)



The dotted and dashed lines indicate the middle 95 and 68 percent of the posterior distribution around the median estimates.

Posterior distribution of the maximum exchange rate response horizon

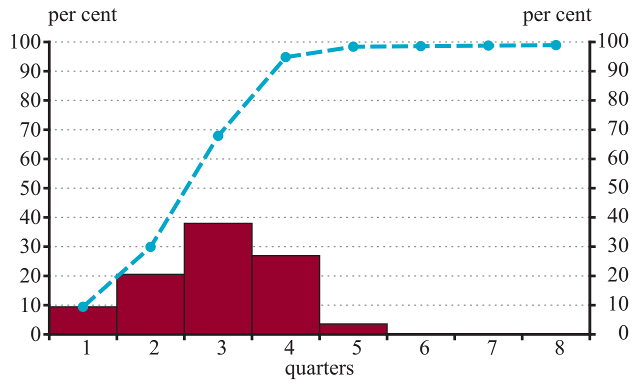
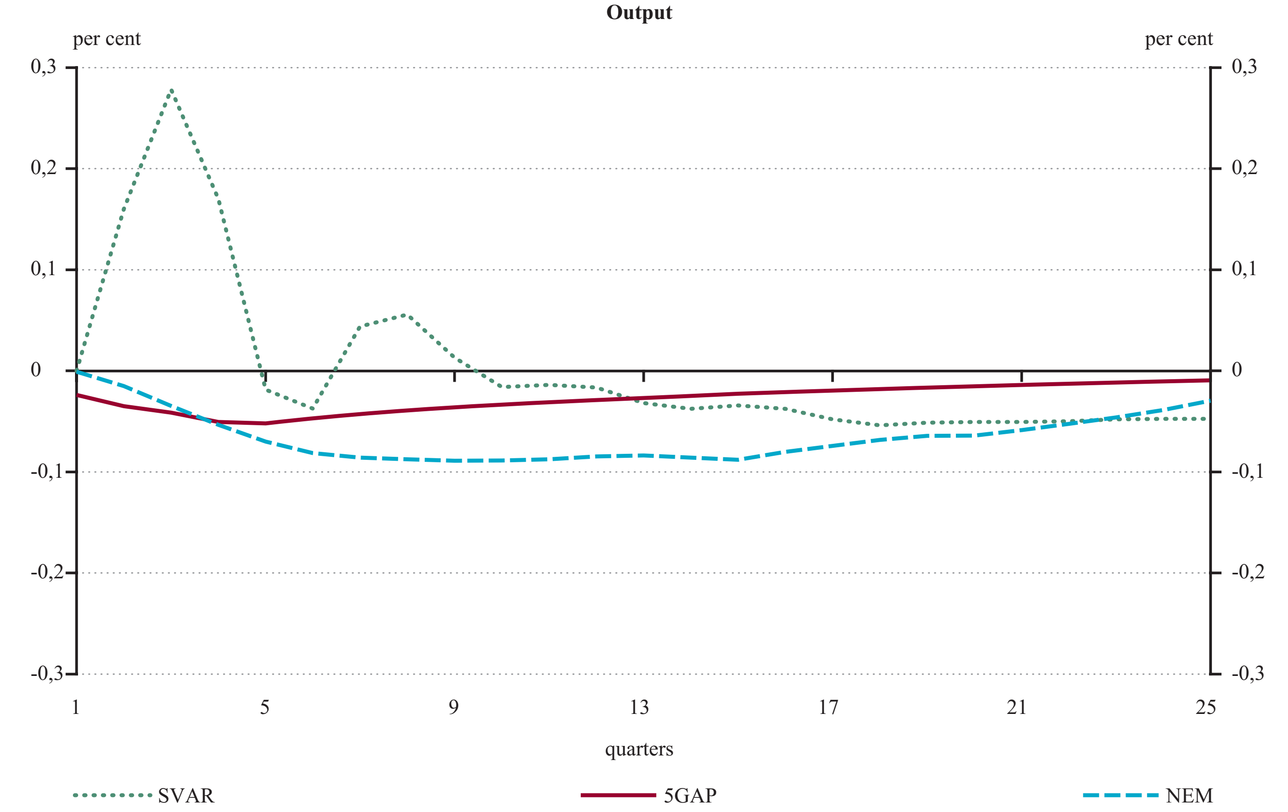


Figure 2.2

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



Note: the SVAR response is a sum of consumption, investment and net export responses weighted by their contribution to GDP.

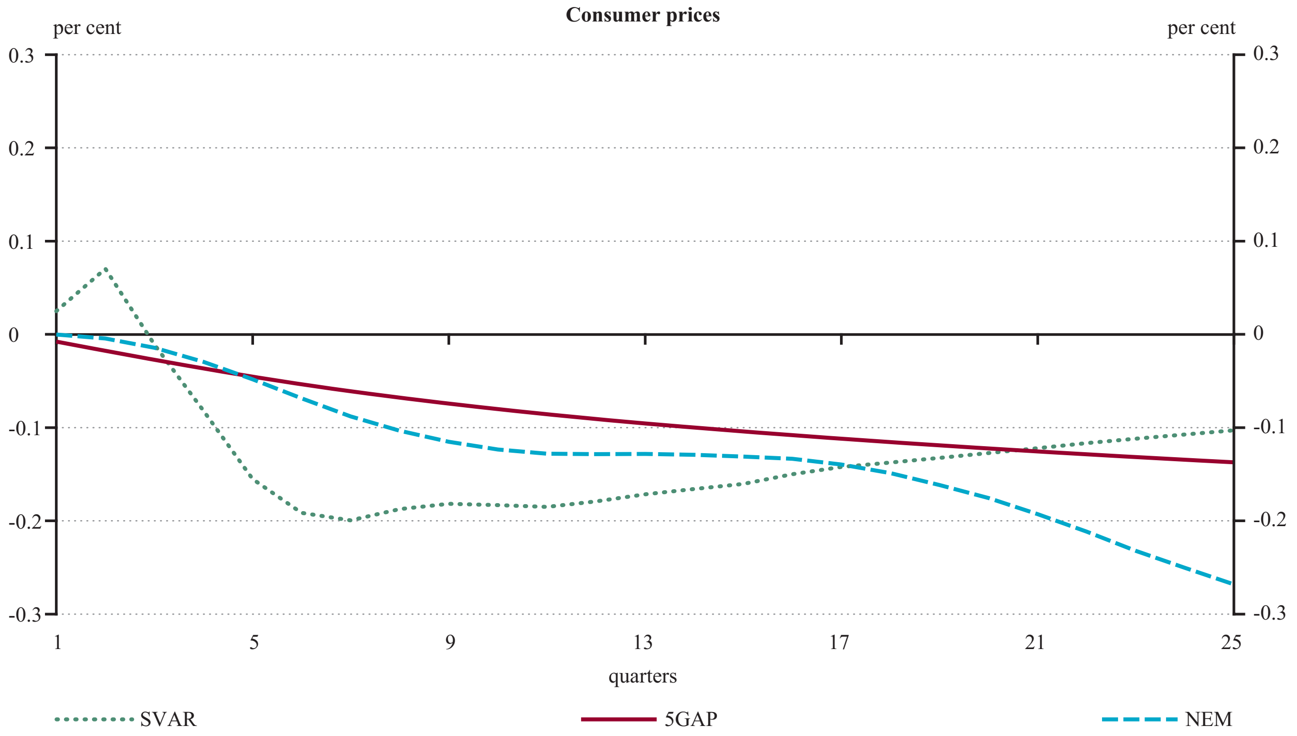


Figure 2.3

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

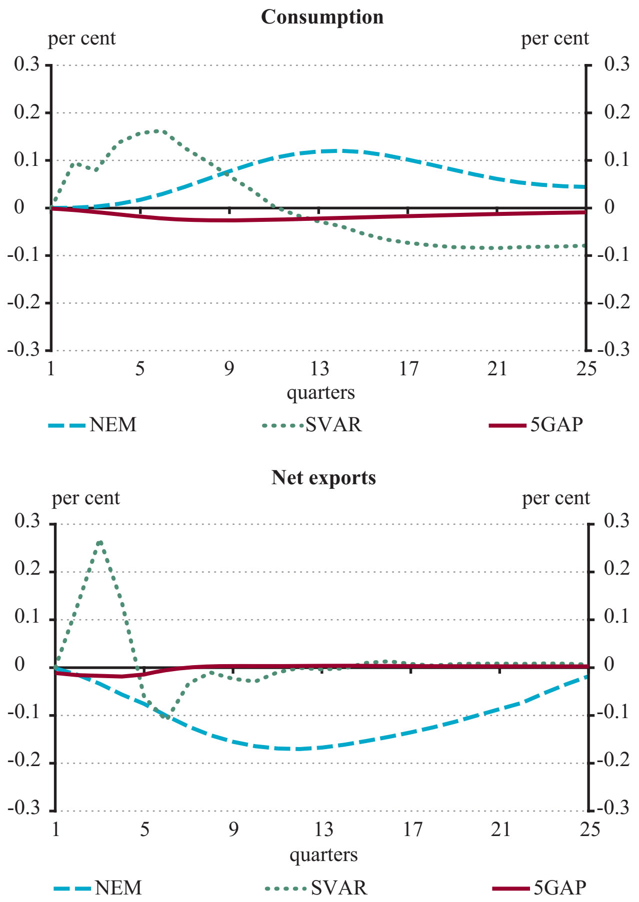
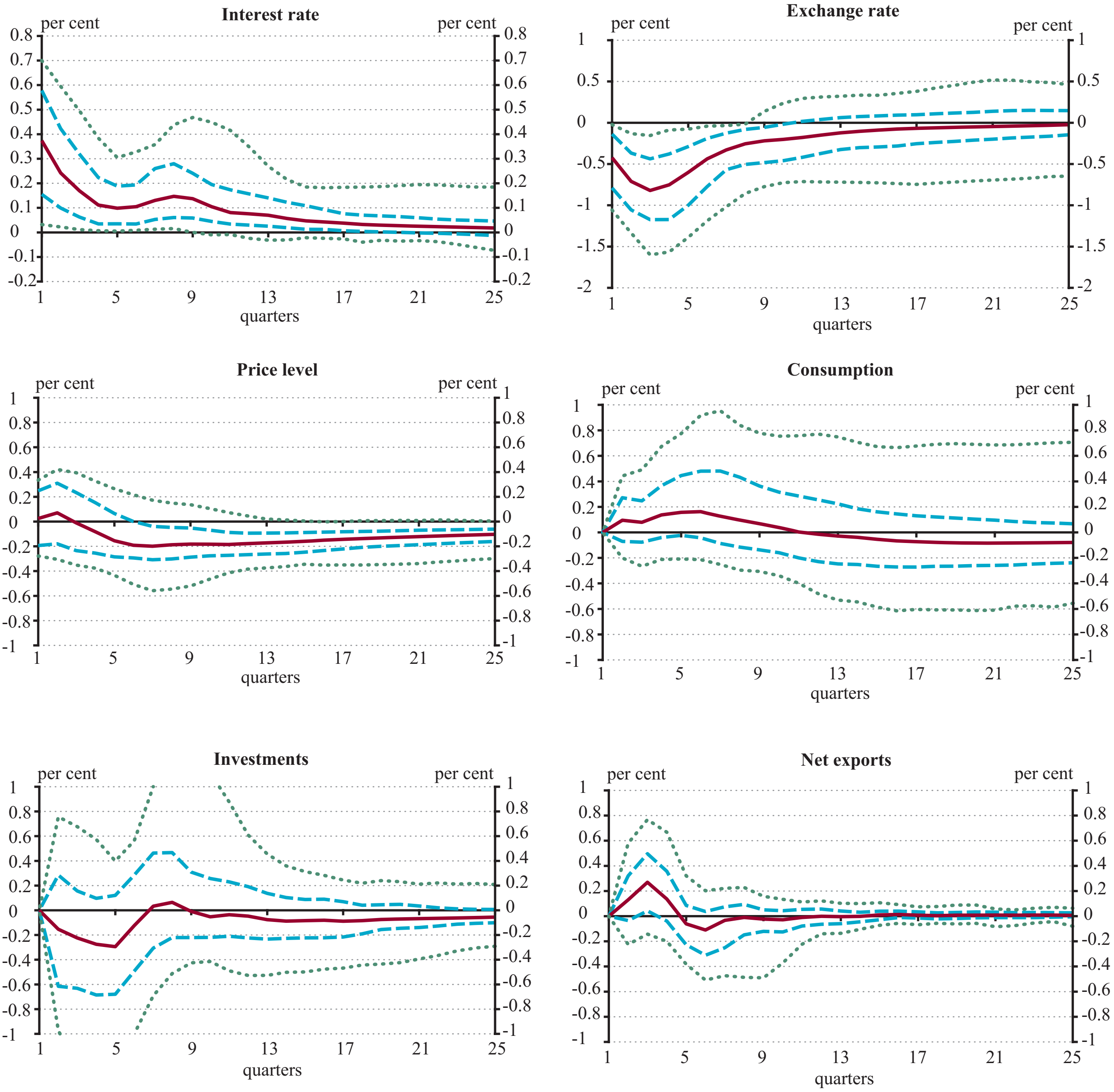


Figure 2.4

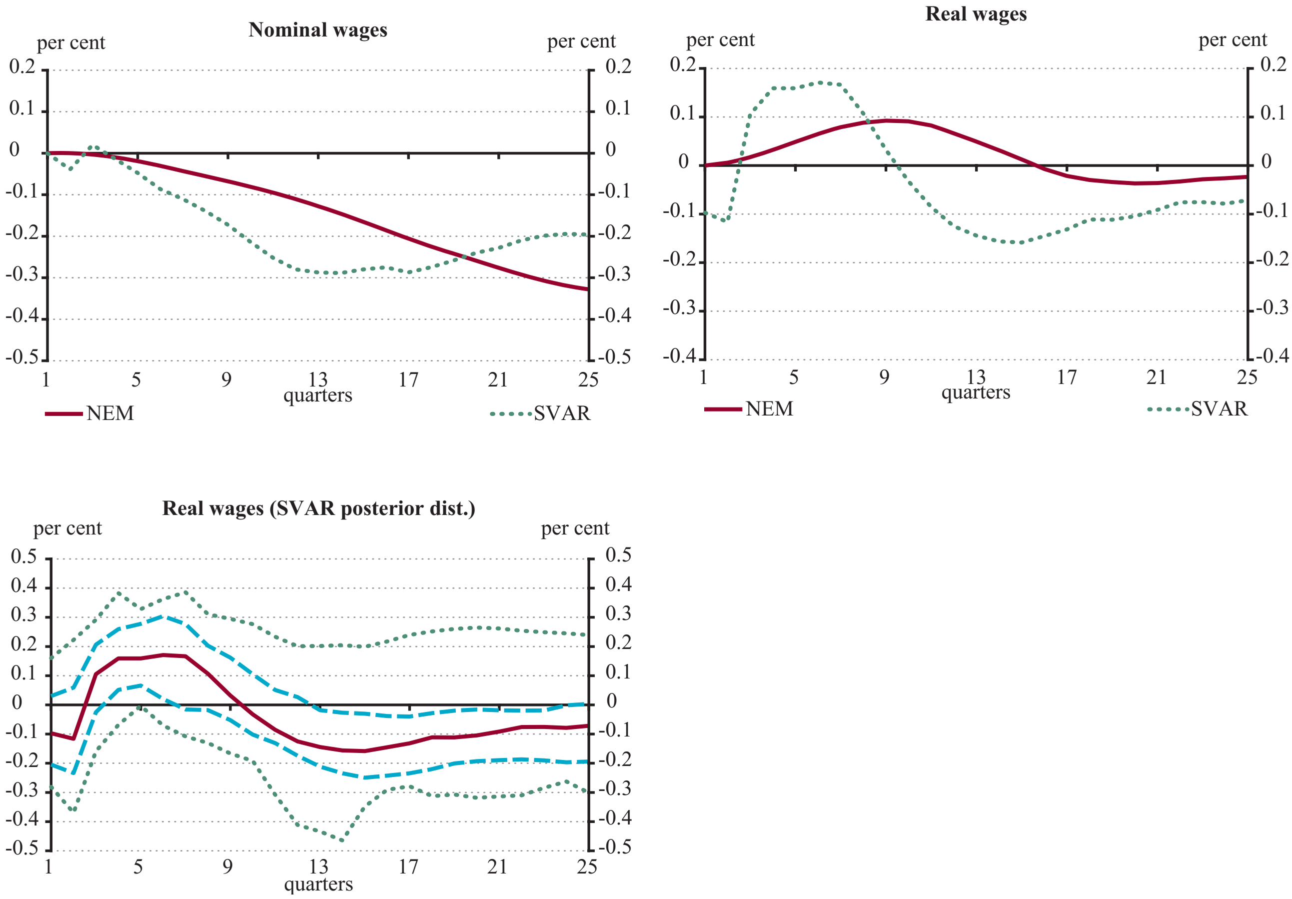
Responses to a one standard deviation tightening monetary policy shock (SVAR estimates; 6-variable model)



The dotted and dashed lines indicate the middle 95 and 68 percent of the posterior distribution around the median estimates.

Figure 2.5

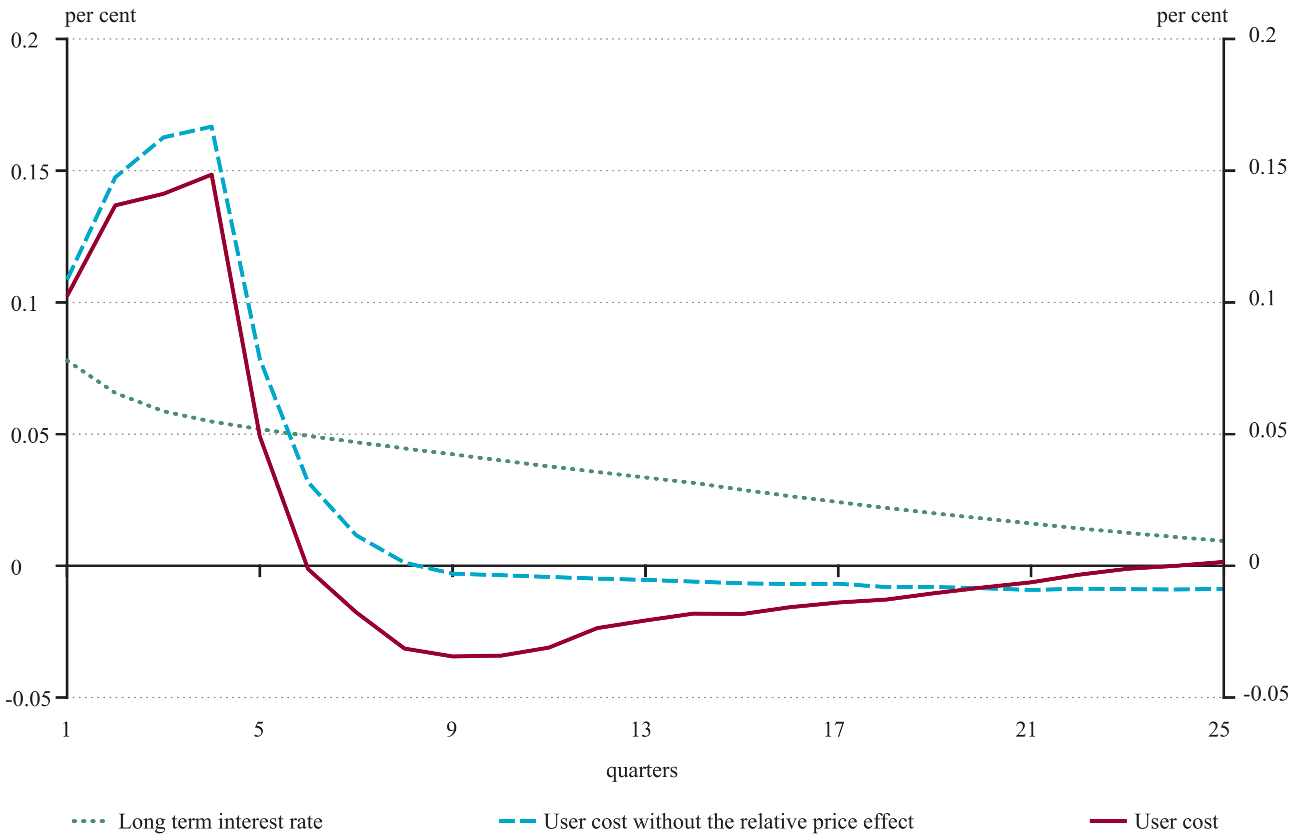
Responses of wages to a tightening monetary policy shock (results from NEM and SVAR)



The dotted and dashed lines indicate the middle 95 and 68 percent of the posterior distribution around the median estimates.

Figure 2.6

Decomposition of the user cost response in the NEM model



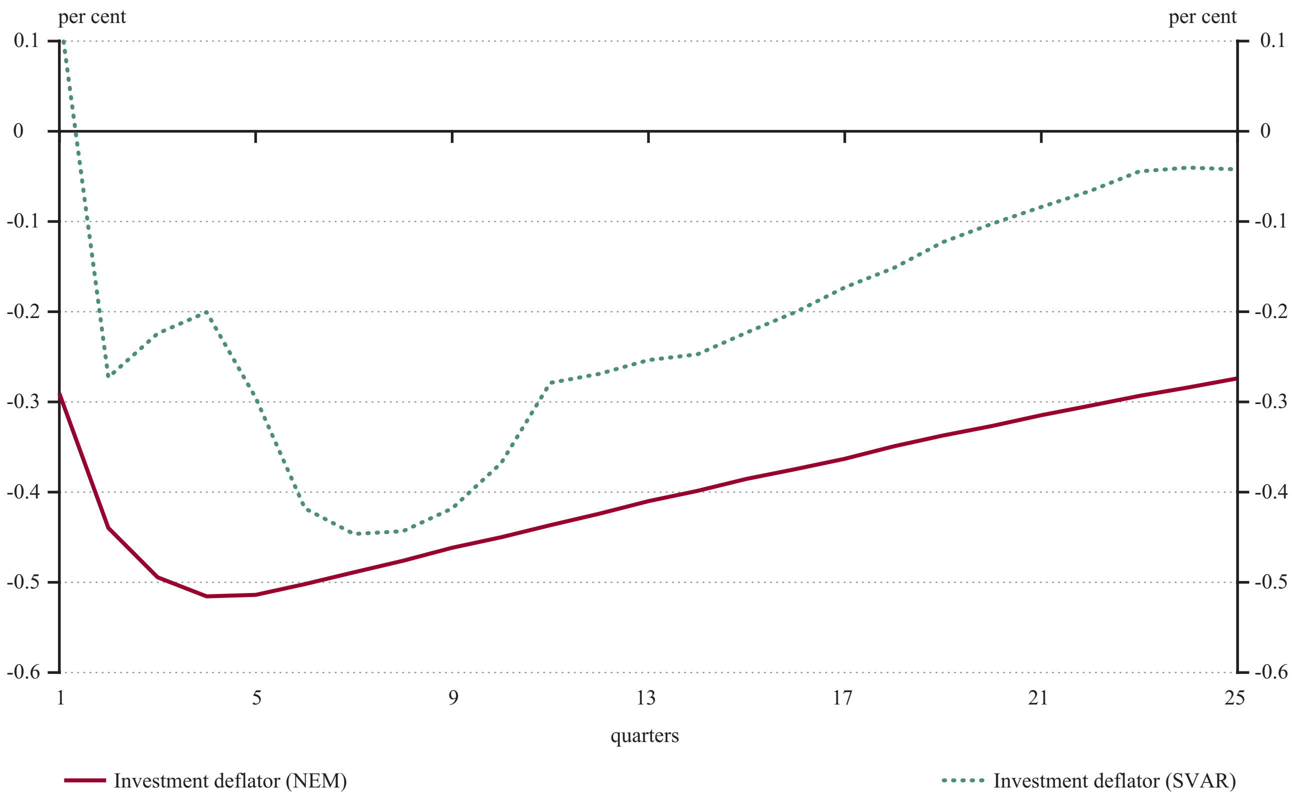
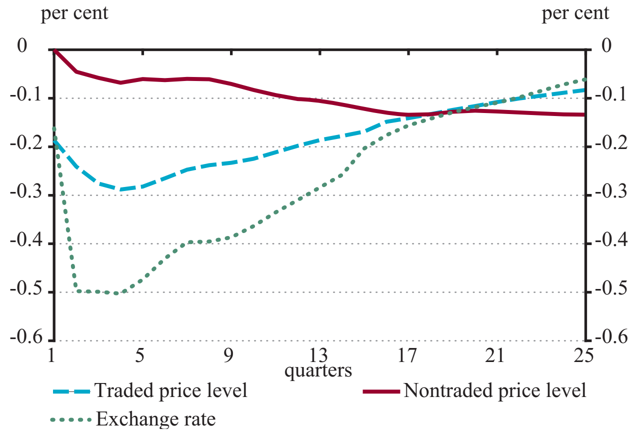
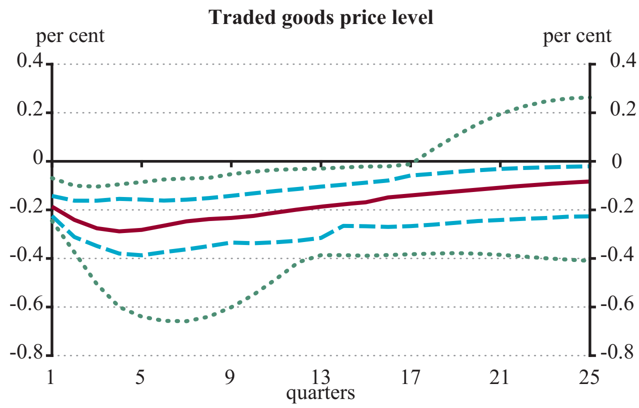


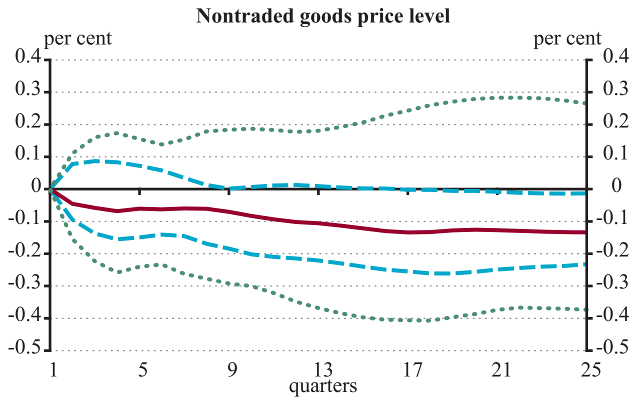
Figure 2.7

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





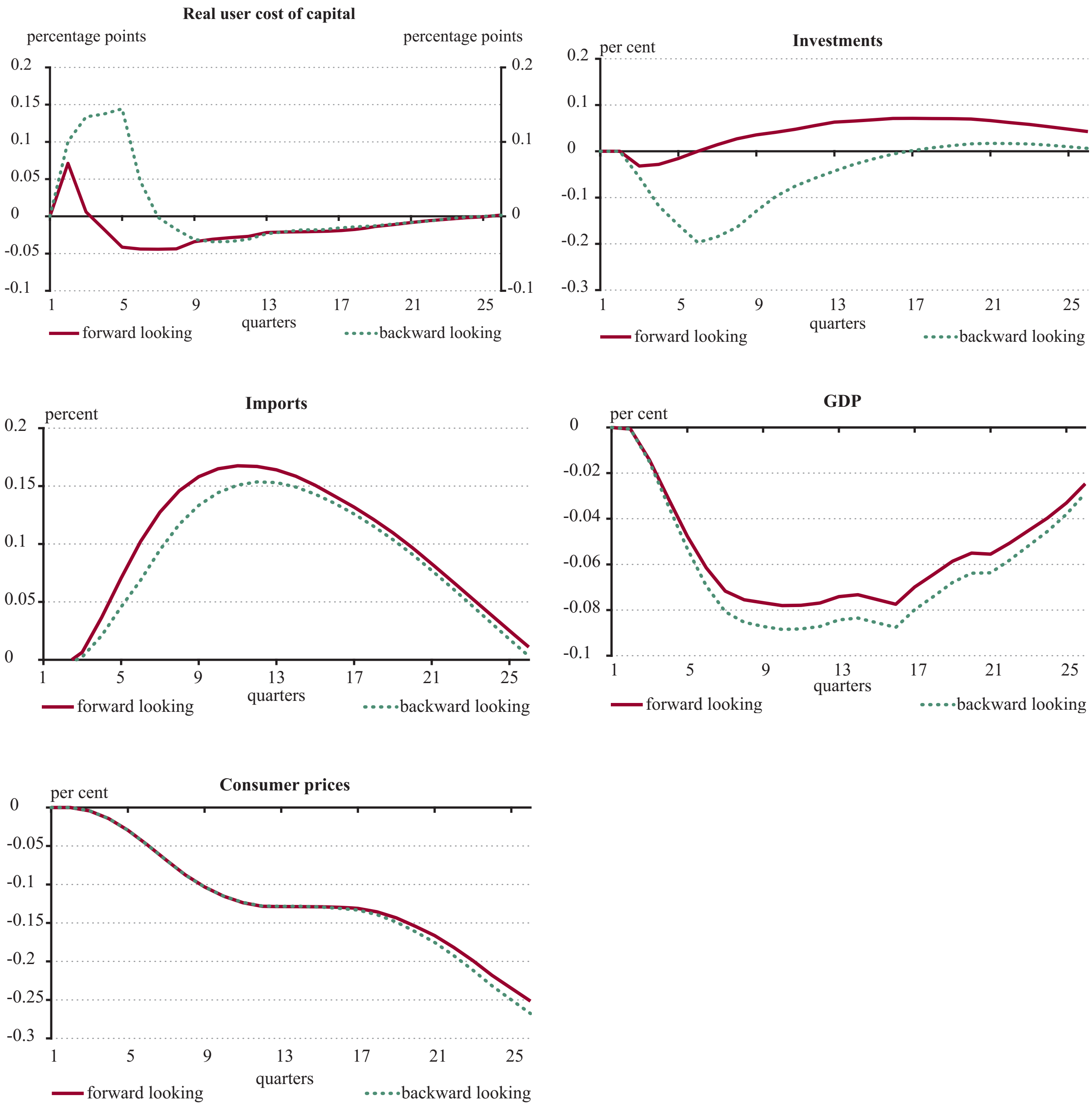
The dotted and dashed lines indicate the middle 95 and 68 percent of the posterior distribution around the median estimates.



The dotted and dashed lines indicate the middle 95 and 68 percent of the posterior distribution around the median estimates.

Figure 2.8

Different impulse responses for different user cost specifications in the NEM model



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