MAGYAR NEMZETI BANK

MONETARY TRANSMISSION IN HUNGARY

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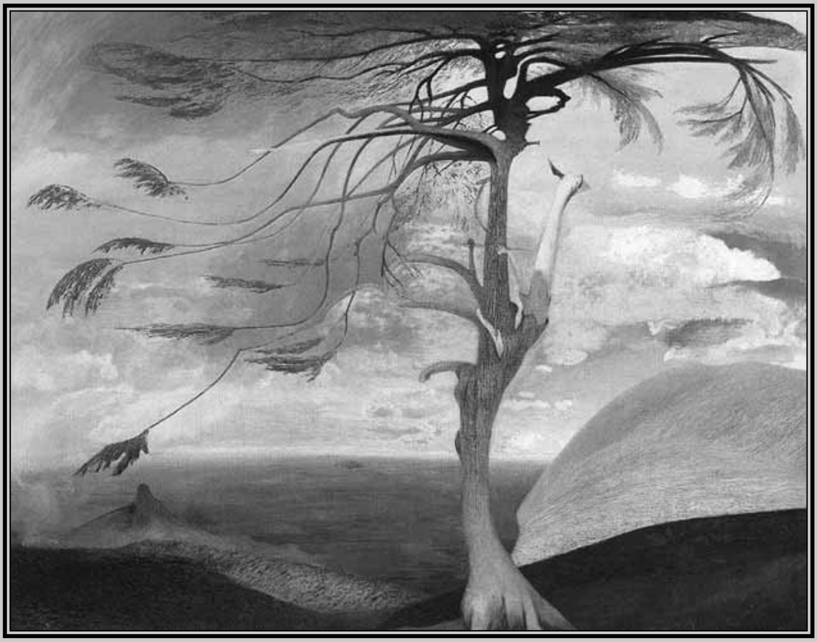
2006



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Published in Budapest by the central bank of Hungary
Publisher in charge: Gábor Missura

Printed in Hungary by D-Plus Print
19-21 Csillaghegyi út, H-1037 Budapest, Hungary

ISBN-10: 963-9383-78-3 (print)
ISBN-13: 978-963-9383-78-4 (print)
ISBN-10: 963-9383-79-1 (online)
ISBN-13: 978-963-9383-79-1 (online)

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On the cover: *Tivadar Csontváry Kosztka [1853-1919], The Lonely Cedar [1907], Oil on canvas, 194 x 248cm.* (Magyar Nemzeti Bank collection, 1994-2005. Donated to Hungarian National Gallery in 2005.)

Csontváry was one of the first Hungarian painters to become well-known in Europe. He painted more than one hundred pictures, the most famous and emblematic of which is probably *Magányos cédrus* (The Lonely Cedar). His art connects with post-impressionism and expressionism, but actually he was an autodidact and cannot be classified into an exact style.

Acknowledgements

The editor would like to thank Ágnes Csermely and István Hamecz for their support to the project. Special thanks to Attila Csajbók for his support to the project as the head of division, and particularly for his help in creating this volume. Erzsébet Heé and Daniella Tóth did an excellent job of turning the manuscript into a finished product.

Contents

Foreword

When inflation targeting was introduced in Hungary in 2001, decision makers in the Monetary Council had to rely on limited knowledge about how the monetary transmission mechanism worked in the Hungarian economy. Apart from some early works, there was no comprehensive empirical research in this area. The main reason for this was the lack of reliable statistical data in the form of long enough time series or large enough cross-section database. Although there were some estimates for the exchange rate pass-through, our empirical evidence lost their validity with the monetary regime change, since those relationships were estimated for a period of tightly managed exchange rate regimes.

The Hungarian Monetary Transmission Mechanism research project was expected to fill the gaps in our knowledge. Almost fifteen years after the beginning of the Hungarian transition to a market economy, we felt that the time has come to launch a comprehensive research project with the purpose of obtaining an understanding based on more solid econometric results. Our project was also motivated by the Monetary Transmission Network in the Eurosystem, which gave us the opportunity to compare the Hungarian transmission mechanism to that of the euro area.

It took almost three years for the colleagues at the Bank's economics department to explore the most important areas of the transmission mechanism. The research faced several challenges. The data used for estimation are still not completely satisfactory. Moreover, the framework of monetary policy, as well as some structural features of the Hungarian economy have changed during the period under investigation. Moreover, the special characteristics of our economy required a focus somewhat different from what is usual in the literature. Due to the uneven information available regarding the various sectors and markets, it was clear from the beginning that some areas would have to receive only limited coverage, rendering the synthesis of individual results difficult. Despite these shortcomings, the empirical work presented in this volume allows us to gain a better understanding of the Hungarian monetary transmission mechanism and has thus served its stated objective well.

The benefits of the project are threefold. First, it confirms our assumption about the primacy of the exchange rate channel in Hungary's small open economy. Second, there are some interesting results that may alter our thinking about how the monetary transmission works. For example, we obtained a refined and – at least compared to earlier beliefs – slightly different picture about the way consumption and investments react to monetary policy actions . Third, it brought to the fore important areas where our knowledge is far from being satisfactory. This recognition calls for further research in order to strengthen the theoretical underpinnings of our monetary policy actions. Such areas are, for example, the labour market and credit markets. We also need a deeper understanding of the factors at work determining the exchange rate.

This volume collects the papers written by the project participants. The volume is structured as follows. Studies dealing with the first stages of the transmission mechanism, i.e. how the monetary policy actions are transmitted to financial markets and asset prices, are presented first. They are followed by papers estimating the macroeconomic effects of monetary policy and the behavior of aggregate demand. The last study in the volume tries to assess the potential consequences on the transmission mechanism of joining the eurozone.

Our hope is that this volume will serve as a useful document for central bankers, as well as for economists and graduate students interested in the Hungarian economy and monetary policy related issues.

György Szapáry
Deputy Governor

1. The Hungarian monetary transmission mechanism: an assessment

Balázs Vonnák

1.1 Introduction

From the central bank's point of view, the transmission of monetary policy to the economy is of distinguished interest among various topics of macroeconomics. Without being aware of the monetary transmission mechanism (MTM) it is not possible to conduct good policy. In Hungary, our knowledge so far has been based mainly on intuitive understanding of the structural features of the economy instead of evidence from quantitative research.

In the beginning of 2004 a comprehensive research project has been launched at the Magyar Nemzeti Bank. The objective of the project was to provide quantitative results about the Hungarian monetary transmission mechanism in order to form an overall picture. The focus of the project was on empirics. We investigated first of all those areas, where most up-to-date econometric methods could be applied.

The sample used for estimations typically covered the period between 1995 and 2004. In some cases when the higher frequency or the existence of panel data endowed us with enough observations, the sample was even shorter. The identification of the effect of monetary policy has been particularly challenging due to the fact that during this period the main driving force behind macroeconomic fluctuation came from the supply side, not from the demand. Being aware of this difficulty, we tried to apply techniques that are capable to disentangle the monetary policy from other sources of shocks.

This paper tries to create a synthetic view from particular results. During 2004 and 2006 nine papers have been published within the project as either an MNB study or an MNB working paper. The synthesis basically relies on those studies, but other research results are also considered as long as they concern the transmission mechanism.

There are some aspects that make our synthesis challenging. The first difficulty to overcome is that the particular estimates were based on various sample periods. Despite this, we will treat the underlying studies as if they referred to the same sample, which is typically the decade between 1995 and 2004. The second problem is that the definition of monetary policy differs across estimations. Some papers consider the effect of an interest rate change, while other authors investigated only those changes that were not an endogenous reaction of monetary policy to some economic shocks. Taking into account their limited comparability, we try to create a qualitative synthesis which is consistent with each individual findings.

I am grateful to Ágnes Csermely, Zoltán M. Jakab and Mihály András Kovács for useful comments.

In the assessment of the overall picture we focus on two particular issues that are of primary interest. The first one is about the effectiveness of the monetary policy. Having an open capital market with predominant presence of foreign investors, interest rates and the exchange rate are strongly influenced by risk preferences and risk assessment of international players. It was sometimes not obvious whether there is an autonomous monetary policy in Hungary that conducts a policy according to its targets, or the interest and exchange rates are driven by international and other factors. Hence, we first posed the question, whether it is possible to detect significant effect of monetary policy on key variables.

The second question we try to answer is whether the exchange rate channel dominates the transmission mechanism. Hungarian monetary policy has paid special attention to exchange rate movements and expectations. The belief was that this is the most, if not the only effective channel of transmission. It was observed that tradable goods prices followed closely exchange rate movements influencing incomes, wages and other prices. Should this picture alters significantly, there might be consequences for the monetary policy strategy.

In order to be able to address the above-mentioned issues we need a comprehensive view of the transmission mechanism. We try to synthesise particular results using a scheme that focuses on two stages of transmission mechanism. At the first stage monetary policy impulses are transmitted by special markets to agents who make decisions on purchasing and production. To describe the first stage we rely on Mishkin's (1996) classification of different channels of transmission mechanism. He distinguishes between the interest rate, exchange rate, other asset price and credit channels. Each mechanism is based on a particular theory of the effect of monetary policy. We add the expectation channel to the analysis, a mechanism that relates to the transparency and credibility of the monetary policy objective and strategy.

Several studies addressed explicitly this first step within the MTM project. Horváth et al. (2004) (HKN henceforth) investigated how commercial bank rates follow the policy rate. Rezessy (2005) presented estimates of the pass through to government bond yields and equity prices. Kiss and Vadas (2005) provide information about the Hungarian housing market. HKN (2006) posed the question whether credit supply of banks is affected by monetary policy.

The first stage includes the behaviour of the exchange rate as well. Unfortunately, the empirical literature produced so far mainly puzzling result regarding the effect of monetary policy. Although these puzzles were interesting from scientific point of view, they were of less practical importance regarding large, closed economic entities like the U.S. or the euro area. Hungary is a small open economy and the exchange rate has played a distinguished role in formulating and communicating monetary policy. Hence, we allocated more resources to this issue than it is usual in the literature of monetary transmission mechanism. Whereas Rezessy (2005) and Karádi (2005) investigated the short term reaction of the exchange rate using high frequency data from the very recent period, Vonnák (2005) obtained estimates for a longer horizon.

After commercial bank interest rates and asset prices accumulated all the information about the stance of monetary policy, economic agents on goods market make their purchase decisions. At this second stage we analyze the behaviour of aggregate demand with special regard to private consumption, investment decisions and foreign trade.

Finally, we give a brief overview about how relative price changes disappear in the long run and what role the labour market plays in this procedure. We can consider this as the third stage of the transmission process. Despite its obvious importance, we cannot have a deep insight as we have no specific research focusing on this area.

The structure of the paper is the following: in section 2 we present the overall picture and put it into an international context highlighting the special features of Hungarian MTM. Section 3 classifies particular results using Mishkin's (1996) approach. In section 4 we investigate aggregate demand. In section 5 we review our knowledge about medium-run effects including labour market and the non-tradable sector. Section 6 concludes and, based on Orbán and Szalai (2005), tries to assess future trends.

1.2 The overall picture

The most important aspect of the transmission mechanism is the way monetary policy can influence inflation and output. Central banks usually have the primary goal to maintain price stability. The volatility of output is also of distinguished concern. In this section we present a bird's eye view of the effect of a Hungarian monetary policy shock. We compare our results for inflation and output to findings for other countries. In the subsequent sections we go beyond the overall picture and try to describe the mechanism in more detail and to explain the special features of Hungarian MTM.

We investigate the behaviour of output and prices after an unexpected monetary tightening. Our monetary policy shock can be characterised as a 30-40 basispoint interest rate hike coupled with a 0.6-0.8 percent exchange rate appreciation. Both changes are transitory, the variables return to the baseline after 3-4 years.

The response of Hungarian consumer prices to the shock is shown in Figure 1.1 borrowed from Jakab et al. (2006; JVV henceforth). There is substantial similarity between the three impulse response functions, each of them coming from a model estimated on Hungarian data. Consumer prices react to monetary tightening by a quick drop. The lower price level seems to persist for several years. In terms of yearly inflation rate, which is the target variable in Hungary, it means that the effect of monetary policy is the largest within the first two years with the peak being somewhere at the end of the first year.

This shape of price response is somewhat different from those found in closed, developed economies like the U.S. or the Euro area. Most SVAR estimates[1] show a slight increase during the first year and prices typically begin to fall only later, but then the decline lasts for several years. Accordingly, yearly inflation rate is higher at the beginning, but later falls below the baseline persistently. This stands in clear contrast with the Hungarian price dynamics.

The response of Hungarian output is not as clear-cut as in the case of prices. While two models in JVV show a slight decline in real activity after the contractionary shock, SVAR estimates using time series of GDP suggest rather a small although not significant increase. The reason for this is that within the same framework a significantly higher consumption of households is detected that offsets the decline in investments. It should be noted, however, that using the same methodology but industrial production data instead of GDP, Vonnák (2005) estimated a significant drop in

[1] For examples see Christiano et al. (1998) and Angeloni et al. (2003).

industrial output and the magnitude was even higher than those found by the other two models in JVV. We conclude therefore that the Hungarian GDP drops somewhat after the contraction.

Estimates for the U.S. and the Euro area show a more pronounced output response. Although there are some studies that could not find significant effect of monetary policy,[2] most results indicate a clear slowdown of the economy after an unexpected monetary tightening. The consensus view fits the basic features of a new-keynesian economy with sticky prices: after the monetary policy action, volumes react quicker to the changes of demand and output returns to its natural level only when price adjustment takes place, that is GDP response leads price response.

In the case of Hungary the same new-keynesian explanation alone is not able to explain fully what happens after a monetary policy shock. The response of output is moderate. The reaction of prices is instantaneous and does not lag behind that of output gap. For Hungary some alternative description of the transmission mechanism is needed. In the following sections we try to identify the special features of Hungarian MTM relying mainly on our fresh results.

1.3 The channels of monetary transmission

The mechanism through which monetary policy affects the economy can be divided into two steps. In the first step monetary policy influences market interest rates, the exchange rate, asset prices, credit supply of the banking sector and the expectations through its policy rate and communication. Economic agents extract signal transmitted by those markets and make decisions on their demand for goods and production. The second stage of MTM consists of the reaction of demand as well as the adjustment process of the supply side and labour market. In this section we classify results that relate to the first stage of MTM relying first of all on Mishkin (1996) who distinguishes between interest rate, exchange rate, asset price and credit channels. We augment this classification scheme by the expectation channel.

Interest rate channel

The first stage of the interest rate channel is the mechanism through which policy rate passes through to commercial bank rates, that is to corporate and household deposit and loan rates. The second stage is when households and firms make their consumption and investment decisions in face of new interest rate conditions. We summarize here our findings concerning the first stage which is far simpler than the second.

Monetary policy has the power to determine the very short end of the yield curve by providing or absorbing liquidity with a maturity ranging typically from overnight to two weeks or one month. The rate set by the central bank is the (opportunity) cost of having excess liquidity for commercial banks, and therefore influences money market interest rates of the same maturity very quickly and effectively. In Hungary during the past ten years a short-term deposit rate acted as policy instrument. Up until 1997 its maturity was one month, since then the policy rate is the two-week deposit rate.

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[2] Uhlig (2005) is such an example.

According to the expectation hypothesis, longer maturities are linked to the policy rate through expectations on future development of short term rates. For example, if an interest rate hike by the central bank is expected to be temporary, longer term interest rates will not be affected to the extent short term rates change. On the contrary, if market expects higher rates will remain for longer period, long term yields increase more, thereby monetary policy may be more effective.

An important feature of most of our research is that typically 3-month money market or T-bill rates are used as policy rate instead of the central bank's deposit interest rate. The reason for this is twofold. On the one hand, for higher frequency estimation (monthly or more frequent) the policy rate sometimes does not reflect the frequent change in monetary policy stance. On the other hand, we can consider 3-month interest rates as embedding more information than the policy rate, since it contains expectations about its movement in the very near future. If, for example, the Monetary Council leaves the base rate unchanged according to market expectations, but at the same time releases a statement containing tightening bias, 3-month market rates will rise and this reflects a genuine monetary tightening correctly, even in the absence of immediate interest rate move. Nonetheless, at monthly or quarterly frequency the policy rate co-moves with 3-month market rates closely, as it is shown in Figure 1.2.

For government bond yields and T-bill rates Rezessy (2005) estimated the immediate effect of an unexpected interest rate move on the yield curve. He found significant impact all along the entire curve. Even the 10-year benchmark yield increases by 10 basispoint after a 100 basispoint surprise policy rate hike on the same day. The one year ahead forward interest rate increased by half percentage point, but beginning with the 5-year horizon, significant decrease was detected. As long as forward rates reflect interest rate expectations, the reaction of forward rates can be interpreted as the half of the unexpected move is expected to be maintained one year later, and to die out completely by the fifth year.

Although the pass-through from short to longer maturities is found to be satisfactory, it is not necessary for an effective interest rate channel because in Hungary the maturity of loans and deposits are typically shorter than in developed countries. In some cases, like corporate loans, even if the maturity is longer, the interest rate is linked to the 3-month interbank rate rendering it essentially a short term debt with frequent re-pricing.

HKN (2004) investigate the connection between short-term money market rate and commercial bank rates. They detect relatively fast pass through with the adjustment of corporate loan rates being the fastest and most complete, but even the most slowly and least completely reacting consumption loan rates absorb the 80 percent of short term interest rate moves.

From our point of view the relevant finding of these papers is that this first stage of the interest rate channel performs well, it depends on the household and corporate sector whether interest rate movements exert direct influence on aggregate demand. As we will see in section 4, the interest rate channel may be effective through mainly investment decisions.

Exchange rate channel

The first, and perhaps empirically the most challenging step of the exchange rate channel is the reaction of the exchange rate to interest rate movements. A very simple and in theoretical modelling widely used assumption is uncovered interest rate parity (UIP). Within the UIP framework risk neutral agents demand excess yield on assets that compensate them from the expected loss caused by depreciation:

$$i_t = i_t * + E_t s_{t+1} - s_t \tag{1}$$

where *i* denotes one period yield, *s* is the home currency (forint) value of the foreign currency (euro) and * stands for foreign variable.

As in Dornbusch's (1976) model, an unexpected interest rate increase with flat foreign rates causes the spot exchange rate to appreciate and/or the expected future rate to weaken. Unfortunately, statistical methods failed to detect this mechanism[3]. The estimated relationship between interest rate and exchange rate was just the opposite, that is appreciation was more frequently coupled with positive interest rate differential.

One possible explanation is the presence of time-varying risk preferences. When the right-hand side of (1) is augmented with a risk premium term, the relationship alters in a way that investors require compensation not only for an expected depreciation, but also for holding domestic assets at all. The latter term can represent, for instance, an exchange rate risk premium if investors are risk averse.

$$i_t = i_t * + E_t s_{t+1} - s_t + rp_t \tag{1'}$$

It is easy to see that an increase in risk premium *(rp)* can lead to higher domestic interest rate, to a spot depreciation or can be offset by an appreciation in the future. If risk premium shocks dominate autonomous monetary policy, the observed co-movement between interest rate and exchange rate will be the opposite of the pure UIP case.

For Hungary the model containing time-varying risk premium is certainly the relevant one. During the past decade, since foreign portfolio investors appeared at forint markets, several episodes were recorded when it was obvious that changing risk assessment and preferences caused large swings in the exchange rate. Monetary policy tried to partially neutralise those shocks, otherwise they would have caused undesired movements in consumer prices.

The presence of shocks to risk premium renders measuring the effect of monetary policy to the exchange rate difficult. Relying purely on the correlation between interest rate and exchange rate would lead to a perverse effect, monetary tightening would seem to weaken the currency. Distinguishing between two types of 'financial' shock, monetary policy and risk premium shocks, is therefore crucial. Unfortunately, due to its limited relevance for developed economies, this problem has not received much attention in the empirical literature.

Three of our research papers dealt explicitly with the reaction of exchange rate to monetary policy. Rezessy (2005) estimated the immediate impact of monetary policy shocks on exchange rate. He used daily data starting in the middle of 2001 when the intervention band of the forint has been widened and the inflation targeting regime has been introduced. His identification strategy exploited the fact that on rate-setting meetings of the Monetary Council monetary policy shocks

[3] For a survey see MacDonald and Taylor (1992).

are typically larger than on other days. He detected significant effect with the expected sign on the first day, and an even larger effect on the day after rate-setting meeting.

For a longer period, beginning in 1995, Vonnák (2005) estimated the dynamic effect of monetary policy shocks on industrial production, consumer prices, short term interest rate and nominal exchange rate. It is important to note that the response of the exchange rate was in one case part of the identifying assumptions, therefore it cannot be considered as being purely estimated. One identification strategy there assumed that out of all the possible shocks that have only delayed effect on output, monetary policy shock is the only one producing negative correlation between the interest rate and exchange rate (higher interest rates with appreciation). The other identification scheme, however, did not use any presumption about the exchange rate, it was based instead on some historical evidence about Hungarian monetary policy. The response of exchange rate was in each case almost identical, and despite the different data set, comparable to Rezessy (2005) results. We are therefore quite certain that during the past 5-10 years monetary policy have been able to influence the exchange rate. An unexpected 25 basispoint rate hike on average appreciates the exchange rate almost immediately by 0.5-1 percent.

Karádi (2005) introduce a more sophisticated model of monetary policy and exchange rate. In his set-up there are two channels of affecting the exchange rate by the central bank: one is the traditional interest rate policy, the second one is influencing exchange rate expectations. The relevance of his model is obvious from the characteristics of the Hungarian monetary policy in the past. During the crawling peg regime the preannounced rate of depreciation anchored expectations. Even later, in the first two years of inflation targeting, a range of exchange rate considered to be consistent with the inflation target was usually announced.

From (1) it is obvious that with full control over the exchange rate expectations it is possible to manage the spot exchange rate without changing the policy rate. With constant foreign and home interest rates, one percent change of expected future exchange rate will move the spot rate by the same amount to the same direction. It is therefore possible to tighten monetary conditions simply by announcing a credible exchange rate target, which is stronger than earlier expected. Something similar happened after the widening of the intervention band in May 2001. The measure itself was a clear message for the markets that the MNB would like to see a more appreciated exchange rate in order to bring down the inflation. As a consequence, the forint appreciated by 10 percent within two month without any policy rate hike.

The second step in the exchange rate channel is the relationship between domestic prices and the exchange rate. This link is traditionally viewed as the most important one in Hungary. Monetary policy strategies have been based on the role exchange rate. Being a small open economy, the consensus view has been that exchange rate movements are tracked closely by tradable good prices and affect tradable sector strongly. Hence, the level of the exchange rate, not the interest rate was considered as a proper representation of the monetary policy stance. Although this link of the MTM belongs rather to the second stage, here we review briefly the most important findings for Hungary.

There is a branch of papers in the literature investigating how exchange rate changes passes through to domestic nominal variables. From our point of view, most of the results are only partly informative, since we restrict our attention to exchange rate movements that are generated by monetary policy. Pass-through coefficient estimates are usually not conditioned to a specific shock, therefore they can be considered as an average across all possible sources of shocks with weights proportional to the importance, or frequency of that particular shock, as it is stressed in Bouakez and Rebei (2005).

In order to highlight this issue let us consider the case of changing risk premium again. In several cases Hungarian monetary policy has been successful in preventing the real economy from being affected by risk premium shocks. It achieved this by quickly reverting exchange rate movements induced by sudden shifts in risk assessment of foreign investors. As a result, these shocks have had virtually no effect on output and prices. In contrast with this, autonomous monetary policy had persistent effect on the exchange rate, and therefore consumer prices also reacted in medium term. Intuitively, after an exchange rate change economic agent are more or less aware of the nature of the shock, and they reset their prices only if they do not expect the exchange rate to return to its previous level quickly.

To our knowledge, two papers have attempted so far to estimate the Hungarian exchange rate pass-through or describe its main features. Darvas (2001) applied an equilibrium real exchange rate framework. He modelled price and exchange rate dynamics in a two-equation system, and estimated time-varying parameters for Hungary, Czech Republic, Poland and Slovenia. He found that long run exchange rate pass-through was high in Hungary during the years of the crawling peg regime, compared to the other three countries.

Jakab and Kovács (2003) investigate the role of expectations, goods market and labour market in the exchange rate pass-through. Simulating with the Hungarian block of the NIGEM model, they conclude that during the first 1-2 years after an exchange rate movement the pass-through mainly depends on the pricing elasticity to cost changes and the role expectations play in price and wage-setting. From the third year onwards the mark-up elasticity becomes dominant. Labour market characteristics, namely the elasticity of wages to unemployment and productivity are important only on longer run, roughly after 5 years after the shock.

Our project has not included any research with the sole aim to obtain fresh estimates for the pass-through. Nevertheless, for the understanding of consumption and investment decisions, JVV could not escape from dealing with exchange rate pass-through. Using information of three empirical macromodels they concluded that pass-through to tradable good prices is immediate and almost complete, but it is slow to prices of non-tradable goods. The pass-through to overall consumer prices seems to be gradual.

Finally, Kovács (2005) gives a very informative insight into the effect of exchange rate depreciations on the real economy using the experiences of the austerity package of finance minister Bokros Lajos in 1995. One central element of that package was the surprise devaluation of the forint by 9% which serves as an excellent example to investigate some aspects of the exchange rate channel. His main conclusions concerning the external equilibrium were the following: (1) the profitability of the corporate sector was not significantly affected by the devaluation; (2) the position of the household sector deteriorated because of the negative income effect of the surprise inflation; (3) the success of the package hinged primarily on the fiscal policy, especially on the fact that the inflating the expenditure side of the budget was not followed by a correction, so there was a persistent improvement in real terms on the expenditure side.

It is in order here to mention the role of intermediate goods in transmitting exchange rate changes. McCallum and Nelson (2001) present an open-economy model in which imports are treated not as finished goods but rather as raw-material inputs to domestic production. Hence, exchange rate movements affect production costs directly through the price of intermediate goods. They show that their model produced a relationship between exchange rate and inflation that is closer to empirical evidence.

We have only little empirical evidence on how exchange rate pass-through works through production costs. Although our project has not covered the supply side, we can invoke some other studies. As Tóth and Vincze (1998) report, the two most important reasons for changing their prices, Hungarian companies in a survey refer to change in 'fuel, raw material, accessories price' or in 'the exchange rate'. On the other hand, demand and productivity are ranked among least important determinants of pricing. This observation suggests that the cost channel may be relevant in Hungary.

Kovács (2005) demonstrates that firms' profit did not significantly improve after the depreciation in 1995-1996. The reason is that while surprise inflation decreased real wages, material related expenses grew considerably at the same time, rendering the total effect nearly neutral. The neutralizing role of material costs was particularly important for firms producing for export. After the nominal appreciation in 2001-2002 similar story but with opposite sign can be read from firm level data. Kovács (2005) makes the general statement that in Hungary corporate sector's profitability is mainly determined by foreign trade partners' business cycle and the role of real exchange rate is negligible.

Asset price channel

According to monetarist as well as Keynesian theories, asset prices decline after a monetary contraction. Higher interest rate results in higher yield expected from bonds decreasing their prices. Stock prices also fall. The loss of property value can be also important as households' consumption spending might be affected through house equity withdrawal.

Mishkin (1996) explains the asset price channel focusing on the stock prices. The first example he cites is Tobin's *q* theory of investment (Tobin, 1969). When equities are cheap relative to the replacement cost of capital, firms do not want to issue new equities in order to buy investment goods, therefore investments decline. The second channel works through households' consumption. Lower equity prices reduce households' wealth and they consume less.

In Hungary there are at least two reasons for considering stock price channel as irrelevant. First, there is no empirical evidence that monetary policy affects stock prices. We have estimates only for the instantaneous impact of monetary policy decisions on the Hungarian stock market index (BUX). Rezessy (2005) found no effect which is in contrast with Rigobon and Sack (2004) who detected significant decrease in major U.S. stock market indices after an unexpected tightening. Taking into account the ability of stock markets to absorb news quickly, it is hard to imagine that monetary policy shocks have only delayed effect on equity prices.

Second, shares play minor role in Hungarian households' financial wealth. They amounted typically roughly to the 10 percent of all financial assets during the past ten years. The same is true for other securities, like government bonds. Their amount has never exceeded ten percent of total assets. Even households' financial wealth itself is not as large as in more developed countries. At the end of 2004 total financial assets excluding items that are not supposed to play role in the asset price channel (cash, deposits, insurance technical reserves) amounted to 40 percent of annual GDP (see Figure 1.3).

Housing wealth may play a more important role in asset price channel, as their market value is more than three times larger than households' financial assets. Kiss and Vadas (2005) estimated the effect of an interest rate increase on house prices. They then fed the results into the consumption function of the MNB's quarterly projection model.[4] It is important to emphasise that they obtained an estimate that combines the asset price channel with the credit channel, as the consumption function cannot distinguish between the two mechanisms. They detected significant effect of interest rate on private consumption and housing investments through house prices. However, if we compare it to other macro level estimates like JVV or Vonnák (2005) and take into account the relative size of the interest rate shock[5], we can conclude that even the housing market is incapable to explain the effect of monetary policy.

Credit channel

The role of credit supply in magnifying the effect monetary policy is discussed in details among others in Bernanke et al. (1995). The basic idea is that monetary tightening leads to higher external finance premium stemming from imperfections on credit market, such as principal-agent problem. They argue that the conventional cost-of-capital effect fails to explain the size, timing and the composition of the observed response of spending on durable goods. The additional mechanism, called credit channel, should not be imagined as a stand-alone mechanism but rather as an amplifier of the conventional way interest rate exerts its effect. It works in the same direction: a monetary contraction not only reduces demand for durables, it also decreases loan supply.

The authors distinguish between bank lending channel and balance sheet channel. The former concept rests on the assumption that a monetary contraction drains loanable fund from the banking sector. Commercial banks can raise new funds only at higher price by issuing certificates of deposits or equity. The balance sheet channel is related to the financial accelerator phenomenon. Changes in interest rate affect the net worth of a firm through its cash-flow and the value of collateral. Higher interest rates thus lead to lower net worth and higher external finance premium.

Stylised facts about the Hungarian economy suggest that even if there exists a credit channel, its contribution to the transmission mechanism may not be highly significant. Large part of commercial banks as well as the non-financial corporate sector is owned by large foreign companies. Loans from the parent company is available for numbers of domestic firms at normal price even if the monetary policy is tight in Hungary, as either these loans are in fact internal financing at firm level or the cost of raising additional funds from external sources is not affected by Hungarian monetary policy. The same argument but to a limited extent also applies to Hungarian commercial banks owned mainly by foreign banks.

[4] A non-technical summary of the model is available on the MNB's website (Jakab et al., 2004).

[5] Kiss and Vadas (2005) assumed a permanent 1 percentage point increase in interest rate and they got 0.3 and 1 percent deviation of consumption and housing investments from the baseline. In JVV a much smaller interest rate shock (0.4 percentage point increase in the first quarter, shrinking to 0.1 by the end of the year) resulted in a 0.1-0.2 percent response of GDP components.

Regarding the estimation, Kashyap and Stein (1995) argue that the easiest way to test for the existence of credit channel is to use cross-section estimates. In this way one can identify credit supply effect that is independent of the demand side. The idea is that certain banks and firms, typically the smaller ones suffer more from higher external premium. HKN (2006) tested whether the existence of cross-bank asymmetries in lending activity can be rejected in Hungary. They estimated several credit supply equation on a panel of 25 commercial banks during the period of 1995 to 2004. They related banks' ability to raise new funds to their size, liquidity, capitalization and foreign ownership. In the regression they also controlled for GDP growth, inflation, exchange rate and foreign interest rate. Using several specifications they could not reject the null hypothesis that the effect of the monetary policy is magnified by the bank lending channel.

As for the balance sheet channel we have no research at hand dedicated exclusively to that phenomenon. However, there is some indirect evidence. Kátay and Wolf (2004) estimated an investment equation on a large panel of non-financial firms. In their specification the investment depended on the user cost of capital, sales revenues and the cash-flow. They found that the latter had significantly non-zero effect on investment spending. Although there may exist several channels through which cash-flow can influence investments, one plausible candidate is the external finance premium, that is the balance sheet channel.

Taking into account the ownership structure of Hungarian banking and corporate sector, as well as the results of HKN (2006) and Kátay and Wolf (2004) we arrive at the conclusion that although empirical evidence points towards the existence of the credit channel, for structural reasons we do not consider it to be a crucial ingredient in the transmission mechanism.

Expectations

In a simple model with a Taylor-type monetary policy rule the long term or steady state inflation is determined by the target of the central bank. Forward looking and rational agents in this model-world anchor their interest rate expectations to the known policy rule, their long run inflation expectations to the known target. If a shock occurs, the monetary policy responds to it according its rule and no one doubts that all the variables, including inflation will return to the steady-state value. As a consequence of forward-lookingness, the effect of the shock is mitigated by the public expectations as well. Similarly, if the central bank changes its target and announces it, expectations may help the interest rate policy achieve the new goal, as long as perfect credibility is assumed. In the model-world the expectation channel has more to do with the policy rule rather than with policy shocks.

In the real world it is usually the case that either the target is not explicit or is not believed by the public (credibility problem). The central bank may want to signal that his target is below or above the current or forecasted level of the inflation. He can do it by communication or in the absence of credibility, by demonstrative, unexpected changes of its instrument. Monetary policy shocks can be thus useful to send messages about the preference of monetary policy and to gain credibility, to signal commitment. In the reality and particularly when policy preferences are changing the expectation channel is related more to monetary policy surprises than systematic policy.

The role of monetary policy in coordinating expectations is most obvious in price and wage-setting, the two mechanisms that play crucial role in new-keynesian theories of monetary transmission. The higher the credibility of the monetary policy, the lower the real cost of disinflation, that is the sacrifice ratio depends heavily on the expectation channel. With more flexible nominal wages, production can be adjusted to changes in real demand without major changes in employment, therefore the short-run supply curve is more vertical than in the rigid-wage case.

An important example for the way expectations determine price-setting is the so-called Taylor-hypothesis. Taylor (2000) investigates the observed low pass-through of cost shocks to consumer prices. He relates the phenomenon to the low inflation and low nominal volatility environment arguing that when setting their prices, producers do not follow closely input prices as changes in the latter are expected to be short-lived due to the nominal stability established by the monetary policy.

Expectations also play role in some of the earlier-analysed channels, especially in the response of asset prices including the exchange rate. The way interest rate steps affect the entire yield curve is determined mainly by what market participants think of the future course and the effectiveness of monetary policy. The reaction of exchange rate as well as other asset prices is also crucially dominated by the assessment of monetary policy.

Unfortunately, we have limited knowledge about price- and wage-setting in Hungary and how it has changed over time. As for pricing behaviour, Tóth and Vincze (1998) and Tóth (2004) report the results of a survey in which Hungarian private companies were asked about their pricing practice in 1998 and 2001. In 1998 the typical frequency of price reviews was lower in Hungary than that was found in the UK by a similar survey reported in Hall et al. (1997). In an environment of higher inflation one would expect more frequent re-optimising of prices, yet, whereas a typical Hungarian firm reviewed it quarterly in the UK respondents chose monthly frequency. Another counterintuitive result was that in the 2001 Hungarian survey the pattern became more similar to the UK pricing practice despite the fact that the Hungarian inflation had been decreasing between 1998 and 2001 even if not very dramatically (from 14-15% to 10%). The relatively rare price-reviewing in Hungary can be justified by the costs of gathering information, as it is argued in Mankiw and Reis (2002). Anyway, firms' responses regarding the reasons for price-changing suggest that costs are more important than expectations.

We know even less about the Hungarian labour market. Pula (2005) gives a comprehensive description of the flexibility of Hungarian labour market. He claims that in Hungary the bargaining power of trade unions and employees are weak compared to other EU-members. On the other hand, JVV found that nominal wages are rigid. After a monetary policy shock, it takes at least one year until nominal wages are modified according to the new path of prices. Putting these two observations together, a plausible reason for wage stickiness is the backward-looking nature of wage-setting. An alternative explanation can be that the disinflationary monetary policy had not enough credibility, thus economic agents expected the past level of inflation to remain.

Some results related to other channels bear information about the expectations. One possible explanation of the findings of Rezessy (2005), namely that long term forward interest rates decrease after an unexpected rate hike is that market participants believed in the success of monetary policy. Interest rate policy served to some extent as a channel for signalling long term monetary policy preferences.

Karádi's (2005) exchange rate model incorporates public expectations about central bank exchange rate preference. His results show that communication was effective in coordinating market participants' exchange rate expectations and it helped exert influence on spot rate, too. These two examples highlight the importance of expectations of agents at financial markets.

Although this channel is the most difficult one from the econometrician's point of view and we do not have specific results, we have the overall impression that while financial market were supportive and expectations made policy more effective, expectations of price and wage-setters has not been anchored by the goals of monetary policy. Nevertheless, the latter fact is quite natural taking into account that the monetary policy in our sample period can be best characterised as shifting gradually from a more external-position-oriented regime towards a price-stability-oriented one and gaining credibility for the new objectives takes time.

1.4 Demand

In basic models of MTM, production is affected by monetary policy mainly through the demand channel, as it is explained in Ireland (2005). According to the new-keynesian view, changes in demand first influence output with prices adjusting only with some delay. The mechanism is the following: tighter (looser) monetary policy reduces (expands) demand for real goods to which firms first respond by temporarily decrease (increase) their output, as re-pricing is costly and thus can be made only later. Lower demand without price adjustment results in output level and marginal costs lower (higher) than natural. As time goes, firms cut (lift) their prices according to the altered environment. Lower (higher) prices stimulate (calm down) demand and production will return to its natural level. This mechanism can be labelled as the output gap, or demand channel.

As for Hungary, there is some empirical evidence of such new-keynesian pattern in the demand channel. Tóth and Vincze (1998) digest the results of a survey taken among Hungarian private companies in 1998. Tóth (2004) evaluates how the picture has changed relying on a 2001 survey. One of the questions in both surveys was the ordering of possible responses to a change in demand. Firms typically ranked steps like adjusting hours worked and employment or changing capacity before re-pricing. Their finding is in accordance with the result of a similar survey in the UK in 1995 (Hall et al. 1997).

In this section we review what we have learned about the behaviour of some key components of aggregate demand, namely, consumption, investment and net export. For this section JVV is our starting point. Using three different macromodels they show that significant effect of monetary policy can be detected first of all in the case of investments. In the following we survey the relevant literature and check how their findings fit existing evidence. At the end of the section we connect the demand components to the individual channels of the transmission.

Consumption

Investigating the transmission mechanism within an SVAR framework, Angeloni et al. (2003) found that while in the U.S. households' consumption dominates the response of output to monetary policy shocks, in the eurozone the contribution of investments is more important. Nevertheless, the sign of impulse responses are intuitive in both economies, namely, after an unexpected tightening both the consumption and investments drop.

In contrast with the eurozone and the U.S., JVV demonstrated that in Hungary there are no empirical evidence of lower consumption after monetary contraction, one model shows even rising consumption. This finding may appear to be counterintuitive especially when one takes into account the results of Kiss and Vadas (2005) who detected significant consumption effect of monetary policy through the housing market.

Nevertheless, there are some empirical studies as well as theoretical ones that suggest this type of consumption response is plausible. Theoretically, one important reason can be that the appreciation of the currency increases the wealth of households. Households then may spend their excess revenue stemming from higher purchasing power of their wealth to either tradable or non-tradable goods depending on the income elasticities of both. Benczúr (2003) shows in a two-sector dynamic growth model how a nominal appreciation can stimulate consumption.

Van Els et al. (2001) compare the main characteristics of MTM in eurozone members using country models. In four out of the twelve countries, consumption is above the baseline during a couple of years after a tightening monetary shock. In Belgium and Italy the authors attribute rising consumption to the net creditorship of households. In the case of Finland their explanation is in line with Benczúr (2003) claiming that the pure exchange rate channel dominates. In the German model prices fall faster than nominal wages raising real wages and thereby consumer spending.

JVV explain the reaction of consumption by the stickiness of nominal wages and relatively quick exchange rate pass-through. Their argument is that tradable prices respond to monetary policy quickly because they track exchange rate movements closely. Since the short-term reaction of non-tradable prices are virtually neutral, overall price level declines already during the first year. Contrary to prices, nominal wages remain unchanged for at least one year meaning that real wages rise. The income effect offsets other mechanisms, like asset price changes etc.

It is important to stress that the empirical evidence of this kind of consumption response is not strong enough. The identification of the effect of monetary policy is complicated by the fact that the appreciation of the forint after the widening of the intervention band coincided with several fiscal measures aimed at stimulating private consumption. Since the band widening in 2001 can be regarded as probably the biggest unexpected monetary tightening during the past ten years[6], statistical methods that do not control for fiscal policy may fail to separate the two effects. Nevertheless, the way JVV explained why consumption does not fall after monetary contraction is in line with Jakab and Vadas (2001) who found that wages are far the most important explanatory variable for consumption and they could not detect significant role for interest rates.

To sum up and putting these findings into Mishkin's framework we can conclude that there are no signs that after a monetary tightening private consumption fall in Hungary. The reason is the relatively quick exchange rate pass-through and the slower nominal wage adjustment. Our interpretation is that the exchange rate channel offsets interest rate, asset price and other channels concerning the behaviour of Hungarian households.

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[6] Actually, one of the identification schemes of Vonnák (2005) was based on that assumption and proved to be equivalent to a completely different approach.

Investments

JVV found that the reaction of investment spending is the most robust ingredient of the demand effect of unexpected monetary policy. Hence, to form an overall picture about the monetary transmission mechanism, it is crucial that we understand the mechanism through which firms' investment decisions are affected.

Kátay and Wolf (2004, KW henceforth) give us a deeper insight into the investment behaviour of Hungarian firms. They estimated an investment function using large number of observations of firm level balance sheet data obtained from the APEH database. The main advantage of their approach over aggregate time series techniques is the high degree of freedom from cross-section.

Most importantly, they found a significant and quick reaction of investments to changes in user cost, which reinforces the finding of JVV. Obviously, there are serious limitations of translating KW's result to macro level. The first problem comes from the cross section heterogeneity. The obtained impulse response is valid at aggregate level only as long as there is no considerable heterogeneity between firms with regard to their investment function, particularly the user cost elasticity.

The second challenge is the missing link between the instrument of monetary policy (in Hungary it is the two-week deposit rate) and the user cost. The specification they used relates investments to the user cost, which consists of expected return on equity, bank lending rates among others. Obviously, monetary policy has no direct control over all these factors. In order to assess the impact of monetary policy on investments, we need to know the relationship between policy rate and user cost, but, unfortunately, we have no empirical evidence.

The third difficulty to overcome is that they estimated only one dynamic equation in which investment spending are explained by the user cost, sales and cash flow. Even if we treat user cost as exogenous, which is also a questionable assumption in itself, cash flow and sales depend apparently on past investments, therefore, for the calculation of the dynamic effect of user cost additional relationships would be necessary.

Finally, monetary policy can affect firms' cash flow and sales through channels other than investments. The adequate exercise would be therefore to simulate the effect of policy instrument on user cost, cash flow and sales, calculate the response of investments to these variables, taking into account that lagged investment changes also influence cash flow and output. The simulated firm level behaviour needs then a proper aggregation technique.

Using the same database as KW, Reiff (2006) estimated on firm-level an investment model for the Hungarian corporate sector in which firms face three types of adjustment costs: the standard convex cost, a fixed cost and an irreversibility cost. Using the estimated model he was then able to analyze at both aggregate and firm-level how investments respond to a so-called profitability shock. In line with KW and JVV he finds that firms react immediately by reducing investment spending after profitability falls. His findings are informative also from the MTM point of view as there are substantial similarities between monetary policy and profitability shocks and he solves the aggregation problem as well.

Despite all the shortcomings mentioned above and the limited comparability of the three models, the high degree of similarity between impulse responses from micro- and macroestimates make us believe that those results reinforce each other and – similarly to the eurozone – investments are key ingredients of the demand effect of monetary policy. As we will show in the next subsection, the demand for investment goods may help keeping foreign trade balanced despite the strong exchange rate response.

Noteworthy to mention is that although the cost-of-capital channel is usually counted to the classical interest rate channel, the role of exchange rate in investment decisions may be important, as JVV emphasize. Since investment goods are typically tradables, their price move closely together with the exchange rate. The cost of capital includes the (expected) inflation of investment goods in a way that declining prices mean higher costs as postponing investment spending pays-off. Their conclusion is that although the existing evidence is insufficient to separate exchange-rate effect from direct interest rate effect, the response of investments is likely to be affected through both channels.

Net exports

The third main component of output investigated by JVV is net exports. The results from the three models they used were less conclusive than for private consumption and investments and the authors concluded that they could not detect any significant effect of monetary policy. Only one model predicted considerable deteriorating of trade balance after an unexpected monetary tightening, the other two suggested rather a balanced path but with substantial uncertainty.

Looking at exports and imports separately it becomes obvious that while the models indicate similar response of exports, it is the reaction of imports that is responsible for diverging results. All three models predict a sizable drop in exports after a monetary tightening. Export prices also decline quickly suggesting that the export sector reacts flexibly to changes in demand. The lack of price stickiness can be understood taking into account the strong competition at international goods markets.

There is, however, much less agreement among models on how import reacts to monetary policy. According to the quarterly projection model of the MNB, imports rise after a tightening. Contrary to that, the other two models used in the referred paper predict declining imports that can explain the rather balanced net export response they obtained.

There might be several plausible explanations for the insignificant net export response, and the ambiguous import response. According to Kim (2001), after an appreciation expenditure-switching results in less export and more import, due to the change in their relative price. The observed behaviour of Hungarian consumption itself would imply higher import demand, at least according to two models used in JVV. On the other hand, contractionary monetary policy may reduce imports through lowering domestic demand, that is through income-absorption. In Hungary the significant drop in investments and exports may easily offset the additional import effect of higher consumption, because of their high import content.

To conclude, foreign trade is probably affected by monetary policy in several ways. First of all, exchange rate changes cause quick response of exports both in volumes and prices. Secondly, changes in investments and consumption as well as exports influence imports. It seems that the import demand from investments and exports dominate imports, therefore income-absorption effect offsets expenditure-switching implying that no significant net export reaction can be detected by econometric methods.

How individual channels of transmission influence demand for real goods?

In this subsection we combine the findings on particular channels of transmission with those regarding demand. Of course, not all channels can be associated with all components of demand; for example, we have no idea how credit supply asymmetries could affect net exports. In other cases even if the relationship exists, the interpretation is not straightforward. This is especially true for the exchange rate channel with regard to consumption and investments. There are also cases that are not covered by our research project, sometimes it is not possible to identify through which channel a certain component of demand was affected. Nevertheless, using this scheme, we can rank the importance of particular mechanisms.

Taking into account the high sensitivity of private investments to monetary policy, the interest rate channel may play an important role in the transmission mechanism. Nevertheless, it is not possible to disentangle it from other channels. JVV explain how exchange rate appreciation can lead to the same reaction through the user cost of capital. Similarly, we cannot exclude that credit supply also contributes. On the other hand, asset price channel seems not to influence the investment behaviour.

In the case of consumption the exchange rate channel was identified as the main reason for the insignificant response. Through the income effect it can offset interest rate and credit channel. Asset prices are not found to be able to explain consumption behaviour.

The role of the exchange rate is trivial in the case of net exports. Although we could not detect significant effect of monetary policy on the trade balance, the quick reaction of export and import prices highlights the dominance of exchange rate channel in short run price development.

We can conclude that exchange rate channel dominates short run output and price effect of monetary policy. Due to the openness of the Hungarian economy, consumer prices react more quickly than in the U.S. or the euro area, while the change in output is smaller due to the lack of households' consumption response. Nevertheless, the significant reaction of investments suggests that interest rate channel may not be negligible in Hungary.

1.5 Nominal adjustment in the medium run

Changes in aggregate demand affect various sectors differently. In the medium run relative prices adjust mainly because labour market transmits monetary policy impulses between sectors. As for Hungary, we expect that tradable price changes spread over the entire economy, including non-tradable goods' prices. In this section we present what we know about the medium run effects of monetary policy. Since we have not conducted specific research in this topic, we rely on some other studies outside of the MTM project and present some fresh estimates.

The most important observation is that although exchange rate and tradable prices dominate the short-run effect of monetary policy, consumer prices remain at a lower level even when the exchange rate return to its initial value. Since tradable prices follow closely exchange rate movements, this indicates some price adjustment of non-tradable goods.

Indeed, SVAR estimates[7] show (see Figure 1.4) that non-tradable prices, approximated by the price index of market services respond slowly to monetary policy. The adjustment of goods prices not directly affected by exchange rate seems to prolong the immediate reaction of tradable prices.

One possible explanation of relative price adjustment is based on labour market. If wages equate between sectors, demand shocks to some sectors spill over to the rest of the economy. In our case the fall in exports and investments after a monetary contraction may exert downward pressure on employment and wages in the entire economy. Lower wages allow producers in sectors not directly affected by lower demand cut their prices. The relevance of labour market in medium run is demonstrated in Jakab and Kovács (2003) who found that several years after an exchange rate shock pass-through depends on labour market developments in Hungary.

In JVV wage responses to a monetary policy shock are shown. Nominal wages tend to react only one year later than the shock occurs, which is not an extremely sticky style of wage-setting, but taking into account the relatively quick exchange rate pass-through to consumer prices, results in significant changes in real wages.

Figure 5 presents impulse responses from an SVAR similar to the previous one used to estimate tradable and non-tradable price response.[8] As in JVV, nominal wages decline slower than consumer prices after a monetary contraction. Real wages, therefore, increase significantly for two years. On the other hand, employment drops quickly and begins to return to the baseline as early as in the second year. Probably it is the higher unemployment rate that promotes the nominal wages to adjust. According to the SVAR estimates, firms respond to higher wage costs first by cutting jobs. Lower employment then pushes wages down allowing firms to keep prices low even 3-4 years after the monetary shock.

1.6 Conclusion and forward-looking remarks

In this paper we reviewed the fresh results of nine studies made under the umbrella of the Hungarian MTM project. Relying on other studies as well, we created a synthesis from particular findings.

Our overall picture about how monetary policy works in Hungary can be summarized as follows: consumer prices are affected immediately in the first year after the monetary policy has increased its policy rate. The response is persistent; the price level remains lower for several years. On the other hand, output reacts only marginally. The reason for this on the demand side may be that while investment drops significantly after a monetary tightening, consumption seems to offset more or less the demand effect of decreasing investment spending.

The output and price dynamics differ significantly from that found for large, developed economies. Empirical estimates for US and eurozone monetary transmission mechanism suggest

[7] The estimation was based on Vonnák (2005). Similarly to the SVAR estimation strategy introduced in JVV, I augmented the 4-variable benchmark monthly VAR (industrial production, CPI, 3-month T-bill rate, exchange rate, sample 1995:m1-2004:m12) with industrial goods and market services sub-indices. For identification of monetary policy shocks I used sign restriction as in Vonnák (2005). The results are comparable to those of the referred paper.

[8] In this case a VAR model of quarterly GDP, CPI, short term interest rate, nominal exchange rate, employment and nominal wages in the private sector was estimated. The identification was the same as in the previous SVAR.

that in those economies output reacts first and significantly, and consumer prices are adjusted only with substantial lag.

We attribute the difference first of all to the central role exchange rate plays in the Hungarian monetary transmission mechanism mainly for two reasons. First, due to openness, exchange rate movements pass through to tradable goods' prices quickly. Second, the output response is mitigated by the fact that because of the short-run nominal wage rigidity and the quick exchange rate pass-through, the income effect offsets the interest rate effect on consumption resulting in a fairly insensitive reaction.

Being an EU-member country, Hungary is expected to adopt the common European currency as soon as it meets the Maastricht criteria. With the adoption of the euro, the most important channel of transmission will disappear. This raises the question, whether it is optimal for Hungary to join the eurozone running the risk that the economy will remain without effective monetary policy that could smooth shocks.

Orbán and Szalai (2005) point out that after euro adoption the scope of the interest rate channel will broaden for at least two reasons. First, common monetary policy shocks in the eurozone will influence Hungarian economy through foreign demand which is now an exogenous factor for monetary policy. Second, ECB's interest rate policy affects interest rate burden on euro-denominated loans directly. They conclude that the differences between Hungarian MTM and those of present eurozone-member countries will not be so important that asymmetric response to common monetary policy and real divergence in the eurozone could be expected.

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Figures

FIGURE 1.1 **CPI responses to an unexpected rate hike (NEM and 5GAP model simulations from JVV, SVAR estimates from Vonnák, 2005)**

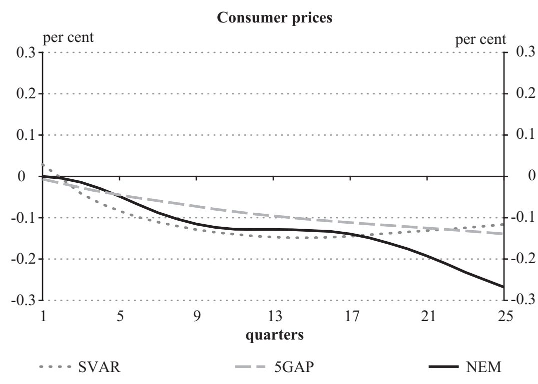


FIGURE 1.2 3-month money market, T-bill rates and the policy rate

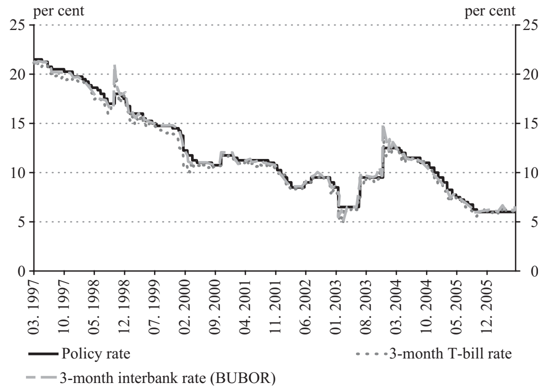


FIGURE 1.3 Households' wealth as a percentage of GDP

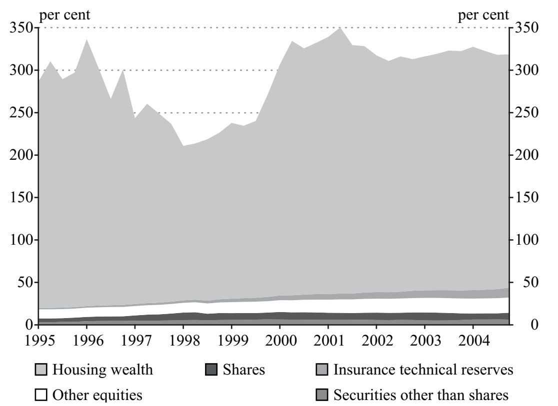
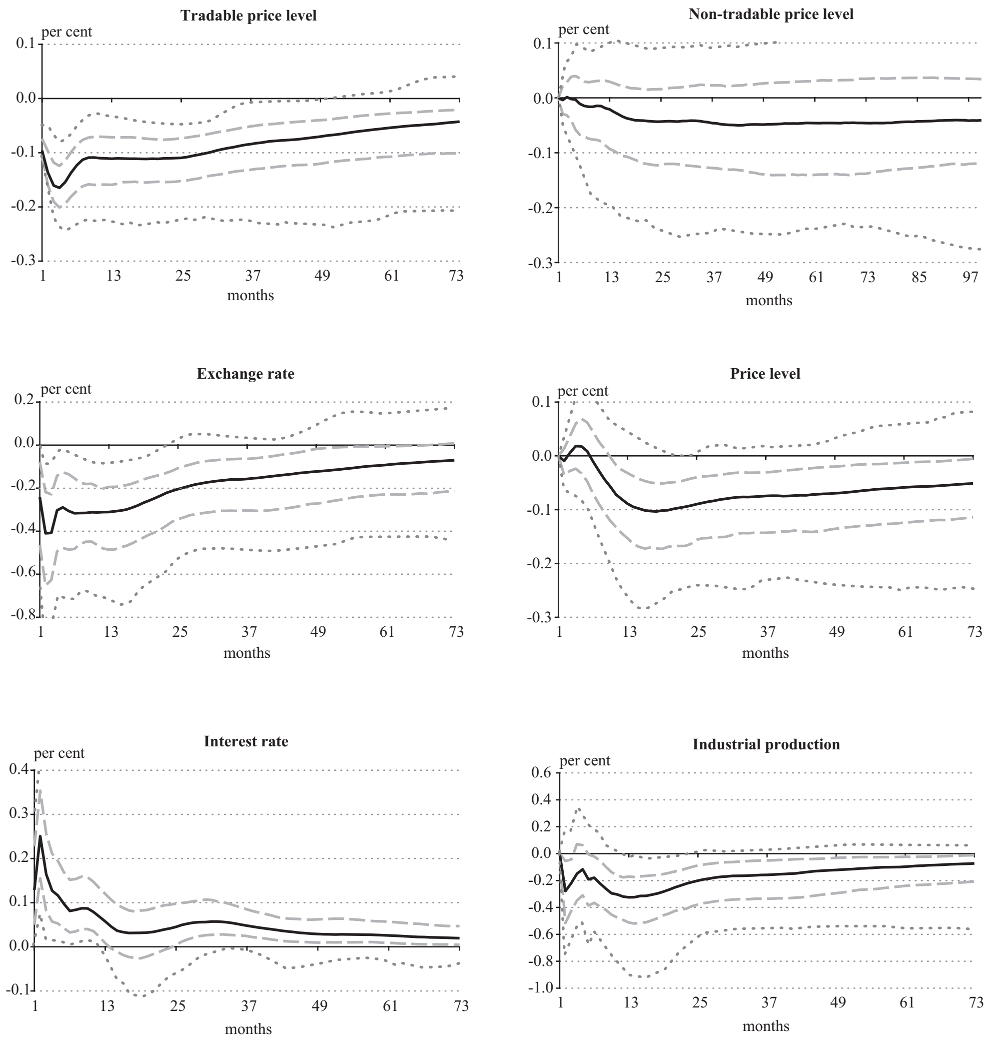
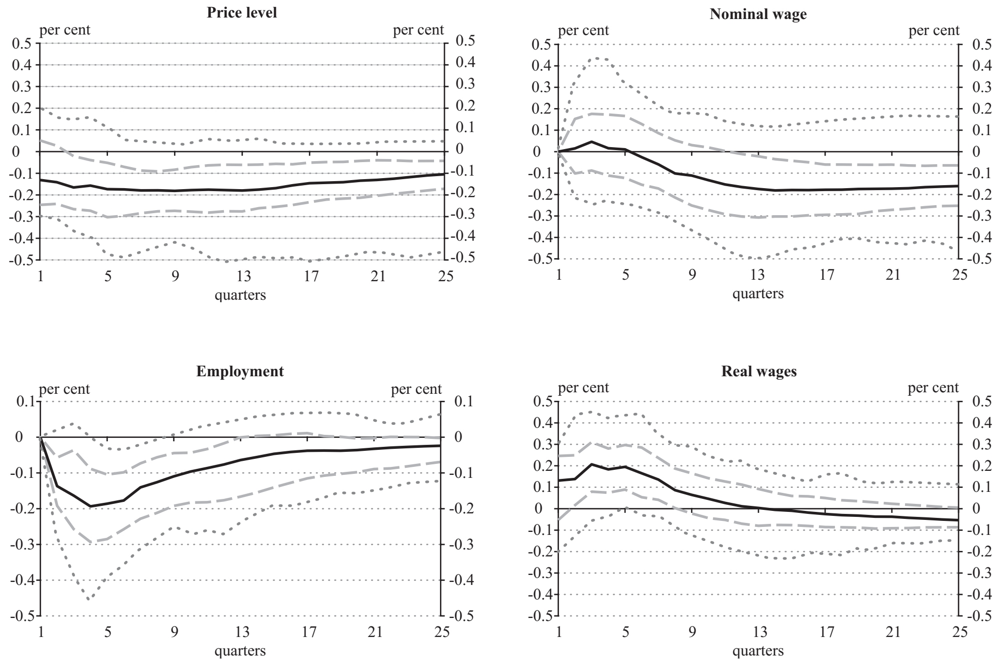


FIGURE 1.4 Response of tradable and non-tradable goods prices to an unexpected rate hike (SVAR estimates)



The median estimates and the middle 68 and 95 percent of the Bayesian posterior distributions.

FIGURE 1.5 Response of employment and private sector wages to an unexpected rate hike (SVAR estimates)



The median estimates and the middle 68 and 95 percent of the Bayesian posterior distributions.

2. Interest rate pass-through: the case of Hungary

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2.1 Introduction

The decisions of banks about the interest rates on their assets and liabilities have an impact on the consumption and investment behavior of deposit holders and borrowers and hence, on the real economy. Interest rates can influence the real economy through three main mechanisms of the interest rate channel. The reaction of companies and households depends on the magnitude of the *substitution effect*, i.e. the change in the relative costs of alternative credit and deposit possibilities. Changes in the interest rates alter the costs and incomes of economic agents and, consequently, their net income *(income effect)*. Finally, they affect the value of real and financial assets and, therefore, the wealth of companies and households *(wealth effect)*.

The way changes in central bank interest rates are passed through to changes in banks' rates determines the strength of these effects to a great extent. Thus, the effectiveness of monetary policy depends on the degree and speed of interest rate adjustment to changes in policy-controlled interest rates.

Both theoretically and empirically, the interest rate channel of monetary transmission has received great attention in the past. Most of these studies focus on the pass-through for the EMU countries. The results of these studies show that interest rate transmission differs both across countries and instruments. Cottarelli and Kourelis (1995) studying several European countries find evidence of complete pass-through for most countries. In their study, the long-term adjustment parameter on average is 0.97 and falls within the range of 0.75-1.25 in most of the cases. In Borio and Fritz (1994) this value is between 0.8 and 1.1. Burgstaller (2003) finds similar results for Austria and so does Bredin (2001) for Ireland. De Bondt (2002), who studies adjustments for the euro countries, concludes the long-term pass-through for bank lending rates is close to 100%.

Differences in the speed of adjustment proved to be much more considerable: duration of adjustment varies between 2 months and 3 years. Mojon (2000) measures the degree of pass-through in five European countries: Belgium, Germany, France, The Netherlands and Spain. He finds (1) sluggish responses of retail rates, (2) the response of short-term rates to be faster than that of long-term rates, and (3) a higher (short-term) pass-through when money rates increase compared to when they decrease. De Bondt (2002) also finds considerable stickiness in short-term adjustment of bank rates and also shows that there is convergence in the pass-through of the euro countries after the establishment of the Monetary Union.

Much fewer but dynamically increasing number of atricles address the interest rate pass-through in CEE countries. Two comprehensive studies are Crespo-Cuaresma et al. (2004) and Sander and Kleimeier (2004). Both studies find some differences across the investigated countries and Sander and Kleimeier (2004) emphasize that these can be explained by differences in the financial structure and

We are grateful for useful comments and suggestions of Zsolt Darvas, Zoltán M. Jakab, Márton Nagy, Katalin Mérő, Balázs Vonnák and participants of discussions organised by the MNB. All remaining errors are our own.

macro environment. An interesting general finding is that the markets for corporate loan rates, in which the competition is the strongest, react the most completely and the fastest in the CEE area and the pass-through appears to be faster and more complete than in most countries in the eurozone.

Világi and Vincze (1995) examine the pass-through in Hungary in the period 1991-1995 and Árvai (1998) in the period 1992-1998. While the earlier article finds sluggish adjustment of interest rates and emphasize that the adjustment is far from complete, even in the long run, the latter concludes that the reaction of commercial banks' interest rates had the tendency for somewhat better adjustment, especially after 1996. Comparing our results with those of Árvai (1998) and Világi and Vincze (1995) the interest rate transmission has improved since the mid 1990s due to the improvement of macroeconomic and financial environment.

Our paper contributes to the existing literature on interest rate pass-through in several ways. First, it examines the pass-through for a less investigated accession country and compares it with the results on the euro area. It is important to have an idea whether monetary policy may have different effect on the real economy across current and future member states due to different degree and speed of interest rate pass-through. Our results imply a rather quick and complete pass-through for corporate loan and deposit rates similarly to the euro-area. At the same time, the household business lines are characterized by incomplete and slower pass-through, however, they are very close to the results of De Bond (2002) for the euro area.

Second, in addition to analyzing the pass-through on aggregate data, we also rely on panel-data and employ different estimation techniques. The obvious advantage of panel data analysis is the higher efficiency in the estimation due to the increased degrees of freedom. This is especially crutial when long-run equilibrium relationships are to be estimated from rather short samples. A panel of commercial bank rates also makes it possible to investigate heterogeneous adjustment among banks in Hungary and analyse asymmetries in the adjustment better.

Third, it explores nonlinearities related to the size and sign of yield shocks; whether commertial bank rates are above or below of its equilibrium level; their distance from their equilibrium level; and volatility of market rate. These non-linearities are captured by Threshold AutoRegressive (TAR) models. Although asymmetric adjustment of interest rates has already been a center of research, to our knowledge, all existing literature focuses on nonlinearities of the adjustment to the long-run equilibrium. In this article we also analyse whether the (immediate) adjustment of bank rates is higher when the MMR increases and whether banks react at a larger extent to larger changes in the MMR. We find this latter asymmetry to be more common and we find that in Hungary size asymmetry appears to be the most important for the investigated periods.

Our panel results show that both for corporate loans and corporate deposits, above a treshold of about 60-80 bs, the speed of immediate reaction of bank rates to changes in the MMR almost triples. This asymmetry may have implications for the euro area where there were no or hardly any larger changes in the policy rate in the past couple of years but may consider such steps in the future.[1]

[1] The ECB has been changing its policy rate in relatively small steps, either by 25bs or by 50bs. In these cases, the non-linear reaction of the interest rates to the changes of the policy rate is likely to be negligible. However, it is not negligible for countries, like the new member states, where the magnitude of changes of the policy rate have sometimes exceeded a threshold level of 60bs.

At the same time, for the corporate loans we find that banks only start adjusting their interest rates towards the long-run equilibrium if its missalignment from its equilibrium value is above 28 bs. An interesting finding of this paper is that although we find some evidence for sign asymmetry it disappears when we estimate a model that incorporates both sign and size asymmetry. This might be due to the fact that increases in the MMR were the relatively large changes. Also, the somewhat surprising results for volatility asymmetry change when we control for size asymmetry. So, the spurious results may be found due to correlation in asymmetries. A sophisticated analysis requires the application of bank-level panel data.

We would like to highlight that our paper focuses on the first stage in the transmission mechanism hence, no direct conclusions can be drawn about the strength of the interest rate channel. We do not investigate the the interest rate sensitivity of consumption and investment expenditures.

The remaining of the paper is organized as follows. In Section 2 we introduce the basic pricing equation that relates bank rates to market rates. In Section 3 we highlight the main structural characteristics of the Hungarian banking system and compare them to those of the euro countries. Section 4 introduces the linear econometric model and presents the results, and Section 5 covers the TAR estimation applied to investigate the potential non-linearities in the adjustment process. Section 6 concludes the paper.

2.2 Model of interest rate pass-through

According to the classical theory, with perfect competition and complete information the price is equal to the marginal cost and the derivative of price with respect to the marginal cost is equal to one. However if these assumptions do not hold, then the margin can be positive and the derivative can deviate from one. For instance, the more the market structure moves away from perfect competition towards monopolistic competition, the more loan rates exceed the marginal cost of funds. Theories explaining why bank rates do not move one for one with the market rate are based on, for example, ideas of adverse selection, switching cost, consumer irrationality and risk sharing. Lowe and Rohling (1992) present an excellent summary of these theories. Moreover, in the presence of fixed adjustment costs, the commercial bank rates might adjust to their equilibrium level with some lags.

Imperfections of the pass-through raise two different, although not independent questions. The first refers to the degree of pass-through, namely the extent at which changes in the MMR are passed through to banking rates in the long run. The second aspect is the speed of the pass-through, namely how long the adjustment takes. A model that captures both dynamic adjustment behaviour and the long-run relationship is the Error-Correction Model (ECM):

$$\Delta i_t = \alpha + \beta_0 \, \Delta r_t \quad \gamma (i_{t-1} - \mu - \delta \, r_{t-1}) + \varepsilon_t \,, \tag{1}$$

where i_t denotes loan or deposit rates of a commercial bank at period t, and r_t is the MMR of month t. The main advantage of using the model in this form is that both the long-run and the short-run parameters can be obtained directly. In the expression for the long-term equilibrium relationship $(i_{t-1} - \mu - \delta r_{t-1})$, δ means adjustment in the long-run to the market rate; $\delta = 1$ refers to the spread between the MMR and bank rates in steady state. $\delta < 1$ refers to complete pass-through in the long-run, $1 < \delta$ suggests incomplete pass-through, while $1 < \delta$ means overshooting.[2] The speed of adjustment parameter is γ, which has sensible economic interpretation if it is positive. If $\beta_0 = \delta$ banks adjust right away to the long-run equilibrium rate; if $\beta_0 < \delta$ adjustment to the equilibrium rate will take place with some delay. The time required for the adjustment to the long-run equilibrium can be expressed, for example, by the duration of 80% adjustment, expressed in months. In this article we will estimate different versions of this model.

We focus on the pass-through from short-term MMRs and not from the policy rate[3] because MMRs are much closer related to the cost of funding of the banks. Moreover, the money market rate is a measure that captures all moneary policy actions not only changes of the policy rate. The main instrument of the monetary policy is the base interest rate. However, in our sample period the central bank also used other monetary policy tools: it changed the required reserve ratio and the interest rate paid on reserves[4]. These changes can be captured by the MMR but not by the base rate.

2.3 Determinants of interest rate pass-through in Hungary

The strength and speed of monetary interest rate transmission can be strongly connected with structural properties of financial systems.[5] Below we review the determinants of the interest rate transmission and review the characteristics of the Hungarian financial system from the point of view of the interest rate pass-through. It is especially important to study the structural factors influencing the interest rate pass-through, because most of these factors are such institutional characteristics, which can only change gradually (see, for example, Mojon, 2001) and will not disappear by the time Hungary enters the euro area, the Hungarian pass-through may converge slowly to the EMU country pass-through. Even in the EMU the pass-through is found to differ substantially across countries (see, for example, Mojon, 2001).

Disintermediation

The degree of disintermediation and the role of non-bank financing have an impact on the elasticity of both loan demand and deposit supply with respect to the money market rate. On the asset side, loan demand is expected to react more intensely to interest rate changes in an economy with developed capital and money markets, as companies may substitute bank loans with other forms of financing. Similarly, households' access to alternative investment opportunities of deposits affects the market rate elasticity of deposit supply.

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[2] Subtracting r_t from both sides of the long-run equilibrium expression we get $i_t - r_t = \mu - (1 - \delta)\, r_t$. Now, it is easy to see that the spread $(i_t - r_t)$ is constant in the case of complete pass-through (if $\delta < 1$), but in the case of incomplete adjustment (that is, if $\delta < 1$) the higher the MMR the lower the spread on the loan market. In the deposit market the opposite holds.

[3] MMR and policy rate are closely related, their correlation is very high, it is around 0.98.

[4] To see the importance of these changes one can make the effect of the changes in reserve requirement comparable with the changes in the base rate by computing the implicit tax on banks through reserve requirements. The official indicator of this implicit tax shows the minimum spread between commercial deposit and loan rates, which led to zero profit of the banks after complying with the minimum reserve requirement. The implicit tax has decreased by approximately 80 basis points in our sample period.

[5] See Cottarelli and Kourelis (1994), Ehrmann et al. (2001), and Mojon (2000).

In order to evaluate households' access to alternative investment opportunities, that is the interest rate sensitivity of the deposits, one should take a look at the financial portfolio of households. In 2002 bank deposits accounted for about 31% of households' total financial assets shows that this indicator has similar values in other European countries.

TABLE 2.1 **Households' bank deposits relative to their total financial assets, 2002**

Country	**Per cent**
Austria	52.1
Belgium	26.1
Finland	32.5
France	28.3
Germany	33.3
Netherlands	19.7
Norway	32.4
Portugal	44.1
Spain	36.5
Sweden	13.6
Hungary	31.0

Sources: Eurostat and Magyar Nemzeti Bank (MNB; central bank of Hungary).

Moreover, the share of bank deposits in the total financial assets declined over the past 5 years. The share of bank deposits fell by about 10 percentage points, while the share of many profitable non-bank investments grew. This reallocation was not in favor of direct investments on the capital market, but mostly in favor of life insurance related investments, which were subsidized by tax deduction opportunities.

From the asset-side point of view, the consequences of the strength of competition between domestic banks and other financial institutions are ambiguous. Capital markets play a marginal role in corporate financing[6]. On the other hand, about 30% of the loans to this sector come from abroad; mostly from banks, and 56% of all loans to the household and corporate sector from domestic and foreign banks are denominated in foreign currency (see Table 2.2). Consequently, corporations, especially large corporations, can relatively easily substitute their domestic bank loans with foreign currency denominated loans, of which the interest rate is not affected by domestic monetary policy.

To sum up, while the dominance of bank financing indicates a high interest rate elasticity of the corporate loan demand, the availability of foreign currency loans might have opposite effect.

[6] In Hungary, the ratio of stock market capitalization to GDP is less than 30% of the EMU country average. However, the financial systems of these countries are also dominated by banks. In Hungary, the corporate bond market is especially underdeveloped and we do not expect substantial progress in the near future. In addition, financial intermediation is continuously deepening.

TABLE 2.2 Distribution of corporate and household loans and deposits by currency denomination (2003)

	Non-financial corporations		Households	
	Loans	**Deposits**	**Loans**	**Deposits**
Domestic banks, HUF	44	54	97	87
Domestic banks, foreign currency	29	12	3	13
Foreign banks, foreign currency	27	34	-	-
Total	100	100	100	100

Source: MNB.

Competition among domestic banks

Intensity of competition among domestic banks also influences the interest rate elasticity of loan demand and deposit supply. A low degree of competition, both among domestic banks and with other financial markets, implies a higher spread and has an influence on banks' pricing behavior.

Both the Herfindahl index and the market share of the top 5 banks show that in international comparison concentration and competition in the Hungarian bank sector are of medium level. The value of the Herfindahl index is about 1000 (see Table 2.3), so the market can be viewed as being almost competitive. However, this aggregate indicator hides the differences across the sub-markets, namely, between the corporate and household business line. The low value of the Herfindahl index (700-800 in previous years) in the corporate business line indicates sharp competition and elastic corporate loan and deposit rates. At the same time, competition is rather limited in the household sector. The Herfindahl index for this sector is much higher, above 2000.[7] However, concentration indices do not necessarily show the strength of competition, because other factors, such as entry rules and regulations, affect the competition as well. (Móré and Nagy, 2003 and Mojon, 2000). Várhegyi (2003) supports our view on the low degree of competition in the retail sector. Based on the difference of the concentration between the household and corporate sector, we expect to have more complete and faster, and perhaps more symmetric pass-through in corporate rates than in household rates.

Capitalization and liquidity position of banks

Well-capitalized and liquid banks are less forced to adjust to changes in monetary policy and have the possibility of swallowing negative shocks, at least temporarily. For example, a better liquidity position and capitalization provide a better opportunity for banks to smooth their interest rates.

The Hungarian banking sector has structural excess liquidity, which is unequally distributed among banks. This excess liquidity ensures more freedom to banks in their pricing policy. Obviously, competition for deposits influences this pricing decision as well. Excess liquidity has

[7] The largest Hungarian bank (OTP Bank) dominates the household market, and deposits of households are also concentrated at this bank.

TABLE 2.3 Concentration of the banking sector in the EMU countries (2002)

	Share of top 5 banks in terms of total assets (%)	Herfindahl index
Austria	46	548
Belgium	82	
Denmark	68	
Finland	79	2000
France	45	
Greece	67	1125
Netherlands	83	1700
Ireland	46	486
Germany	20	150
Italy	31	
Portugal	60	1000
Spain	53	870
Average in the EMU region	*39*	*640*
Hungary	**55**	**950**

Sources: MNB (2004), ECB (2002).

been declining in recent years, which is advantageous for the planned shift from passive-side regulation to active-side regulation. The anticipated further shrinking of liquidity and the shift to active-side regulation will presumably improve the efficiency of the pass-through.

Monetary policy and interest rate volatility

Changing interest rates on bank instruments incur adjustment costs to banks. Due to these so-called menu costs, the adjustment of bank rates depends on banks' assessment of whether a change in the policy rate is temporary or permanent. If a change is considered to be temporary, and to be (partially or fully) reversed soon, a bank might decide to smooth interest rates. Hence, the pricing behavior of commercial banks is influenced by their perception of the nature of changes in interest rates. Accordingly, higher volatility in interest rates is likely to lessen the degree/speed of adjustment, as each shift in the market rate is probably regarded as temporary. Mojon (2000) as well as Cottarelli and Kourelis (1995) find evidence in their multiple country empirical study for interest rate volatility influencing the pass-through.

The market rate in Hungary as well as the central bank base rate changed by relatively large steps in the recent years. This fact motivates the banks to adjust their rates more quickly than in other countries enjoying a more stable financial environment. Due to menu costs and banks' intention to smooth interest rates for their customers, higher changes in the market rates enforce faster reaction compared to smaller ones (25-50 basis points), which can be absorbed more easily by the interest rate margin. On the other hand, the variability in the sign of the changes in the market rate might decrease the speed of pass-through, since it is rational for banks to disregard temporary changes in the market rate in the presence of menu costs.

Hungary's future entry into EMU causes a downward trend of the domestic interest rate because of the interest rate convergence. This trend is not very stable, since the exact time of the entry is uncertain. So, deviations from the trend are possible as is exemplified by the rate hikes at the end of 2003. The expected downward trend could result in upward rigidity of bank rates, but other factors might counterbalance this effect.

Credit risk

Adverse selection might be more relevant in the Hungarian banking sector than in countries with a more advanced financial system because in Hungary potential borrowers usually have rather short credit history or no credit history at all. Credit history can help banks to make inferences about the risk of customers, but the not yet very deep financial intermediation and the lack of a positive inter-bank credit register system for the household sector further limits the available information about credit risk.

Term structure of loans and deposits

We study the pass-through by analyzing the interest rate movements of new loans/deposits, although from the point of view of the transmission mechanism it is not only these loans but the entire set of loans that matters. The speed of interest rate transmission is influenced not only by the adjustment of new loan/deposit rates, but also by the term structure of existing loans/deposits. The higher the weight of short-term instruments and instruments with variable interest rate in the portfolio, the faster the pass-through is. In comparison to the European average, loans and deposits have shorter average terms in Hungary (more than 90% of corporate loans and deposits and household deposits have shorter than one year repricing period). This is typical of countries with higher inflation and higher interest rate volatility. With the anticipated decline in inflation and the strengthening of economic stability, the duration of loans is expected to become longer, indicating a possible slowdown in the interest rate pass-through in the future.

Expected tendencies for the future

We believe that some tendencies could change the pass-through in the future. The relatively weak competition in the household sector is expected to improve, likely resulting in a faster and more complete pass-through. Some of the banks, for example, started to fight for household deposits, considered as advantageous core funding, of which about 40% is still owned by one bank. Adjustment in the deposit rate might be improved by the anticipated further shrinking of excess liquidity in the financial system coupled with the shift to active-side regulation from the present passive-side regulation. As excess liquidity disappears, competition for deposits is expected to sharpen. Progress with the adjustment of household loan rates depends mainly on the future trends in the markets of consumption loans and housing mortgages. The extraordinary high spreads of consumer credit rates might motivate banks to enter this segment and step up competition, leading to lower spreads and improved pass-through. Up to recent times, most of the mortgage loans were government-aided with fixed rates, so policy rate changes could and can hardly have any effect on these rates. The regulation of government-subsidized loans changed in December 2003. Since then, the maximum rate of newly granted subsidized loans has depended on the market rate with same maturity. Obviously, this change in the regulation improves the pass-through. And a final hypothesis is that as the average maturity of loans extends in accordance with declining inflation and interest rate uncertainty, the average loan rate is expected to become less dependent on the policy rate.

2.4 Empirical analysis

Data

For the investigation of pass-through we use interest rate data of 23 individual banks and aggregate data as well. The motivation for investigating pass-through on aggregated data in addition to panel data is threefold. First, the sample period is longer; second, for the household instruments we have reliable data only on the aggregate level; finally, we exclude some of the banks from the panel analysis due to serious data failure or because they had an insignificant market share or focused mainly on non-market-based loans[8]. Aggregate data comprises information about the interest rates of all banks. Finally, our panel results utilize data of each bank equally (we have unweighted estimates). Aggregate data uses weighted data for each bank. So, for the corporate business line we can contrast the results obtained from aggregate and panel analysis for robustness checks, while on the household business line we can only rely on results from aggregate data.

At the aggregate level data are available on short-term corporate loan and deposit rates, short-term household deposit rates and consumer credit rates.[9] We exclude household mortgage rates from our analysis because the majority of mortgage loans were government-aided[10] and were not subject to market-based pricing. Household mortgage loans are not the only government-subsidized loans supplied by banks, since the corporate sector was subsidized with government guarantee on loans as well. Unfortunately, we have no detailed data on these loans and, consequently, we cannot isolate and eliminate them. In the case of consumer credit, we use the average credit cost indicator instead of contract rates, since this indicator captures non-interest costs as well. These additional costs are significant: the average credit cost indicator exceeds the contract rate by about 5%-6%. The aggregate data on short-term corporate loan rates and on household and corporate deposit rates are from the period January 1997-April 2004, whereas data on consumer credit rates are available for a shorter period, namely May 2001-April 2004. The selection of the sample peri-

[8] Our panel data includes only 23 banks of the 41 banks that exist at the end of 2003. The main reason for having only 23 banks in the sample is that many of the banks did not report their loan and deposit rates at all. Only two banks among the excluded ones supplied data for some period, but the number of consequtive observations are less than 12 in both cases. Additionaly, we do not consider the banks that focused mainly on non-market-based loans. The market share of these 23 banks exceeds 80% in terms of the total assets over the entire sample period. Consequently, even if the sample is not representative, the measured interest rate adjustment characterises the adjustment in the entire banking system well.

[9] Data are available at http://www.mnb.hu.

[10] Government-subsidized mortgage loans have a significant share in household loans: from 2002 about half of long-term household loans were government-aided mortgage loans. Their share increased over the period, reaching its highest value by the 2003.

od is motivated by data availability and by the fact that changes in the banking system and in the monetary regime make data of previous years uninformative.

Our panel data include short-term corporate deposit rates of 23 banks and short-term corporate loan rates of 21 banks for the sample period, January 2001-January 2004.

Method of estimation

In order to better capture the dynamics of commercial rates we extend the model of equation (1) with further short-term dynamics.

$$\Delta i_t = \alpha + \sum_{k=0}^{K} \beta_k \Delta r_{t-k} + \sum_{h=1}^{H} \xi_h \Delta i_{t-h} - \gamma (i_{t-1} - \mu - \delta r_{t-1}) + \varepsilon_t \qquad (2)$$

We estimate equation (2) using the two-step approach of Engle and Granger (1987), i.e. first we estimate the expression for the long-run equilibrium ($i_t = \mu + \delta r_t$) and then we substitute the error correction term into equation (2) based on aggregate and panel data.

Estimation techniques applied for the ECM based on aggregate data

In the aggregate level analysis, the long-term coefficients are estimated using the ARDL approach developed by Pesaran and Shin (1997), while the standard errors are calculated using Bewley's regression (Bewley, 1979).

Estimation techniques applied for the panel ECM

In order to find the proper panel ECM specifications, we test the assumption of equal slope and intercept parameters over the cross-sectional units (banks).[11] The F-tests suggest the use of bank-specific constants (banks work with different interest rate spreads) and same slopes for the long-run equilibrium equation, both for corporate loans and for deposits. When estimating the second stage, in the case of the short-term dynamics, we can accept the null of common slope and common intercept and the estimated common constant turned out not to differ significantly from zero.

In light of the above results, we use three estimation methods.

1. First, we estimated the long-run equation with fixed effect, and the ECM with a common effect model (see as FE-OLS).

2. Second, we estimated both the long-run equation and the ECM with the same method under the fixed effect specification, substituting ($i_{n,t-1} - \mu_n - \delta_n r_{t-1}$) into the ECM (see as FE-FE).

[11] We also estimate the ECM separately for each bank (we do not show these results here). This is important, on the one hand, to gain some insight into the adjustment behavior of each bank separately, keeping in mind the fact that the estimates – especially the long-run equilibrium parameter – are based on a quite limited number of observations. On the other hand, it provides ideas on cross-sectional heterogeneity and on the final choice of the panel model. We find high and reasonably fast pass-through among the 23 banks and very similar parameters. So, average pass-through parameters can be interpreted properly in models with common slope coefficients.

3. The second method might be biased due to the lagged dependent variable in the ECM, but by increasing the sample in the time dimension the magnitude of bias diminishes. Although our panel seems to be sufficiently long to neglect the bias, we also estimated the ECM equation with GMM (Generalized Methods of Moments) using the approach of Arellano and Bond (1991) (we refer to this as FE-GMM).

For January and February 2003 we introduce two time dummies, because in the period January 17-February 25 the interest rate corridor was wider. However, these dummies turn out not to be significant, so we exclude them from the final model

As it is not entirely clear which is the instrument that should be considered as the effective MMR, we perform the analyses using different measures (1 and 3-month BUBOR and the 1, 6, and 12-month treasury bills). The results differ somewhat, but the overall message is the same, so we only present the results obtained with the 3-month BUBOR in the article.

Based on separate Augmented Dickey-Fuller tests for each variables, and the panel unit root tests of Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003) we find that all time series for corporate and household deposit and loan interest rates follow an I(1) process and so do the considered MMRs. Johansen cointegration tests between each interest rate series and the MMRs indicate one cointegrating vectors at least at the 10% level. According to the residual-based cointegration test in panel data of Kao (1999) we have to reject the null hypothesis of no cointegration already at the 1% level for both the corporate loan and deposit markets. Model (2) is capable of capturing such a cointegrating relationship. During model selection we proceed from the more general model (2), fixing the maximum lags at 3, and through excluding the insignificant variables we arrive at the final model.

ECM results

Results from aggregate-level analysis

As Table 2.4 shows, the results are consistent with the conclusions derived from the stylized facts but, in addition to providing general insights into the adjustment behavior, now we can measure and interpret long-run and short-run adjustment separately. The results suggest a clear difference in the adjustment of corporate and household interest rates. Corporate loans and deposits have somewhat higher long-run pass-through, but the short-run adjustment parameters differ markedly, implying that the mean adjustment lag is significantly lower than in the household segment. The corporate loan market is the only market with a long-run pass-through parameter close to unity, that is, complete adjustment. In all other markets the long-run parameter is lower than one, which suggests incomplete pass-through[12]; although in the case of consumer loans the null of complete adjustment cannot be rejected because of the very high stan-

[12] While for corporate and household deposits we reject the null of complete pass-through, the null of complete adjustment cannot be rejected for consumer loans. However, for the consumer loans we do not find this statistical test informative, because of the high standard errors, probably arising from the very short sample. The point estimate of δ is lower for consumer credit than for any other instruments; its 95% confidence interval is about eight times wider than that of corporate or household deposits.

dard errors probably arising from the very short sample. In the corporate loan and deposit markets the pass-through is reasonably quick; the greatest part of the adjustment takes place within two months. This fast and quite high degree of adjustment is probably due to high competition in the corporate segment. The incomplete and slow adjustment of consumer credit and the very high spread can be explained partly by the low interest rate elasticity of demand and due to the high risk of providing consumer credit.

These results are in line with those of Crespo-Cuaresma et al. (2004), despite the different estimation method used and the different time-span of the data, who find complete pass-through for the short-term corporate loan rate and incomplete pass-through for the household deposit rates in Hungary.

TABLE 2.4 **Results for the ECM estimated on aggregated data (January 1997-April 2004)**

	Corporate loans	Corporate deposits	Consumer loans[a)]	Household deposits
	Long term equation			
Constant *(μ)*	1.26***	-0.56*	20.03***	-0.76***
δ	0.98***[b)]	0.87***	0.81***	0.86***
Complete pass-through? (δ=1?)	Yes	No	Yes	No
Adjusted R^2	0.95	0.95	0.1	0.96
	Short term dynamics (ECM)			
Contemporaneous adjustment β_0	0.67***	0.64***	0.05	0.41***
γ	0.56***	0.32***	0.54***	0.34***
80% adjustment (months)	2	2	4	3
Adjusted R^2	0.88	0.72	0.44	0.64
Number of observations	88	88	36	88

** significant at 10%, ** at 5%, *** at 1%.*

a) For consumer loan interest rates, data are available from May 2001.

b) The long-term coefficients are estimated using the ARDL approach developed by Pesaran and Shin (1997), while the standard errors are calculated using the so-called Bewley's regression (Bewley, 1979).

Results of the panel data analysis

The panel results are similar to those on aggregate data and the results are alike in the case of all the three estimation techniques.

Table 2.5 clearly shows that short-term corporate loan rates appear to fully and quickly adjust to the MMR. Most of the adjustment to the long-run equilibrium (80 per cent) takes place within two months. The long-run adjustment parameter is close to one and we cannot reject the null-hypothesis of complete long-run adjustment at the 5% level. According to the panel results, the point estimate of the long-run pass-through of MMR changes to corporate deposit rates is very similar to that obtained from the aggregate analysis, however in this case we cannot reject the null hypothesis of complete pass-through. The immediate adjustment parameter is similar to that of corporate loan rates, and the speed of adjustment parameter is slightly lower.

Table 2.5 Results for the panel regression for corporate loans and corporate deposits

	Corporate loans			Corporate deposits		
	FE-OLS	**FE-FE**	**FE-GMM**	**FE-OLS**	**FE-FE**	**FE-GMM**
	Long-run equation					
δ	0.95 [a)]	0.95	0.95	0.87	0.87	0.87
Complete pass-through? (δ=1?)	Yes***	Yes***	Yes***	Yes***	Yes***	Yes***
$\bar{R}^2$	0.85	0.85	0.85	0.71	0.71	0.71
	ECM					
β_0	0.67***	0.67***	0.69***	0.66***	0.54***	0.70***
	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)
β_1	0.10***	0.09***	-	0.22***	0.22***	-
	(0.04)	(0.04)		(0.03)	(0.03)	
γ	0.61***	0.61***	0.57***	0.29***	0.28***	0.30***
	(0.03)	(0.03)	(0.08)	(0.03)	(0.03)	(0.12)
80% adjustment (months)	2	2	2	2	2	2
N	748	748	748	820	820	820
$\bar{R}^2$	0.47	0.45	0.41	0.53	0.52	0.48

a) To investigate the whether there is complete pass-through on a market we apply the following procedure. We estimate the long-run relationship assuming complete pass-though and test the stationarity of the residuals using panel unit root tests. Rejection of the null hypothesis of unit root implies complete pass-through.
Monthly data, January 2001-January 2004.

Diagnostic checks

We consider modeling the interest rate pass-through in a vector error correction form however weak exogeneity tests support the use of single-equation ECMs for the aggregate as well as for the panel data. In May 2001 the Hungarian monetary regime switched to inflation targeting (IT). In order to check whether the introduction of the new regime resulted in significantly different pass-through we estimate the pass-through on two separate samples of aggregate data and compared the results. Whereas in case of the shorter panel data no reliable estimation is possible for the pre-inflation targeting period, consequently, we compare the estimates on the full sample with the estimates on the subsample characterized by the IT regime. We find no significant difference in the pass-through of the two regimes on none of the data sets. Therefore, in this article we show the estimation results that utilize all available data. We test for serial correlation in the residual series by investigating the correlogram of the residuals and by using the Breusch-Godfrey LM test with different lags. We find that the residual series are white noise processes in all cases for both the aggregate series and panel series.

2.5 Analysis of non-linear adjustment

There are a number of theoretical reasons for the non-linear adjustment of bank rates. If conditions of perfect competition are violated, the pricing behavior of banks might depend on properties such as the size and/or the direction of money market rate shocks, and the volatility of the MMR. Below, we examine these three non-linearities.

Non-linear models

The general form of the non-linear model is the following:

$$\Delta i_t = \alpha + \beta_0 \Delta r_t + \beta_0^* \Delta r_t I_t - \gamma (i_{t-1} - \delta r_{t-1} - \mu) - \gamma^* (i_{t-1} - \delta r_{t-1} - \mu) G_t + \varepsilon_t, \tag{3}$$

where

$$I_t = \begin{cases} 1, & if \quad y_t > c_2 \\ 0, & if \quad y_t \le c_2 \end{cases}, \text{ and } G_t = \begin{cases} 1, & if \quad x_t > c_1 \\ 0, & if \quad x_t \le c_1 \end{cases}. \tag{4}$$

In this specification the immediate adjustment in one regime $(i_t = 0)$ is characterized by β_0. However, in the other regime $(i_t = 1)$ the corresponding parameter is $\beta_0 + \beta_0^*$. The speed of adjustment parameters to the long-run equilibrium in the two distinct regimes can be interpreted accordingly (γ in regime $G_t = 0$ and $\gamma + \gamma^*$ if $G_t = 1$). We opted for this specification because the possible difference between the regimes can be simply captured by the β_0^* and γ^* parameters.

The indicator variables (x, y) can be specified the following ways to capture the three types of asymmetries:

1. Size asymmetry: $y_t = |\Delta r_t|$ and $x_t = |i_{t-1} - \delta r_{t-1} - \mu|$ (5)
2. Sign asymmetry: $y_t = \Delta r_t$ and $x_t = -(i_{t-1} - \delta r_{t-1} - \mu)$ and $c_1 = c_2 = 0$ (6)
3. Volatility asymmetry: $y_t = x_t = stdev(r)$, and $c_1 = c_2 = c$. (7)

First, we investigate adjustment of bank rates differ depending on the *size* of MMR change and/or deviation from the long-term equilibrium. Due to presence of menu costs and the intention of banks to smooth interest rates for their customers, banks may react more intensely to larger changes in the money market rate. In this case the adjustment might be significantly faster above a certain threshold. This effect was investigated, for example, by Sander and Kleimeier (2003).

We also investigate whether the adjustment process depends on the *sign* of the MMR change and/or the *sign* of the deviation from the long-term equilibrium. Asymmetric adjustment might be entailed by the low interest rate elasticity of loan demand and deposit supply, due to the profit maximizing behavior of banks under market imperfections and adjustment costs. A usual finding in the literature (e.g. Hannan and Berger 1991, Sander and Kleimeier 2002) is that loan rates are more rigid downward, while deposit rates tend to be sticky upward.

Third, we analyze the effect of yield *volatility* on the pass-through. Higher volatility, and hence higher interest rate uncertainty, might attenuate the adjustment, as banks judge the changes in the money market rate as transitory. This effect was demonstrated by Mojon (2000) in an analysis of European countries. However, in our view, higher volatility is often accompanied by larger changes in yields, which hastens the adjustment process. The final outcome, emerging from these two opposite effects, is highly uncertain.

Estimation of the non-linear models

We apply TAR models[13], in which the adjustment parameters differ depending on the position of the indicator variable. These threshold effects were investigated, for example, by Sander and Kleimeier (2003), where the authors constructed two regimes with different gamma parameters. We introduce two regimes not only for the speed of adjustment, but also for the contemporaneous adjustment parameters.

When analyzing size and volatility asymmetry, the threshold values are estimated by the so-called sequential conditional least squares. This means that we estimate a simple OLS under different thresholds, and then the model with the smallest standard error is chosen (see Franses and van Dijk, 2000, p. 84, for further details). The set of possible threshold values were established taking care that each regime contains at least 15 per cent of the total observations. We estimate the model on both aggregated and panel data and use the FE-OLS specification for panel data analysis.

Volatility is measured by the 2-month standard deviation of the 3-month benchmark yield. We do not present the results for consumer loans due to the very limited number of available observations.

Results of TAR estimations

Size asymmetry

Both aggregated and panel data estimations confirm that the pricing of corporate loan and deposit rates is non-linear, but depends on the size of MMR change and the size of deviation from the long term equilibrium (see Table 2.6). In the case of corporate loan rates, both the speed of adjustment and the contemporaneous adjustment parameters are significantly higher above a certain threshold, according to both the aggregate data and the panel data. According to the panel results, a change in the MMR which is higher than 59 basis points entails three times larger contemporaneous adjustment than in the case of lower MMR changes. At the same time, banks only start adjusting their corporate loan rates towards the long-run equilibrium if its missalignment from its equilibrium value is above 28 bs. In the case of corporate deposit rates, the panel results suggest non-linearity only for the contemporaneous adjustment parameter, while aggregated results show asymmetry for both relationships. Aggregate data show non-linearity in the contemporaneous parameter for household deposit rates, but no non-linearity for the speed of adjustment towards the long-term equilibrium. For the contemporaneous adjustment parameters, the thresholds for which standard error of regression is minimized turn out to be rather high values, around 60-80 basis points.

We get different ideas about the importance of size asymmetry depending on whether we rely on the aggregate or on the panel results. This might be due to either the different sample period or the sample selection relating the cross sections in the panel data. So, to make the results more

[13] We also estimated Smooth Transition AutoRegressive (STAR) models, which provided us with rather odd results, so we choose to present here those obtained from TAR models.

comparable, we also run the aggregate analysis for the period between January 2001 and Jan 2004. In addition, to get a better understanding whether this discrepancy may be due to the significantly lower number of degrees of freedom when working with aggregate data, we aggregate the interest rates of the 23 banks that we use in the panel analysis[14] and also run the regression with this variable. Our results are very similar to that on aggregate data presented in Table 2.6. This suggests that the difference between the estimates on panel and aggregate data presented in Table 2.6 is not due to the difference between the scope of banks or to the difference in the sample period, but probably because of the higher efficiency of the panel estimates. This implies the need for using panel data for a more appropriate measure of size asymmetry.

TABLE 2.6 Size asymmetry – TAR results

	Panel data (Jan. 2001-Jan. 2004)		Aggregate data (Jan. 1997-Apr. 2004)		
	Corporate loans	**Corporate deposits**	**Corporate loans**	**Corporate deposits**	**Household deposits**
β_0	0.28**	0.20**	0.56***	0.22**	0.14**
β_0^*	0.46***	0.56***	0.14**	0.46***	0.35***
c_1 (percentage point)	0.59	0.67	0.82	0.70	0.82
γ	0.16	0.30***	0.46**	0.25***	0.45***
γ*	0.80***	-	0.25**	0.30***	-
c_2 (percentage point)	0.28	-	0.52	0.24	-
N	748	820	89	89	89

Sign asymmetry

Our results on asymmetric sign responses (presented in Table 2.7) are partly in line with other empirical studies which report downward stickiness in the loan market (see, for example, Mojon, 2000 and Sander and Kleimeier, 2002). Panel and aggregate results turn out to be similar for corporate deposits rates; both fail to detect evidence of sign asymmetry. Corporate loan rates prove to be sticky downwards, i.e. the immediate adjustment is significantly higher (at 5%) when the MMR increases than when it decreases. Panel results suggest slower adjustment to underpricing than to overpricing (hence, downwards stickiness), while the opposite is found in the aggregate analysis.

One might expect downward stickiness in loan rates and upward rigidity in deposits rates due to the profit maximizing behavior of banks in case of weak competition, if loan demand and deposit supply are inelastic with respect to possible smoothing of changes in MMR. However, taking into account the strong competition in the corporate segment and the fact that our linear model shows quick and complete pass-through for the corporate loan rates, our results might be regarded as somewhat surprising. In addition, the expected downward trend of domestic interest rates due to Hungary's future entry into the EMU (discussed in Section 2) possibly refers to

[14] When aggregating we weight the interest rate data of banks with their relative deposit/loan share.

upward rigidity. Another remarkable result is that household deposit rates react more intensely to MMR increases than to decreases. These unpredicted results might be partly attributed to the fact that the average size of MMR rate increases is higher than that of MMR falls and size effect may dominate sign effect in our analysis.

Table 2.7 Sign asymmetry – TAR results

	Panel data (Jan. 2001-Jan. 2004)		Aggregate data (Jan. 1997-Apr. 2004)		
	Corporate loans	**Corporate deposits**	**Corporate loans**	**Corporate deposits**	**Household deposits**
β_0	0.59***	0.62***	0.53***	0.61***	0.26***
β_0^*	0.19**	0.16	0.24***	0.04	0.28***
γ	0.54***	0.44***	0.71***	0.27*	0.38***
γ^*	0.16*	-0.12	-0.34*	0.09	-0.09
N	748	820	89	89	89

Volatility asymmetry

Although our results vary somewhat over the different types of instrument, at least one of the adjustment parameters turns out to be significantly higher above a certain level of yield volatility for all types of bank rates (see Table 2.8). This indicates that the effect of higher interest rate changes on the pass-through exceeded the adverse effect of higher interest rate uncertainty. It is important to emphasize that we cannot distinguish between the effect of higher uncertainty on expectations and the effect of larger changes in yields, which is a consequence of higher interest rate volatility. This makes the interpretation of our results difficult. The year 2003 serves as a good illustration. In this period, money markets could be characterized by high uncertainty about the convergence process, which was reflected in the increased risk premiums and volatility of yields. Higher volatility was accompanied by wider movements in yields. Monetary policy reacted by unusually large policy rate changes to the risk premium shocks.

Table 2.8 Volatility asymmetry – TAR results

	Panel data (Jan. 2001-Jan. 2004)		Aggregate data (Jan. 1997-Apr. 2004)		
	Corporate loans	**Corporate deposits**	**Corporate loans**	**Corporate deposits**	**Household deposits**
β_0	0.43***	0.22**	0.50***	0.36***	0.15*
β_0^*	0.34***	0.52***	0.23***	0.37***	0.32***
γ	0.54***	0.37***	0.55***	0.24***	0.25***
γ^*	0.21***	-0.01	0.14	0.41**	0.24***
c (percentage point)	0.09	0.06	0.14	0.08	0.12
N	748	820	86	86	86

Controlling for different asymmetric effects

Despite the above mentioned difficulties in distinguishing the different sources of asymmetric effects, we make an attempt to separate the different asymmetric effects from each other (i.e., to control for one effect when investigating the other). We estimate TAR models that include two types of asymmetries. We suspect, among the three interrelated effects, size effect to dominate. So, we run regressions where we control for the size effect. Due to the highly increased number of regimes, we only focus on the panel data for this exercise. Since increases in the MMR were in general higher than the decreases, we allow the threshold values to differ when distinguishing big and small increases and decreases in the 3-month BUBOR.

Size and sign asymmetry

According to the results in Table 2.9, for the corporate loan market, immediate adjustment to small falls in the MMR is slow (β_0=0.14) and insignificant. Increases induce faster immediate adjustment (the parameter for the cross product with i_{St} is 0.17 but is only significant at the 10% level) while we again find evidence for a strong size effect (the parameter expressing the size effects is 0.48 and is significant at the 1% level). For the speed of adjustment to the long-run equilibrium, we only find evidence of the size effect. Results for the corporate deposit market are very much in line with what we found when analyzing the sign and size asymmetries separately: we find

TABLE 2.9 Sign and size asymmetry, volatility and size asymmetry

	Panel data (Jan. 2001-Jan. 2004)		Aggregate data (Jan. 1997-Apr. 2004)	
	Corporate loans	Corporate deposits	Corporate loans	Corporate deposits
β_0	0.14	0.05	0.33***	0.18**
β^*_{0S}	0.17*	-0.07	-	-
β^*_{0M}	0.48***	0.83***	0.51***	0.50***
β^*_{0V}	-	-	-0.15**	0.18**
c_{1M}^+ (percentage point)	1	1	0.70	0.78
c_{1M}^- (percentage point)	-0.23	-0.24	-0.59	-0.60
c_{1V}			0.17	0.19
γ	-0.07	0.58***	-0.20	0.32***
γ^*_S	-0.16*	0.11	-	-
γ^*_M	0.79***	-0.19	0.77***	-0.09
γ^*_V	-	-	0.25**	-0.10*
c_{1M} (percentage point)	0.28	0.49	0.19	0.82
c_{1V}	-	-	0.28	0.19
N	748	820	748	820

Subscripts S, M, and V refer to sign, magnitude (size), and volatility, respectively.

no significant asymmetric effect for the speed of adjustment to the equilibrium, while the immediate adjustment turns out to be significantly and considerably higher for big changes in the MMR than for small ones (the parameter belonging to the cross product with I_{Mt} is 0.83 and significant at the 1% level). These results support the idea that size effects dominate sign effects.

Size and volatility asymmetry

Results of a regression that includes factors for size and volatility asymmetry at the same time differ from those obtained from separate regressions with respect to the volatility asymmetry while the finding that bigger changes in the MMR induce faster adjustment appears to be robust (see Table 2.9). On the corporate loan market the parameters belonging to the size dummies are considerably higher than those of the volatility dummies, and are positive and significant even at the 1% level. The parameter that captures the difference of immediate adjustment between the more and less volatile periods is negative (-0.15) and significant at the 5% level, suggesting that when there is more uncertainty around the future evolvement of the MMR, banks are more reluctant to modify their interest rates. On the corporate deposit market we find significant and about 3.7 times faster immediate reaction of the interest rates for bigger changes in the MMR than for smaller ones while we could not find significant size asymmetry in the adjustment to the long-run equilibrium. At the same time, this adjustment appears to be significantly slower (only at the 10% level) in more volatile periods, but immediate adjustment turns out to be faster when the MMR is more volatile.

2.6 Conclusions

In this paper we analyzed the interest rate pass-through in Hungary. Our results suggest a clear difference in the pricing of household and corporate instruments. In the case of corporate deposits and loans, both the degree and the speed of adjustment exhibit a stronger transmission than the corresponding household interest rates do. Corporate loans and deposits have higher long-term pass-through and faster short-term adjustment, which is also reflected in the significantly lower value of mean adjustment lag than in the case of the household loan and deposit markets. This result is probably due to the fact that in the corporate segment – in contrast with the household sector – competition is very intense. In the corporate market we found complete pass-through, while in the household segment the estimated long-run parameter turned out to be significantly lower than one. The adjustment of consumer credit interest rates proved to be exceptionally incomplete and slow, probably reflecting the low interest rate elasticity of loan demand and the high proportion of risk premium. Comparing our results with those of Árvai (1998) and Világi and Vincze (1995) the interest rate transmission has improved since the mid 1990s due to the improvement of macroeconomic and financial environment. Our results are in line with those of Crespo-Cuaresma et al. (2004), despite the different estimation method used and the different time-span of the data. They also find complete pass-through for the short-term corporate loan rate and incomplete pass-through for the household deposit rates in Hungary.

Most European empirical studies conclude that short-term corporate loan rates adjust completely in the long run. Hence, corporate loan rates in Hungary behave similarly to other European countries' loan rates, in terms of long term adjustment. Regarding the short-term adjustment of corporate loan rates, we find the Hungarian rates to adjust very fast; the recent ECB study (de Bondt, 2002) find the first period adjustment to be less than 50% for the EMU countries, whereas we estimated this adjustment parameter to be much higher, about 70%. The few studies that analyze the adjustment of deposit rates and household loan rates find that even the long term adjustment of these rates is very slow: ranges between 40-70%. Even so, consumer credit rates in Hungary are found to be more rigid in international comparison, at least with regard to the instant adjustment.

We analyzed the potential non-linearities of banks' pricing with threshold ECM models. The results suggest that the speed of the pass-through of MMR changes to bank rates depends on the size of the changes in the MMR and, in particular for corporate loan rates, on the size of the distance of bank rates from their long-term equilibrium. The sign of yield shocks also turned out to be influential for the speed of adjustment. In line with international experience, we found that corporate loan rates are characterized by downward rigidity, probably due to the profit maximizing behavior of banks. Surprisingly, the sharp competition in the corporate loan segment could not fully counterbalance this downward rigidity. We also found that household deposit rates adjust more rapidly to upward than to downward shifts in the MMR. With respect to volatility, we find that at least one of the parameters determining the speed of pass-through changes towards faster adjustment when the volatility of the market rate exceeds a certain level. The seemingly counterintuitive findings can be explained by the fact that size effects cannot be separated from the other two types of asymmetric effects in separate equations. The counterintuitive findings with respect to volatility asymmetry are mitigated as soon as we make an attempt to control for the size effect.

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3. Estimating the immediate impact of monetary policy shocks on the exchange rate and other asset prices in Hungary

András Rezessy

3.1 Introduction

Monetary policy exerts its influence on the economy through several channels, and asset prices play a major role in the propagation of changes in the monetary stance. Mishkin (2001) mentions debt instruments, the exchange rate, stock market prices and real estate prices as the major assets from the point of view of the transmission mechanism of monetary policy. In order to assess how the transmission mechanism works in reality, it is necessary first to get a picture how the central bank's decisions affect the prices of these assets. As part of the series of studies of the Magyar Nemzeti Bank on the monetary transmission mechanism, this paper analyses the immediate impact of monetary policy on three classes of asset prices: the exchange rate, market interest rates and the stock exchange index.

Theory does not provide an unambiguous answer how monetary policy affects the exchange rate. The traditional view maintains that an increase in the domestic interest rate makes domestic debt more attractive to foreign investors and generates demand for the domestic currency. In a standard uncovered interest parity (UIP) framework, an increase in the domestic interest rate implies a strengthening of the domestic currency assuming that exchange rate expectations and the risk premium are unchanged. However, there can be several factors that can complicate this relationship, some of which can even lead to a 'perverse' opposite relationship. Blanchard (2004) and Stiglitz (1999) point out that – under certain circumstances depending among others on the level of indebtedness and share of foreign financing in a country – a large increase in the domestic interest rate might result in an increase of default risk thus reducing the attractiveness of domestic debt which can lead to a weakening of the currency. In addition, Garber and Spencer (1995) describe how the dynamic hedging activity in options markets can lead to a 'perverse' effect of monetary policy on the spot exchange rate.

The theoretical predictions of the likely reaction of market interest rates to monetary policy are also mixed. Standard theories of monetary transmission suggest that monetary contraction leads to higher short-term and long-term interest rates, i.e. an upward shift in the yield curve (Mehra, 1996). Some add that because long-term rates are an average of expected future short-term rates based on the expectation hypothesis of the term structure, monetary policy has a smaller impact

I am grateful for the useful comments of Csilla Horváth and Balázs Vonnák and participants of discussions organised by the MNB.

on long-term rates (see for instance Cook and Hahn, 1989). Other studies emphasise, however, that while monetary tightening raises short-term interest rates, it reduces expected future inflation through higher real rates on the short term and therefore expected short-term interest rates for future years decline (Mehra 1996, Romer and Romer 2000, Ellingsen and Söderström 2001). Based on the expectation hypothesis of the term structure, this can imply a negative impact on long-run rates on sufficiently long maturities provided that the impact on expected inflation is sufficiently large. Therefore the impact on long-term yields depends on the size of the reaction of short-term rates and on the impact on average expected inflation for future years.

Concerning the impact of monetary policy on stock prices, theory predicts a negative reaction, i.e. a rise in the interest rate leads to a fall in stock prices (see for instance Thorbecke, 1997 and Mishkin, 2001). In a standard stock valuation model, the value of a firm's shares is equal to the present value of its expected future net revenues. Monetary easing can therefore increase the value of the firm on the one hand by reducing the discount factor and on the other hand by increasing the firm's future nominal revenues.

Earlier studies on how Hungarian monetary policy can influence asset prices include Kiss and Vadas (2005), who examine the role of housing markets in the transmission mechanism. Vonnák (2005) uses a structural vector autoregression approach to trace the impact of monetary policy shocks on macroeconomic variables including the nominal exchange rate and market interest rate. Pintér and Wenhardt (2004) use the event study method to estimate the immediate impact on forward government bond yields. This paper uses a slightly different approach from that adopted by the latter paper, which is able to provide consistent estimates for the immediate response of the exchange rate as well, in which case the event study method fails.

The event study method is commonly used in the literature to analyse the impact of monetary policy on various asset prices. The main assumption of this approach is that if one considers a certain subsample of all observations – e.g. days of monetary policy decisions – the only important source of innovations in a given asset price is monetary policy. However, Rigobon and Sack (2004) point to the limitations of this approach which becomes especially relevant if common shocks or shocks to the asset price itself are present in the subsample chosen for the analysis. Hungarian data indicate that this is a serious problem in the case of the exchange rate, and less so in the case of yields which implies that other methods are necessary to analyse the reaction of the exchange rate.

Rigobon and Sack (2004) propose a method called identification through heteroskedasticity which can provide consistent estimates even in cases when the event study estimate is biased due to common shocks or asset price shocks. This paper uses this method to investigate how the interest rate decisions of the Magyar Nemzeti Bank affected the exchange rate of the forint vis-à-vis the euro throughout the first three years following the widening of the exchange rate band in the middle of 2001. The paper also examines the impact of monetary policy on spot government bond yields, on forward yields to assess the impact on the term structure and also on the stock exchange index.

The paper is structured as follows. Section 3.2 presents the theoretical considerations of identifying the impact of monetary policy and provides a brief description of the estimation method applied here. Section 3.3 presents the baseline results obtained with the heteroskedasticity-based method, compares those with the event study method and checks the robustness of the baseline results. Finally, Section 3.4 concludes.

3.2 Identifying the immediate impact of monetary policy shocks

When trying to estimate the response of asset prices to monetary policy steps, one encounters the problem of endogeneity of the variables. The two variables are simultaneously determined, i.e. the central bank reacts to changes in asset prices while asset prices themselves are also influenced by monetary policy decisions. Another source of endogeneity is the presence of factors that affect both variables e.g. macroeconomic news, changes in the risk premia etc. In the presence of endogeneity, the standard ordinary least squares (OLS) estimation method gives biased estimates and this necessitates the use of other techniques.

One way to identify the response of asset prices to monetary policy commonly used in the literature is the event study method. The main idea here is to use institutional knowledge and to consider only certain periods when changes in the asset price are dominated by news about monetary policy. In practice, this usually implies running an OLS regression on days of policy decisions of the central bank. This method was first used to estimate the impact of monetary policy on money market yields by Cook and Hahn (1989) in the case of US. An application of the event study method for Hungarian data is provided by Pintér and Wenhardt (2004) who find a significant impact of monetary policy shocks on forward yields up to a 3-year horizon.

Rigobon (2003) and Rigobon and Sack (2004), however, point out that the strict assumption of the event study method – i.e. that the only important source of innovations in a carefully selected subsample of all observations is news about monetary policy – may not be satisfied even in a short window of one day and the estimates obtained may be biased. They propose an alternative identification method which makes less stringent assumptions about the heteroskedasticity present in the data. Their heteroskedasticity-based estimation method can thus lead to consistent estimates even in cases when the event study method suffers from a bias.

Rigobon and Sack (2004) consider the following two-equation system to model the simultaneous relationship of monetary policy and the price of a given asset:

$$\Delta i_t = \beta \Delta s_t + \gamma z_t + \varepsilon_t \tag{1}$$

$$\Delta s_t = \alpha \Delta i_t + z_t + \eta_t \tag{2}$$

where the first equation is a monetary policy reaction function and the second one is an asset price equation. Δi_t is the change in the short-term interest rate, Δs_t is the change in the price of the given asset and z_t is a vector of common shocks. ε_t is the monetary policy shock while η_t is a shock to the asset price. The parameter of interest here is α which measures the reaction of the asset price to changes in the policy variable.

It can be shown that running an OLS regression on (2) will yield a consistent estimate only if the variance of the monetary policy shock σ_ε is infinitely large in the limit relative to the variance of the asset price shock σ_η and to the variance of the common shock σ_z. The event study method assumes that this holds if one considers only a certain subset of all observations, e.g. days of monetary policy decisions. Though in many cases this might be a plausible assumption, it may not always be the case.

A further problem of this approach is that it is not possible to test the validity of these strict assumptions.

On the other hand, the heteroskedasticity-based estimator considers two subsets of observations: policy dates – which can be defined as days of monetary policy decisions – and non-policy dates – which can be defined as preceding days – and assumes that the variance of the monetary policy shock increases from non-policy dates to policy dates, while there is no systematic change in the variances of the other shocks from one subset to the other. Thus the method does not assume that only monetary shocks matter on policy dates, but rather that the relative importance of monetary shocks with respect to the other shocks increases between the two subsets. In this sense, non-policy dates are used as a control group in this approach to control for the effect of asset price shocks and common shocks on the covariance of the two variables observed on policy dates this way identifying the effect of monetary policy.

To illustrate the difference between the two approaches further, one can say that the event study method assumes that the OLS estimate is unbiased if one considers only days of policy decisions. In contrast, the heteroskedasticity-based method does not assume unbiasedness on policy days; instead it estimates a from the change in the bias that occurs between the two subsamples.

Assuming the above-mentioned structure of heteroskedasticity and that the parameters α and β are stable across the two subsets and that the structural shocks are not correlated with each other and have no serial correlation, Rigobon and Sack (2004) show that the difference of the covariance matrices of Δs_t and Δi_t calculated for the two subsamples *($\Delta\Omega$)* simplifies to:

$$\Delta\Omega = \Omega^{policy} - \Omega^{nonpolicy} = \lambda \begin{bmatrix} 1 & \alpha \\ \alpha & \alpha^2 \end{bmatrix} , \tag{3}$$

where:

$$\lambda = \frac{\sigma_{\varepsilon}^{policy} - \sigma_{\varepsilon}^{nonpolicy}}{(1-\alpha\beta)^2} . \tag{4}$$

Thus, $\Delta\Omega$ is a function of α and a parameter λ, which measures the shift in the monetary policy shock from non-policy dates to policy dates. From this, one can impose three restrictions on the change in the covariance matrix to obtain α (and λ) since there are three independent elements in this matrix.

The estimation can be implemented in two different ways: through an instrumental variables (IV) interpretation or with generalised method of moments (GMM). Though the IV approach is easier to implement, it considers only one of the three possible restrictions. Therefore this estimation method leads to three different estimates, where one is a geometric average of the other two. The GMM approach, on the other hand, takes into account all three restrictions at the same time and provides more efficient estimates. Therefore the GMM estimate provides a cross-check for the multiple estimates obtained with IV. This is useful because even though the multiple IV estimates should be asymptotically equal for a given asset, it can happen that quantitatively they are far from each other if one of the IV estimates has high standard errors. In this case, the quantitative interpretation is more straightforward and more reliable with the help of the GMM estimate.

Another useful feature of the heteroskedasticity-based approach is that it is possible to test the assumptions of the model. This can be done either with the IV method by comparing the multiple estimates using the property that these should be asymptotically equal. A rejection of the hypothesis that this holds indicates that the assumptions are not valid. It is also possible to test the assumptions in the GMM approach. Since we impose three restrictions on the matrix in (3) and estimate only two parameters (α and λ), the system is overidentified and the standard test of overidentifying restrictions can be applied for this purpose. A significant overidentifying test statistic implies that the assumptions of the model are not valid.

3.3 Empirical application

Data

The paper analyses the impact of monetary policy on the exchange rate of the forint vis-à-vis the euro, on spot government bond yields with maturities of 1, 5 and 10 years, on forward yields 1, 5 and 10 years ahead and on the index of the Budapest Stock Exchange (BUX). The spot yields are the benchmark yields published daily by the Government Debt Management Agency Ltd., while the forward yields are estimates made by the MNB using the yield-curve estimation method developed by Svensson (1994). The data are represented as first differences of daily observations, with the exchange rate and the stock index treated as logarithmic differences. Thus, what is measured here is the impact of monetary policy in one day[1].

Policy dates include days of rate-setting meetings of the Monetary Council of the Magyar Nemzeti Bank, while non-policy dates are the preceding working days. Because of the variations in the timing of the variables, the data series are corrected in a way that the observations for policy dates contain the information from the central bank's decisions. The sample covers the period August, 2001 – November, 2004 and contains 160 observations: 80 dates of Monetary Council meetings and 80 non-policy dates. The sample includes the regular meetings of the Monetary Council, which took place every second week until July, 2004 and once every month since then, and also includes four irregular meetings.

The analysis focuses on unanticipated moves of the central bank, which take financial markets as a surprise[2]. This is captured by the change in the three-month benchmark yield, as it is assumed to change only as much as the central bank's move represents a surprise to the market. Approxi-

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[1] The section examining the robustness of the results presents estimations with a two-day window. One could perform the estimation for longer windows measuring the effect of monetary policy on a longer horizon. However, there is a tradeoff here as in a longer estimation window it is less likely that the importance of policy shocks rises sufficiently for the model's assumptions to be satisfied.
The time-frame of the measured effect is not exactly one day, because different variables are recorded at different hours of the day and the timing of the publication of the central bank's interest rate decision varies in the sample. For instance, the exchange rate and the benchmark yields are collected around 15-30 minutes after the publication of the central bank's decision in a large part of the sample, while forward yields are collected the following morning except in the case of irregular meetings of the Monetary Council.

[2] See Vonnák (2005) for a discussion on the importance of focusing on the surprise element of the central bank's actions in analysing the transmission mechanism of monetary policy. In addition, Kuttner (2001) emphasises that only surprise elements of monetary policy decisions have an impact on market interest rates.

mating the surprise element of policy rate changes with three-month yields also has the advantage that they are less likely to be influenced by the uncertainty regarding the timing of the central bank's action. It is worth noting that with this approach, keeping the central bank's policy rate unchanged can also represent a surprise to the market which would then be reflected in a change in the short-term yield. In the paper, the term 'policy rate' refers to this approximation of the surprise element.

Since the estimation method is based on the change in the variance/covariance structure of the data from one subsample to the other, it is worth analysing this structure. As can be seen in Table 3.1, the variance of the policy rate is more than twice as high on policy dates as on non-policy dates, which is in line with the assumption that the importance of monetary policy shocks is higher on policy dates.

TABLE 3.1 Variances of the variables and their correlations with the policy rate[3]

	Variances		**Correlations with policy rate**	
	Non-policy	**Policy**	**Non-policy**	**Policy**
Policy rate	0.14	0.33	n.a.	n.a.
HUF/EUR	0.47	0.66	0.28	-0.09
1Y BMK	0.20	0.27	0.90	0.94
5Y BMK	0.17	0.16	0.76	0.72
10Y BMK	0.11	0.11	0.75	0.57
1Y FW	0.20	0.29	0.55	0.62
5Y FW	0.19	0.16	0.00	-0.40
10Y FW	0.28	0.23	0.31	-0.42
BUX	1.07	1.41	-0.07	-0.15

The correlation structure of the exchange rate shows a positive co-movement with the policy rate on non-policy dates – suggesting that a rise in the short-term interest rate is associated with a depreciation of the forint – whereas the relationship is slightly negative on policy dates[4]. The positive relationship on non-policy dates can be the result of common shocks such as changes in the risk premia or macroeconomic news, which are likely to affect the exchange rate and the short-term interest rate in the same direction. On policy dates, however, when the importance of monetary shocks increases substantially while other shocks are still present, the co-movement becomes slightly negative, which may imply that monetary policy affects the exchange rate negatively. From this correlation structure, one would expect a negative coefficient for the estimate of a in the case of the exchange rate.

This change in the correlations is also visible on the scatter plots of the two variables for the two subsamples in Figure 3.1 and 3.2. The positive relationship is clearly visible on non-policy dates, while there is a much less discernible direction on policy dates.

[3] Where HUF/EUR denotes the exchange rate, BMK the spot benchmark yields for the relevant maturities, FW the forward yields with the relevant starting dates and BUX the stock exchange index.

[4] A rise in the value of the exchange rate variable represents a depreciation of the forint against the euro.

Each observation plotted on the graphs can be interpreted as an intersection of the asset price curve and the monetary policy reaction function curve. These intersects are moving because shocks are continuously hitting both curves. If it is almost exclusively the monetary policy curve that is being hit by monetary shocks while the asset price curve is stable and there are no common shocks – that is the assumptions of the event study method are fulfilled – the intersects will be close to the asset price curve. However, the apparently strong role of common shocks in the case of the exchange rate suggests that this may not hold on policy dates and the slope coefficient α estimated with OLS for this subsample will suffer from a positive bias.

FIGURE 3.1 Scatter plot of the exchange rate and the policy rate on non-policy dates

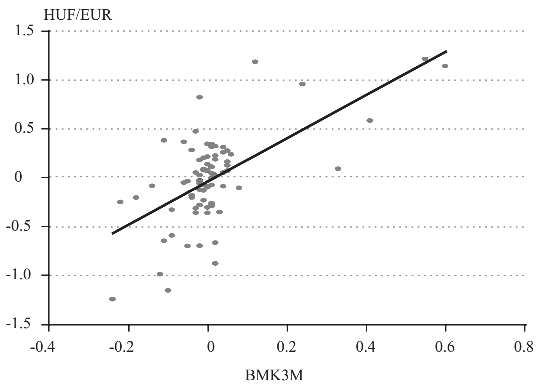
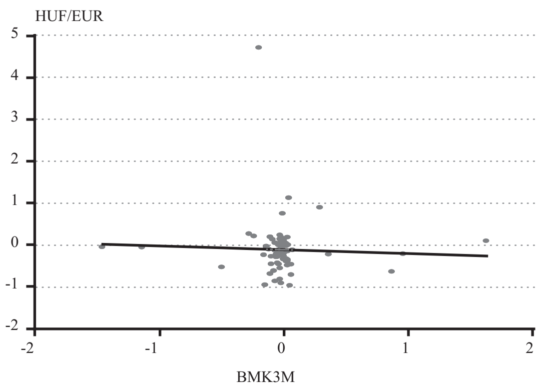


FIGURE 3.2 Scatter plot of the exchange rate and the policy rate on policy dates



On the other hand, given that there is a substantial increase in monetary policy shocks between the two subsamples, the cloud of the intersections of the two curves will be rotated towards the monetary policy curve from non-policy dates to policy dates. As mentioned earlier, the heteroskedasticity-based method estimates α from the change in the size of the bias, which in this context appears as the rotation of the cloud of realisations. Thus, the correlation structure of the exchange rate suggests that the heteroskedasticity-based method may provide a better estimate of α than the event study method in the case of the exchange rate and also that the difference between the two may be substantial.

The correlations of the benchmark yields with the policy rate show a positive co-movement on non-policy dates which increases on policy dates. This may suggest some role of certain common shocks which push the two variables in the same direction even on non-policy dates. It also suggests that, contrary to the case of the exchange rate, monetary policy might affect the 1-year benchmark yield positively. The correlations of the benchmark yields at longer horizons show a similar structure. Based on this correlation structure, one would expect a much smaller difference between the two estimation methods for the benchmark yields.

Regarding the forward yields, one can find a structure similar to that of the benchmark yields at the short horizon, while the correlation structure of the 5 and 10 year forward yields are more similar to that of the exchange rate. The BUX index shows a negative co-movement for both subsamples which increases substantially for the policy dates.

FIGURE 3.3 Scatter plot of the 1-year benchmark rate and the policy rate on non-policy dates

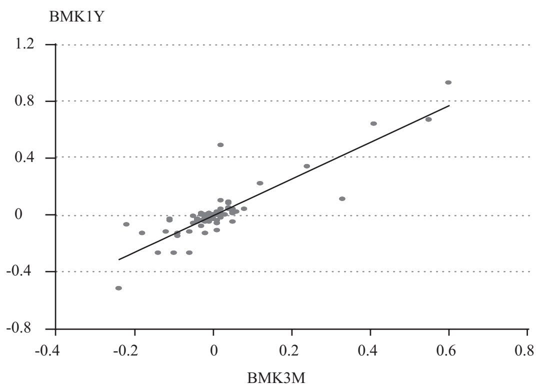
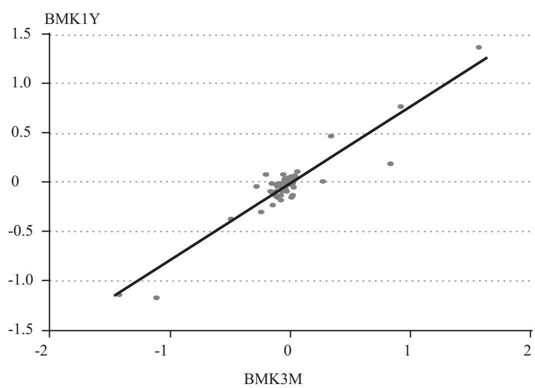


FIGURE 3.4 Scatter plot of the 1-year benchmark rate and the policy rate on policy dates



Results of the heteroskedasticity-based method

The paper applies both ways of implementation of the heteroskedasticity-based estimation method: the IV and the GMM approach. The estimation is implemented on a joint set of policy dates and non-policy dates for each asset. The instrument for the IV estimation is based on a transformation of the policy rate where the instrument is equal to the policy rate with a positive sign on policy dates and with a negative sign on non-policy dates. For a proof why this is a valid instrument and why it really leads to estimating α from (3), see Rigobon and Sack (2002). The IV estimation can also be carried out with an instrument obtained with a similar transformation of the asset price variables. The coefficients thus obtained are not significantly different from the ones reported here (except for the ten-year forward yield), though they show much higher standard errors.

The IV estimation can be carried out with a standard single-equation two-stage least squares (TSLS) method. In this case, the asset price variable is regressed on the policy rate separately for each asset using the relevant instrument. Alternatively, the estimation can be carried out in a system including all the individual asset price equations using three-stage least squares (3SLS). The latter one is usually preferred as it is more efficient. However, the coefficients obtained with the two IV methods are almost identical and the improvement in efficiency is marginal, therefore only the 3SLS results are reported here. Since the efficiency gain from estimating in system is negligible as compared to single equations in the case of the IV method, the GMM method is carried out only in single equations. A formal description of the implementation of the GMM method is provided in Rigobon and Sack (2004).

As can be seen in Table 3.2, the coefficients are significant with both methods except in the case of the BUX index. The coefficients obtained with IV and GMM are close for all variables except for the stock exchange index. This is important because the two estimations should yield asymptotically equal results provided that the assumptions of the model are satisfied. The overidentifying restrictions are in line with the fact that only the BUX shows strongly different coefficients with IV and GMM. The significant overidentifying test statistic for the BUX index implies that the model's assumptions are not satisfied in this case, while the overidentifying restrictions cannot be rejected for any of the other variables.

TABLE 3.2 **The results of the instrumental variables and generalised method of moments estimations**

	IV		GMM			
	Coefficient	**Std. error**	**Coefficient**	**Std. error**	**Overid. restr.**	**t-stat. of λ**
HUF/EUR	-0.60*	0.28	-0.54*	0.21	1.93	3.5*
1Y BMK	0.66*	0.05	0.70*	0.05	3.05	4.17*
5Y BMK	0.21*	0.06	0.26*	0.04	1.75	4.54*
10Y BMK	0.10*	0.04	0.11*	0.03	0.07	3.88*
1Y FW	0.48*	0.09	0.55*	0.08	2.25	3.76*
5Y FW	-0.24*	0.08	-0.25*	0.08	2.92	3.41*
10Y FW	-0.50*	0.12	-0.39*	0.12	2.56	4.61*
BUX	-0.68	0.56	-20.10*	9.41	12.65*	1.13

** Significant at 5% level.*

The heteroskedasticity-based method shows a negative coefficient for the exchange rate. It implies that a 50 basis-point surprise rate hike results in an immediate 0.27-0.30 percent appreciation of the forint. Thus, the results show no evidence of the presence of a 'perverse' effect of monetary policy on the exchange rate, the direction of the impact is in line with the classic intuition. Though it is not possible to test the UIP hypothesis with this method due to the lack of high-frequency data on exchange rate expectations, if one assumes that these expectations do not react to changes in the policy rate, the result is in line with the UIP condition.

Considering benchmark yields, the results indicate that monetary policy has a positive impact on spot government bond yields. A 50 basis-point surprise increase of the central bank's policy rate leads to a 33-35 basis-point rise in the 1-year benchmark yield and this effect reduces to around 10 and 5 basis points for the 5 and 10-year yields respectively. This is in line with the intuition and implies that monetary policy can affect short-term yields – with a positive sign – but has a much more limited impact on long-term yields. The effect of monetary policy almost dies out at the ten-year horizon. The structure of the impact of monetary policy on forward yields helps explain this phenomenon.

The estimated impact of monetary policy on the 1-year forward yield is close to that on the 1-year benchmark yield; it is only slightly below the latter one. On the other hand, an unexpected 50 basis-point rate-hike results in a 12 basis-point fall in the 5-year, and a 20-25 basis-point fall in the 10-year forward yield. In other words, monetary policy affects the short end of the forward yield curve positively and has a negative impact on the longer end of the curve, which increases with maturity. Thus, the results suggest that an unanticipated change in the policy rate leads to a rotation of the forward curve. Based on the expectation hypothesis of the term structure, this implies that the impact of monetary policy on spot yields diminishes gradually as the maturity increases.

The result suggesting a rotation of the forward curve in response to monetary shocks is in line with the insight from the literature that emphasises the role of expected future inflation in long-term forward yields. As these yields can be interpreted as the market's expectations for the future short-term interest rates, the results indicate that a surprise central bank rate-hike leads to an increase in the short-term horizon and a decrease in the long-term horizon of the expected future path of short-term interest rates. The explanation of this can be that a surprise increase in the policy rate may signal a reinforced commitment of the central bank to its mandate of achieving and maintaining price stability allowing lower interest rates in the long-run with the help of higher interest rates temporarily in the short-run. This may have been an important factor in the years following 2001, when the central bank started an inflation targeting regime with the aim to help fulfil its mandate.

As mentioned earlier, the highly significant overidentifying test statistic for the BUX implies that the model's assumptions are not satisfied in this case and therefore these results are not interpretable. The reasons for this can be that the parameters, α, β or the shocks to the BUX index or the common shocks show instability between the two subsamples.

Comparison of the event study and the heteroskedasticity-based methods

Rigobon and Sack (2004) also construct a hypothesis test with which it is possible to test formally whether the results obtained with the event study method are biased. Table 3.3 compares the results of the GMM and event study methods and presents the biasedness tests[5].

[5] The biasedness tests comparing the event study and the IV estimates mainly lead to the same conclusions and therefore they are not reported.

TABLE 3.3 Comparison of the event study and the heteroskedasticity-based methods

	Event study		GMM		Biasedness test
	Coefficient	Std. error	Coefficient	Std. error	
HUF/EUR	-0.09	0.22	-0.54*	0.21	-38.36*
1Y BMK	0.78*	0.03	0.70*	0.05	4.98*
5Y BMK	0.35*	0.04	0.26*	0.04	14.74*
10Y BMK	0.19*	0.03	0.11*	0.03	54.85*
1Y FW	0.53*	0.08	0.55*	0.08	0.25
5Y FW	-0.19*	0.05	-0.25*	0.08	0.79
10Y FW	-0.30*	0.08	-0.39*	0.12	0.79
BUX	-0.65	0.48	-20.10*	9.41	4.28*

A quick comparison of the coefficient estimates reveals that the two methods give similar results for spot and forward yields. The event study approach produces significant coefficients for these variables just as the GMM, and the differences between the coefficients are usually at the second decimal. On the other hand, the event study method fails to give a significant coefficient for the exchange rate, as the parameter obtained is strongly below the GMM estimate in absolute value. This difference in the size of bias for the exchange rate and for interest rates can be explained with the different correlation structures as outlined in section 3.1.

The GMM-based result shows that the unbiased coefficient is strongly negative for the exchange rate. However, there was indication of a strong presence of common shocks which presumably push the policy rate and the exchange rate in the same direction thereby reducing the negative impact of monetary policy even on policy dates. As the event study method ignores this issue, the result obtained with this approach is biased upwards and thus it gets close to zero. The biasedness test provides strong evidence that the event study approach gives a biased result in the case of the exchange rate.

In the case of the benchmark yields, the tests indicate that the event study results are biased, though they are quantitatively closer to the GMM coefficients than in the case of the exchange rate. The event study estimates exceed the GMM values for all the benchmark variables which can again be the result of common shocks ignored by the former method.

Finally, forward yields represent the only asset class, where the biasedness tests cannot reject the hypothesis that the event study method provides unbiased estimates. For long-term forward yields – as their coefficients are negative similarly to that of the exchange rate – the event study results are smaller in absolute value than the GMM results, but the size of the bias is small therefore the coefficients remain significant. It is worth noting that in this case, the event study approach is more efficient than the heteroskedasticity-based method.

Robustness

There are several aspects from which the robustness of these results can be checked. The stability of the coefficients in time is assessed by performing the estimations on a smaller timeframe: from August, 2001 until December 2002. The reason why this subperiod is especially interesting is that it excludes the year 2003, in which Hungarian financial markets experienced several episodes of extreme turbulence. As Table 3.4 shows, the results for the spot and forward yields obtained for this period are similar to the baseline estimation, but there is a slightly positive but insignificant coefficient for the exchange rate. This could imply that only the large changes in the policy rate – which were associated with the turbulent episodes of 2003 – have had a significant impact on the exchange rate. However, caution is necessary when interpreting these results as the methods applied are asymptotic estimations and therefore require large samples. The fact that the sample is much smaller may explain some of the differences as compared to the baseline estimation.

TABLE 3.4 **Results for the period August, 2001–December, 2002**

	IV		GMM			
	Coefficient	**Std. error**	**Coefficient**	**Std. error**	**Overid. restr.**	**t-stat. of λ**
HUF/EUR	0.32	0.34	0.10	0.11	5.29*	2.07*
1Y BMK	0.94*	0.06	1.03*	0.02	6.63*	1.92
5Y BMK	0.34*	0.05	0.33*	0.03	3.76	1.98*
10Y BMK	0.17*	0.04	0.16*	0.02	1.33	2.09*
1Y FW	0.77*	0.11	0.83*	0.06	6.49*	2.33*
5Y FW	0.02	0.09	0.04	0.04	4.49*	2.27*
10Y FW	-0.14	0.20	-0.13	0.07	1.20	2.17*
BUX	-1.72	1.27	-1.24	0.28	11.73*	2.10*

** Significant at 5% level.*

To investigate the importance of large moves in the policy rate, the estimation is also implemented on the entire sample with the exclusion of these observations[6] (Table 3.5). The coefficients for the benchmark and forward yields are similar to the baseline estimation, however the assumptions of the model are not satisfied in many cases. The t-statistics for the λ coefficients are considerably lower than in the baseline estimations. A possible reason for this can be that the exclusion of the largest monetary policy steps renders the rise in the variance of policy shocks insufficient to reach identification in some cases which can be one factor behind the breakdown of the model. On the other hand, the model's assumptions are satisfied for the exchange rate, the λ coefficient is weakly significant and both heteroskedasticity-based methods give a negative coefficient larger than the baseline results. While the coefficient obtained with 3SLS is insignificant, the GMM result is weakly significant providing weak evidence that small monetary policy steps can also have an impact on the exchange rate, which in fact may be somewhat greater than the impact of large steps.

[6] The excluded observations are days on which the central bank changed the base rate by at least 100 basispoints. There are altogether 6 such occasions in the sample.

TABLE 3.5 Results for the entire sample excluding large changes in the policy rate

	IV		GMM			
	Coefficient	**Std. error**	**Coefficient**	**Std. error**	**Overid. restr.**	**t-stat. of λ**
HUF/EUR	-0.81	0.94	-1.01	0.59	0.62	1.85
1Y BMK	0.42	0.24	0.77*	0.09	4.66*	2.94*
5Y BMK	-0.24	0.34	0.37*	0.05	8.09*	2.00*
10Y BMK	-0.06	0.20	0.10	0.07	2.10	1.81
1Y FW	0.03	0.41	-0.58	0.79	0.11	2.40*
5Y FW	0.23	0.32	-0.20	0.21	11.12*	2.51*
10Y FW	-1.03	0.58	0.03	0.20	4.97*	1.67
BUX	-5.13	2.66	2.33	5.16	14.24*	-0.69

Finally, I also check whether the results change when the estimation is carried out with a two-day data window[7]. As can be seen in Table 3.6, there is a marked difference for the exchange rate, as the coefficients obtained for two days are around 3-6 times higher than the result with a one-day window. This large difference can be interpreted as a failure of the model to provide stable coefficients. Another and perhaps more realistic explanation can be the inefficiency of financial markets as it takes time for market participants to fully adjust to monetary policy shocks[8]. The GMM estimate is strongly significant and the very low overidentifying test statistic for the exchange rate supports the validity of this result. It is close to the result of Vonnák (2005) stating

TABLE 3.6 Results obtained with a two-day data window

	IV		GMM			
	Coefficient	**Std. error**	**Coefficient**	**Std. error**	**Overid. restr.**	**t-stat. of λ**
HUF/EUR	-3.62	1.95	-1.74*	0.51	1.49	2.69*
1Y BMK	0.24	3.20	0.18	0.19	0.03	2.42*
5Y BMK	0.08	0.40	-0.04	0.12	3.45	2.47*
10Y BMK	-0.72	0.51	-0.15	0.09	2.36	2.36*
1Y FW	-0.57	0.36	0.46	0.12	11.49*	3.09*
5Y FW	-0.65	0.63	-0.19*	0.11	4.15*	1.85
10Y FW	-0.41	0.32	1.20	1.05	5.38*	-1.24
BUX	-0.68	0.41	-1.23	1.16	1.44	1.45

[7] There is a technical difficulty in the implementation here because there are two occasions in the sample when two policy decisions took place on consecutive days. As it is impossible to define policy and non-policy dates in a two-day window without overlaps in these two occasions, these observations are omitted from the sample.

[8] It is important to note, however, that the data for the exchange rate and benchmark yields are collected some 15-30 minutes after the publication of the central bank's decision in a large part of the sample. Thus, what the results show is that markets fail to incorporate fully the innovation from the central bank's decision in the exchange rate in such a short timeframe.

that a 25 basis-point rate-hike results in a 1 per cent immediate appreciation of the nominal exchange rate on quarterly data.

On the other hand, the coefficients for spot yields are smaller than the baseline results and suggest no significant impact of monetary policy on yields in a two-day window. It would be interesting to see what kind of response in the term structure lies behind this, but the method provides no interpretable results for forward yields. Nonetheless, the point estimates of spot yields' reactions show a similar structure to the baseline results, i.e. there is a positive impact on the short horizon which falls as the horizon increases. An interesting result is that the coefficients become slightly negative for long-term spot yields. This can be partially explained by the small response of the short end of the curve and highlights again the importance of inflation expectations for long-term interest rates.

An interesting feature of the two-day results is that the model gives a valid result for the BUX index. The coefficient is negative, in line with the theoretical prediction, though it is not significant. This result indicates that monetary policy in Hungary does not have a substantial influence on the stock exchange index.

3.4 Conclusion

The paper estimates the immediate impact of Hungarian monetary policy on three classes of asset prices: the exchange rate of the forint vis-à-vis the euro, market interest rates and the stock exchange index. The endogeneity problem – which stems from the simultaneous relationship of monetary policy and asset prices and from the presence of common shocks – is treated with the method of identification through heteroskedasticity as described by Rigobon and Sack (2004).

The results obtained with the heteroskedasticity-based method support the validity of the classic impact of monetary policy on the exchange rate for Hungary for the period 2001-2004. There is evidence of a significant negative impact on the exchange rate in one day suggesting that a 50 basis-point surprise increase in the policy rate causes 0.3 percent appreciation. This negative effect increases by around 3-6 times when the estimation is carried out with a two-day window suggesting the inefficiency of markets in incorporating monetary policy decisions in asset prices in a short period of time. Though it is not possible to test the UIP hypothesis with this method due to the lack of high-frequency data on exchange rate expectations, if one assumes that these expectations do not react to changes in the policy rate, the results are in line with the UIP condition.

The results provide evidence that monetary policy affects spot yields positively, but this effect gradually dies out as the horizon gets longer. This can be explained with the impact on the term structure of the yield curve, as the results suggest a positive impact on short-term and a negative impact on long-term forward yields implying that a surprise change in the policy rate leads to a rotation of the forward curve. The minor impact on long-term spot yields and the negative impact on long-term forward yields are in line with the insight provided among others by Romer and Romer (2000) and Ellingsen and Söderström (2001) who emphasise that the reaction of long-term yields to monetary policy depends strongly on the impact of the monetary policy shock on expected future inflation.

In the baseline estimation, the method does not provide interpretable results for the stock exchange index. When the estimation is carried out with a two-day data window, the method provides a valid result: a negative but insignificant coefficient. The sign is in line with the intuition, which suggests that monetary contraction leads to a fall in the stock index. However, the insignificant coefficient indicates that this impact is not substantial in Hungary.

The significant negative coefficient for the exchange rate shows robustness in several alternative estimations. In these estimations, the results for spot yields follow a similar pattern as in the baseline case with a positive response declining gradually as the horizon increases, though there is less information in this case as the method does not produce valid results in many cases. There is very little information about the robustness of the results for forward yields, since the model usually does not provide interpretable results in the robustness checks for this variable. Indirect evidence is available though, as the declining tendency of the response of spot yields suggests a very low, possibly negative impact on long-term forward yields in all alternative estimations.

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4. Exchange rate smoothing in Hungary

Péter Karádi

4.1 Introduction

This paper is part of the transmission mechanism research of the Central Bank of Hungary, and its main motivation is to explore futher the interrelationship of short term interest rate and exchange rate development in Hungary using high frequency data. It argues that this relationship is strongly influenced by the systematic exchange rate smoothing behavior of the central bank, and applies a methodology which is capable of numerically assess some of its effects.

In open economies, like Hungary, exchange rate can play an important role in the transmission mechanism, and its volatility can cause various, potentially substantial welfare distortions. These considerations provide incentives for the central bank – even in pure inflation targeting frameworks – to pay attention to the exchange rate developments (Svensson, 2000, and Taylor, 2001). The empirical exchange rate smoothing or 'fear of floating' literature presents evidence that many open economy central banks indeed use direct and indirect methods to influence exchange rate developments in practice (Calvo-Reinhart, 2000). One strand of this empirical literature examines the exchange rate smoothing behavior of central banks by estimating open economy interest rate rules with an exchange rate term (Clarida, Galí and Gertler, 1997 and Mohanty and Klau, 2004). This term is usually proxied by the depreciation of the exchange rate theoretically motivated by some vague 'lean against the wind' interest rate policy. This paper suggests a more structural approach which assumes that, on the one hand, the central bank has a preferred exchange rate level and uses its interest rate policy to maintain this target in the medium term, and, on the other, market participants form rational expectations about the monetary policy and influence the current exchange rate accordingly.

In most cases, this preferred exchange rate level is not directly observable, because strategic considerations make the central bank silent, or sufficiently vague about it. But – given it is persistent – past interest rate decisions of the central bank provide informative signals about this unobserved target variable. Furthermore, assuming rational expectations and forward looking price determination in the foreign exchange market (e.g. uncovered interest parity), current exchange rate developments will reflect the market participants' best assessment of this target. This means that the econometrician can also use the behavior of the exchange rate to gain a better estimation of the unobserved target.

The paper applies Kalman filtering to gain the best linear estimate of the unobserved exchange rate target variable and simultaneously estimate an interest rate rule and an exchange rate equa-

I would like to thank the participants of the conference of the Applied Econometrics Association and the seminar at the Central Bank of Hungary, especially Gábor Kőrösi, Zsolt Darvas and Csilla Horváth for their useful comments, and Gábor Csiszár for his research assistance. All remaining errors are mine.

tion consistent with this target. The estimated system is able to provide interest rate and exchange rate impulse responses to known changes in the exchange rate target, and premium shocks. Furthermore, it can also provide estimates for the ceteris paribus exchange rate effects of expected and unexpected interest rate changes, where the latter takes into consideration that an unexpected interest rate move changes the market participants' beliefs about the central bank's exchange rate target.

The paper uses weekly data during a fairly homogeneous period from the widening of the exchange rate band in May 2001 to the end of 2004. The frequency of the data provides a moderately large sample, but hinders the usage of more fundamental variables – like inflation or output – in the estimated rules. Not considering these variables in the interest rate rule can be partly justified by the communication of the Central Bank of Hungary (CBH) during the period. The CBH stressed its belief on the small direct influence of the interest rate on the aggregate demand, and argued that the major influence of its interest rate policy is exerted through its effect on the exchange rate. The framework does not estimate the effects of these fundamental variables on the exchange rate target either.

The paper is organized as follows. Section 2 presents some theoretical results about the welfare implications of exchange rate smoothing in the recent New Open Economy Macroeconomics literature. The section also presents some empirical results emphasizing the widespread use of exchange rate smoothing in small and open economies. Section 3 presents some evidence for exchange rate smoothing in Hungary using the explicit exchange rate target announcements of the Central Bank of Hungary available up to the end of 2003. Section 4 presents the unobserved variable framework and the estimation results. Section 5 concludes.

4.2 Exchange rate smoothing

In small and open economies, exchange rate development can have a substantial influence on prices and output, which makes it a potentially important indirect channel of the transmission mechanism. It does not necessarily mean, however, that open economy central banks should also smooth the exchange rate, i.e. react directly to exchange rate developments by their interest rate policy. Along these lines have Clarida, Galí and Gertler (2001) and Galí and Monacelli (2002) questioned the seminal arguments of Ball (1997) and Svensson (2000) supporting exchange rate smoothing. Applying microfounded models capable of welfare analysis CGG and GM argued that the existence of the exchange rate channel does not theoretically imply any reason for exchange rate smoothing. In their frameworks, there are only quantitative differences between closed and open economy monetary policy problems: the exchange rate channel makes the aggregate demand more responsive to interest rate policy and it increases the importance of output gap stabilization. But as the exchange rate variability causes no distortions in these models, there are no reasons for any nominal exchange rate smoothing, or for stabilization of wider inflation aggregates than domestic inflation.

Justification for exchange rate smoothing, however, reappears in the microfounded models as well, if the various potential welfare distortions caused by exchange rate volatility are also considered. Benigno and Benigno (2001), for example, argued for the positive welfare effects of exchange rate smoothing in a two country open economy model. In their model, deviations from the flexible terms of trade – resulting from excess nominal exchange rate fluctuations and sticky prices – cause distortions in production among the countries, leading to lower joint welfare. According to their centralized welfare criterion, rules with interest rate smoothing and explicit reactions to exchange rates – similarly to the one estimated in this paper – can approximate the first best optimal policies.

Microbased models considering only the welfare of an individual country have also found justifications for exchange rate smoothing. One line of recent research, for example, justified it by the welfare consequences of imperfect exchange rate pass-through – a general finding in empirical works (see e.g. Campa and Goldberg, 2004) –, which makes the producers' profits dependent on the exchange rate development. Corsetti and Pesenti (2001) found reasons for exchange rate smoothing in their two-country open-economy framework, and similar results were replicated in small open economy models as well. McCallum and Nelson (2001), for example, consider imports as inputs for production, which implies that exchange rate development influence the costs of production. Excess volatility of the exchange rate reduces welfare, because in the sticky price framework firms adjust their prices only gradually. Optimal monetary policy is found to smooth exchange rate also in the small open economy model of Monacelli (2003), which introduces imperfect pass-through to the model of Galí and Monacelli (2002) considering imports as consumption goods. The reason is that deviations from the law of one price due to imperfect pass-through cause welfare costs, which an optimizing monetary policy should counteract. Other justifications also exist in the current literature: in a novel example, Faia and Monacelli (2002) examine the role of external borrowing in a model with imperfect capital markets and find further justifications for exchange rate smoothing.

If one assumes that exchange rate stability is beneficial for welfare, the quantitative importance of a rule-based direct reaction to exchange rate development might increase further, as argued by Monacelli (2003). Rule-based decision-making can have important advantages in dynamic monetary policy settings, as, thereby, the central bank can have essential effects on expectations. Clarida, Galí and Gertler (1999) argued that a rule based policy can improve the short-run inflation-output tradeoff in case of persistent supply shocks. The reason is that the stronger interest rate response to shocks influences the inflation expectations by promising tough responses to further shocks. Woodford (1999), similarly, argues that the observed interest rate smoothing of central banks can be justified by assuming that they would like to meet their inflation and output targets without causing much interest rate volatility, which they can obtain by committing to a rule which helps them influence inflation expectations. Following these lines of reasoning, commitment to exchange rate smoothing might improve the efficiency of the central bank in influencing exchange rates by guiding exchange rate expectations. As an illustration, consider a generalized UIP equation with a persistent premium shock

$$s_t = E_t(s_{t+1}) + i_t + \mu_t,$$

where s_t is the nominal exchange rate, i_t is the interest rate differential and μ_t is the premium shock. Ruling out bubbles and solving the difference equation forward we can get:

$$E_t\left(s_t\right) = E_t \sum_{j=1}^{T} i_{t+j} + E_t \sum_{k=1}^{T} \mu_{t+k} + E_t s_T$$

showing that the expected exchange rate is influenced by an expected long term nominal exchange rate $(E_t s_T)$ and the expected interest rate determination and premium shock development up to date T. The UIP equation implies that by following an exchange rate smoothing interest rate rule, the monetary policy can influence the exchange rate (s_t) not only through the current interest rate differential (i_t), but also through the exchange rate expectations $[E_t\ (s_{t+1})]$. If one assumes that besides exchange rate stability, monetary policy also prefers smooth interest rate developments, it can improve the short-run trade-off between these two variables by committing to an interest rate rule which reacts to a premium shock more strongly, than its optimal discretionary counterpart.

Turning to the empirical results, in a widely recognized article, Calvo and Reinhart (2000) found overwhelming evidence about exchange rate smoothing – or with their words 'fear of floating' – in a wide range of open – mostly, but not exclusively emerging – economies. Examining volatilities and correlations of various variables, countries were shown to use direct foreign exchange market interventions and interest rate policy to avoid large exchange rate fluctuations. They present it as evidence supporting their claim that countries do not do what they actually say: despite the evidence of real life exchange rate smoothing, IMF classification shows a clear tendency towards floating exchange rate arrangements. But this evidence can be approached from a different angle: that countries tend to move towards reduced transparency about their exchange rate policy. A floating exchange rate regime, by itself, is a non-transparent arrangement, with no explicit information about any exchange rate target or accepted exchange rate volatility. This general tendency towards reduced transparency – with the notable exception in Europe – can be justified by the increasingly liberalized capital markets and the existence of speculative capital, which seem to have contributed to the excess exchange rate volatility in countries with transparent arrangements (Obstfeld and Rogoff, 1995b). The reduced transparency, thereby, might be seen as a further measure to contribute to the smooth development of the exchange rate.

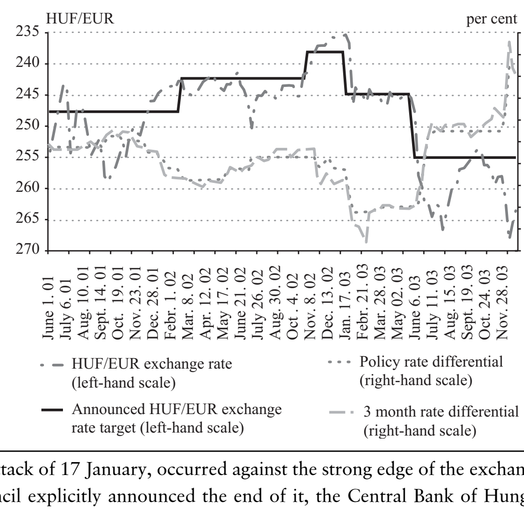
In a seminal paper estimating monetary policy rules in the G3 (US, Japan, Germany) and E3 (UK, Italy, France) countries, Clarida, Galí and Gertler (1997) also find evidence for exchange rate smoothing, especially in the E3 countries. In their estimated interest rate rules with reactions to anticipated inflation, and output gap, they also examined the role of exchange rate or – which also implies exchange rate smoothing – the interest rate of a partner country. They have found some, but quantitatively not important evidence for exchange rate smoothing among G3 countries, but this effect was much stronger among the E3 countries and Germany, which eventually initiated a 'hard ERM' policy with fixed exchange rates. In a more recent paper, Mohanty and Klau (2004) examined robust interest rate rules in 13 emerging countries containing also an exchange rate term. The significant estimated exchange rate depreciation terms make the authors conclude that their result support the hypothesis of exchange rate smoothing or 'fear of floating' in these countries.

4.3 Estimates using announced targets

The verbal announcements of the central banks about their preferred exchange rate target, if they are specific enough, can provide a straightforward proxy for the unobserved exchange rate target variable. By announcing its exchange rate target, the central bank, on the one hand, might be able to influence expectations and thereby might gain some leverage over the exchange rate developments. On the other hand, however, announcing explicit exchange rate targets can have serious drawbacks, as they can easily be mistaken as nominal anchors potentially in conflict with other anchors (e.g. inflation target), and an explicit target – as a fixed exchange rate – could provide a focal point for speculation against the exchange rate. But if the central bank chooses to announce its exchange rate target, announcements, in most cases, might be considered truthful, as it can be assumed that reputational considerations prevent central banks from lying to financial markets with fast learning abilities. It might be noted, though, that even if the announcements are considered truthful, their influence on the rates and market expectations might be limited, as the ability and willingness of the central bank to influence exchange rates might be considered questionable by market participants.

The central bank of Hungary was unusually explicit about its preferred exchange rate target even after abandoning its narrow band crawling peg exchange rate regime in May 2001. Functioning in a 'shadow ERM II' ±15% exchange rate band and following inflation targeting, it periodically announced an exchange rate target it considered preferable and in line with its inflation targets. It maintained this policy of exchange rate transparency up until the end of 2003, when it fully abandoned it. Using the Statements by the Monetary Council, a periodically changing exchange rate target variable can be put together from June 2001 till December 2003.[1] Figure 4.1 shows the

FIGURE 4.1 The exchange rate, the announced target and interest rates (June 2001 –December 2003, weekly data)



[1] Between the speculative attack of 17 January, occurred against the strong edge of the exchange rate band, and 26 May 2003, when the Monetary Council explicitly announced the end of it, the Central Bank of Hungary intervened in the exchange market by gradually reselling the euro it bought during the attack. Although, there were no announcements about any new preferred exchange rate, the behavior of the CB on the exchange market provided clear price signals about a preferred exchange rate around 245 HUF/EUR.

weekly announced preferred exchange rate of the Central Bank of Hungary together with the HUF/EUR exchange rate, the policy rate differential[2] and the difference between the 3 month interbank lending rates.

The graph shows the close relationship between the announced target and the exchange rate. However, there were periods – during the second half of 2001 (the financial crisis in Argentina) and in 2003 (after the devaluation of the forint exchange rate band), for example – when there were significant gaps between the exchange rate and the announced target. In these periods, we can also observe higher interest rates suggesting some exchange rate smoothing behavior of the central bank.

To examine the relationships formally, Phillips-Hansen fully modified OLS method is applied, as it is a robust methodology handling the facts that 1) the variables follow unit root processes (see appendix 4.7), 2) the shocks can be autoregressive and 3) simultaneity is expected to exist between exchange rate and interest rate developments (see Phillips and Hansen, 1990). The exchange rate equation is estimated in the following unrestricted form:

$$s_t = \alpha + \gamma i_t + \chi s_t^* + \delta s_{t-1} + \mu_t, \tag{1}$$

where s_t is the exchange rate, i_t is the interest rate differential, s_t^* is the announced exchange rate target, and μ_t is a premium shock.[3] The parameter χ measures the immediate effect of the target on the exchange rate, while the framework – by including a lagged exchange rate term, and allowing persistent shocks – allows for a gradual adjustment to this exchange rate target. The estimation results of the exchange rate equation using short term interest rates with 2 week and 3 months maturities are presented in Table 4.1.

The results show significant effects of the announced exchange rate targets on the exchange rate, even allowing for the appearance of the lagged exchange rate in the equation. The sum of estimated coefficients $(\chi+\delta)$ of the exchange rate terms, furthermore, does not significantly differ from 1 according to the fully modified Wald test supporting the view that the exchange rate would fully adjust to the target level under 0 interest rate differential (though the marginally significant constant terms might cast some doubts for this result). The results show gradual, but relatively fast adjustment to the target level (approximately one third of the difference disappears weekly). The stability properties of the estimated coefficients are not straightforward, but overall acceptable using the stability tests of Hansen (1992).[4]

[2] The difference between the interest paid on 2 week deposits by the CBH and the 2 week refinancing rate of the ECB.

[3] The announced target (s_t^*) might exert its influence on the exchange rate through direct channels – if the central bank intervenes in the foreign exchange market – or indirectly – through its effect on expectations. As for direct interventions, the Central Bank of Hungary stressed during the period that it refrains from using direct interventions in the foreign exchange market to influence rates inside its ±15% exchange rate band, but it intervenes at the edges of the band. The unsuccessful speculative attack against the strong edge of the exchange rate band in 17-18 January forced it to buy excessive amounts of euros and in the following period up until 26 May 2003, it was present in the foreign exchange market to resell a good part of this amount. Except for this period, however, influence of the exchange rate targets on the exchange rates can be expected to be exerted through influencing expectations by the credible promise of sustained exchange rate smoothing policies.

[4] The presented LC tests do not reject the null hypotheses of stability at 5% significance for any of the equations. One of the two – not shown – other tests (meanF test) can never reject the null of stability at usual significance levels, though the other test (SupF test) rejects it always at the 1% level.

TABLE 4.1 Estimates of the exchange rate equation using announced targets (June 2001–December 2003, weekly data)

Dependent			**Explanatory variables**		**Stability tests**
log(hufeur)	const	dif2w	**log(hufeurt)**	log(hufeur[-1])	LC
	-0.428**	0.010	**0.34*** **	0.739***	0.606*
std.dev.	(0.180)	(0.062)	**(0.053)**	(0.043)	
log(hufeur)	const	dif3m	**log(hufeurt)**	log(hufeur[-1])	LC
	-0.323*	0.064	**0.349*** **	0.709***	0.51
std.dev.	(0.179)	(0.055)	**(0.052)**	(0.043)	

***** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

The interest rate rule is estimated in the following unrestricted form[5]:

$$i_t = \lambda + \rho i_{t-1} + \beta s_t + \kappa s_t^* + \eta_t \tag{2}$$

The parameter ρ represents interest rate (differential) smoothing. If $\beta=-\kappa$, then the estimation does not reject the hypothesis that it is the exchange rate gap term that influences the interest rate determination. The process η_t follows is not determined ex ante, it can be expected to follow an autocorrelated process, as the central bank made decisions about interest rates in every two weeks up until the summer of 2004, when it switched to monthly decisions.

The results with different short term interest rates are presented in Table 4.2. The results show that the announced exchange rate target has significant effects on the short term interest rates. They also give some support that its effect is exerted through the exchange rate gap: the $\beta=-\kappa$

TABLE 4.2 Interest rate differential rules using announced targets (July 2001–December 2003, weekly data)

Dependent			**Explanatory variables**		**Stability tests**
dif2w	const	dif2w(-1)	log(hufeur)	**log(hufeurt)**	LC
	-0.135**	0.937***	0.09**	**0.065** **	1.393***
std.dev.	(0.063)	(0.020)	(0.012)	**(0.026)**	
log(hufeur)	const	dif3m(-1)	log(hufeur)	**log(hufeurt)**	LC
	-0.215***	0.901***	0.105***	**0.065*** **	2.94***
std.dev.	(0.059)	(0.017)	(0.014)	**(0.019)**	

***** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

[5] Using the interest rate differential, though unusual, offers an acceptable simplification. In small open economies, foreign interest rate can be considered exogenous (it does not react to the monetary policy of the observed country), and if the central bank is interested in influencing the exchange rate, it is the interest rate differential that matters. Furthermore, in many cases, and certainly in Hungary during the period, the foreign interest rate was substantially less volatile than the domestic one, so the volatility of the differential mainly comes from the decisions of the domestic central bank.

hypothesis cannot be rejected at the 5% level for the policy rate differentials, though it is rejected for the 3 month rates. The estimated effects of exchange rate gap on interest rates are also significant economically: a 5% gap would increase the interest rate by approximately 50 basis points. It should be noted, though, that the tests reject the stability of the equations, which might be the result of changes in policy or missing variables.

The results applying the exchange rate target announcements of the Central Bank of Hungary broadly support our framework and the hypothesis of exchange rate smoothing. The interest rate determination, according to the results, was significantly influenced by the exchange rate gap meaning that the monetary policy lived up to its periodically changing exchange rate announcements and systematically determined its interest rates accordingly. The announced exchange rate targets, furthermore, had important influence on the exchange rate determination. A problem with using announced preferred exchange rate targets, however, is that it is not available in many countries which use their interest rate policies to influence exchange rate determination, as it is also unavailable in Hungary after the end of 2003, when the Central Bank of Hungary stopped announcing any preferred exchange rate explicitly.

4.4 Unobserved variable framework

If announcements about the exchange rate target are unavailable, unobserved variable methods can be used to gain estimates about their development using information inherent in observables, like the interest rate or the exchange rate. The method can also provide simultaneous estimates of the parameters of the interest rate rule and exchange rate equation consistent with this target.

The exchange rate equation is assumed to take the following form:

$$s_t = \gamma i_{t-1} + \chi s_t^* + (1-\chi)\, s_{t-1} + \mu_t, \tag{1'}$$

where $s_t{}^*$ here stands for the unobserved implicit (medium term) exchange rate target of the central bank. The market participants are assumed to form rational expectations about this target.[6] The equation allows gradual adjustment to this medium term target (but by constraining the parameter of the lagged term it requires it to be complete). The error term μ_t is considered an unobserved premium shock. The equation contains the lagged interest differential for primarily technical reasons[7], but can also be justified by portfolio adjustment lags. Notice that though equation 1' assumes that the direct interest rate effect is lagged, the signalling effect of an interest rate move has immediate influence on the exchange rate.

The interest rate (differential) equation is assumed to take the following form:

$$i_t = \rho i_{t-1} + \beta(s_{t-1} - s_t^*) + \eta_t, \tag{2'}$$

[6] Rational expectations imply that market participants are assumed not to make systematic errors when forming expectations about the exchange rate target. Formally $s_t^* = s_t^{*e} + e_t$, where e_t is a white noise process. If we assume that this target-expectation influences the current exchange by affecting future exchange rate expectations according to the following equation $s_t = \gamma i_{t-1} + \chi s_t^{*e} + (1-\chi)\, s_{t-1} + \mu_t'$ then equation 1' can be regained with $\mu_t = \mu_t' - \chi e_t$.

[7] Featuring the current endogenous observable variables among the explanatory variables makes the estimation substantially more complicated.

where the Central Bank of Hungary is assumed to modify its interest rate differential by reacting to the gap between the lagged exchange rate and its current exchange rate target. The reason of this – though it is also required by the Kalman filter – is that the regular interest rate decisions of the Central Bank of Hungary were made on Mondays during the period, so it was only a lagged exchange rate that it could have responded to.

The implicit exchange rate targets of the central bank (s_t^*) are unobserved and assumed to follow a random walk process:

$$s_t^* = s_{t-1}^* + \varepsilon_t \tag{3}$$

This assumption ensures that shocks to this target are permanent, and allows us to infer its value from past behavior of observed variables. Shocks to equations 1' (μ_t) and 2' (η_t) are also unobserved variables of the system assumed to follow first order autoregressive processes:

$$\mu_t = \varsigma \mu_{t-1} + \phi_t \tag{4}$$

and

$$\eta_t = \upsilon \eta_{t-1} + \psi_t, \tag{5}$$

where $0 \leq \varsigma,\ \upsilon \leq 1$. ε_t, ϕ_t and ψ_t are assumed to follow white noise processes with variances $\lambda\ \sigma_\phi^2, \sigma_\phi^2, \sigma_\psi^2$ respectively. Specification tests of the estimated system could not reject the hypothesis that the realised error terms are indeed white noise.

So, the estimated system consists of two observable variables: the nominal exchange rate (s_t) and the nominal interest rate (i_t) determined by (observation) equations 1' and 2', and three unobservable variables: the nominal exchange rate target s_t*, the premium shock to the exchange rate (μ_t) and the shock to the Taylor type rule (η_t) determined by (state) equations, 3, 4 and 5. The Kalman filtering method simultaneously estimates the 9 unknown parameters $(\gamma, \chi, \rho, \beta, \varsigma, \upsilon, \lambda, \sigma_\phi^2, \sigma_\psi^2)$ of the model and provide the best linear estimations for the unobserved variables using the available information up to that date (filtered estimates, $s_{t|t}^*, \mu_{t|t}, \eta_{t|t}$, where t is a date in the past), and using all information available in the sample (smoothed estimates, $s_{t|T}^*, \mu_{t|T}, \eta_{t|T}$ where T refers to the last element of the sample). The mean squared error matrix of the estimated unobserved variables are $P_{t|t}$ for the filtered estimates and $P_{t|T}$ for the smoothed estimates.

The matrix representation of the state space system – following the notation of Hamilton (1994) – is going to be presented. The state equation is:

$$\xi_t = F\xi_{t-1} + v_t,$$

where

$$\xi_t' = \begin{bmatrix} s_t^* & \mu_t & \eta_t \end{bmatrix}$$
$$F = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \zeta & 0 \\ 0 & 0 & \upsilon \end{bmatrix}$$
$$E\left[v_t v_t'\right] = Q = \begin{bmatrix} \lambda\sigma_\phi^2 & 0 & 0 \\ 0 & \sigma_\phi^2 & 0 \\ 0 & 0 & \sigma_\psi^2 \end{bmatrix}.$$

And the observation equation is

$$y_t = A'x_t + H'\xi_t,$$

where

$$y_t' = \begin{bmatrix} s_t & i_t \end{bmatrix}$$
$$x_t' = \begin{bmatrix} s_{t-1} & i_{t-1} \end{bmatrix}$$
$$A' = \begin{bmatrix} 1-\chi & \gamma \\ \beta & \rho \end{bmatrix}$$
$$H' = \begin{bmatrix} \chi & 1 & 0 \\ -\beta & 0 & 1 \end{bmatrix}.$$

The assumption of random walk target development introduces unit root to the state equation, which hinders the application of standard asymptotic theory developed by assuming stationarity (e.g. Hamilton, 1994). But stationarity is not a necessary condition for asymptotic convergence of the estimator: Harvey (1990, pp. 210), for example, provides regularity conditions for the state space model ensuring the asymptotic convergence of the maximum likelihood estimator. These regularity conditions are satisfied in our model as it was shown in a related work by Csiszar (2005). A further sign of convergence of our estimator is that the mean squared error of the estimates of the unobserved variables ($P_{t\,|t}$ and $P_{t\,|T}$) show clear – and relatively fast – convergence to a fixed value.

The Kalman filter and its maximum likelihood estimation assume normality of the error terms, which might be questionable in our case both by observation of the data and by more formal approaches. The assumption of normality, for example, requires frequent small changes in the shocks with rare sizeable moves. As for the exchange rate target shock (ε_t), this requirement can be acceptable if the target is thought to change constantly as new information flows in. But for the shocks to the exchange rate premium (ϕ_t) and the interest rate rule shock (ψ_t) we can observe fairly stable periods and occasional sizeable moves not characteristic of the normal distribution. A further problem is that the shadow ERM II exchange rate regime truncates the possible values of both the exchange rate target and the premium shocks. White (1982) suggested a test for distributional misspecification building on the fact that in case of correct distributional specification the estimated Hessian of the maximum likelihood function at the optimum is equal to the negative of the outer product of the gradient at the same point. In our case, the difference between these two matrices suggests distributional misspecification. But, as it was shown by White (1982), even if the normality assumption does not hold, maintaining it in the so called quasi-maximum-likelihood framework can provide consistent parameter estimates, though the estimator will not be efficient. The covariance matrix of the estimator, however, should be chosen and estimated differently from the normality case.

The results presented are obtained by using the 2 week policy rate differential, which is determined by the central banks without any expectation effects from the markets. But it should be noted that the 3 month interbank rate differentials result in very similar results both in parameter values and estimated exchange rate targets (not shown).

Obtaining valid starting values for the parameters and the state variables are important tasks of the estimation. Not surprisingly, the robustness and the convergence properties of the estimator improves significantly, if the value of λ – determining the proportion of variance of the exchange rate premium shock and that of the target – is restricted, so this restriction can be used to obtain starting parameter values. The volatility of the announced target change between July 2001 and December 2003 is one fifth of the volatility of the exchange rate change. By restricting λ to 0.2, two different (local) maximum with similar values of log likelihood can be obtained (see appendix 6.2). The estimated interest rate (differential) rules are fairly similar, the main difference between the two system is the relative weight given to the exchange rate target in the exchange rate equation. While the weight is below 0.1 in the first system, it is almost 0.9 in the second. It is only the second system of parameters, however, which stays robust after lifting the restriction on λ.

The estimated parameters and the obtained standard deviation assuming normality (stdev MLE) and using the robust standard errors suggested by White (1982) (stdev QMLE)[8] for Hungary are presented in Table 4.3.

The results support the hypothesis that the implicit exchange rate target influences both the interest rate and the exchange rate determination. The interest rate differential rule finds a weekly interest rate smoothing parameter very close to 1 and the parameter on the exchange rate gap implies that, on average, a 5% gap results in an approximately 20 basis points change. The total interest rate response to an exchange rate gap can be obtained by cumulating the periodic interest rate moves to the gradually closing gap. The error term of the interest rate differential rule is found slightly autocorrelated, probably resulting from the fact that regular interest rate decisions were made in every two weeks up to May 2004 and monthly afterwards. The parameter of the exchange rate target term in the exchange rate equation – differently from the estimates using the announced targets – does not significantly differ from 1, suggesting very fast convergence to the estimated exchange rate target. The parameter of the interest rate, however, – contrary to the UIP hypothesis – has the wrong sign and is insignificant.

The Kalman filtering provides optimal periodic estimates for the implicit exchange rate target of the central bank using the development of the observed variables and assuming that the

[8] The differences between the standard errors are substantial as a sign of the already mentioned distributional misspecification. The robust covariance estimator suggested by White (1982) implies extremely significant parameters. But we cannot rule out that it underestimates the true covariance matrix (as Wooldridge, 2002, pp. 396. notes, the outer product estimator of the information matrix can be poorly behaved in even moderate samples), we presented the standard errors assuming the errors were normal.

TABLE 4.3 **Unobserved variable estimation (May 2001–December 2004, weekly data)**

Dependent		**Explanatory variables**			**Error term**
dif2w	dif2w(-1)	**log(hufeur[-1]/hufeurt)**		ar(1)	log(stdev)
	0.994***	**0.037****		0.285***	-11.93***
stdev MLE	(0.013)	**(0.018)**		(0.072)	(0.106)
stdev QMLE	(3.4E-07)	**(2.1E-07)**		(2.1E-06)	(4.0E-07)
log(hufeur)	dif2w(-1)	**log(hufeurt)**	log(hufeur[-1])	ar(1)	log(stdev)
	0.104	**0.867*****	0.133	0.933***	-9.65***
stdev MLE	(0.249)	**(0.083)**	-	(0.047)	(0.162)
stdev QMLE	(7.2E-06)	**(1.3E-06)**	-	(1.1E-06)	(4.9E-06)
log(hufeurt)		log(hufeurt[-1])			lambda
		1.000			0.192
stdev MLE		-			(0.169)
stdev QMLE		-			(4.9E-06)

**** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

parameters are as estimated previously. The functioning of the filter is intuitive. In every period, using the current estimate of the unobservables, the filter formulates forecasts of the observable interest rate and exchange rate for the next period. If the interest rate and exchange rate develop according to these forecasts, there are no reasons to update the beliefs on the exchange rate target, the exchange rate premium shock, or the interest rate rule shock. If there is a surprise caused by an unexpected interest rate or exchange rate move, however, it is optimal to change the beliefs about the unobserved variables. But as the reason for the unexpected move is unknown, it is optimal to attribute it partly to all of the unobservables depending on the uncertainties of their development. The Kalman filter solves this complicated signal-extraction exercise and provides estimates about the expected exchange rate and interest rate reaction to these unexpected shocks.

Formally, the essence of Kalman filtering is the optimal updating of a linear projection using the information obtained from the development of the observables. In our framework, this updating happens as (for details, see Hamilton, 1994):

$$\widehat{\xi}_{t|t} = \widehat{\xi}_{t|t-1} + Z_t \left(y_t - \widehat{y}_{t|t-1} \right), \tag{6}$$

where

$$Z_t = P_{t|t-1} H \left(H' P_{t|t-1} H \right)^{-1}$$

and

$$\widehat{y}_{t|t-1} = A' x_t - H' \widehat{\xi}_{t|t-1}.$$

The updating equation has the intuitive feature that the estimates of the unobserved variables $\left(\widehat{\xi}_{t|t}\right)$ change only if there is a surprise in the development of the observed variables $y_t - \widehat{y}_{t|t-1}$ and the effect of the surprise is influenced by the effect of the unobserved variables on the observables *(H)* and the potentially time-varying mean squared error of the prediction of the state variables $\left(P_{t|t-1}\right)$. It is straightforward to see that

$$\widehat{\xi}_{t|t-1} = F\widehat{\xi}_{t-1|t-1}$$

and substituting it to provides us with the following equation showing how periodic estimates $\left(\widehat{\xi}_{t|t}\right)$ are updated using the new information:

$$\widehat{\xi}_{t|t} = F\widehat{\xi}_{t-1|t-1} + Z_t\left(y_t - \widehat{y}_{t|t-1}\right). \tag{7}$$

The value of Z_t because of its already mentioned fast convergence, gets constant soon and gets equal to:

$$Z = \begin{bmatrix} 0.304 & -0.874 \\ 0.737 & 0.758 \\ 0.011 & 0.968 \end{bmatrix}.$$

The first row of the matrix implies that a 1 percentage point surprise increase in the interest rate results in a 0.87 percent appreciation of the estimated exchange rate target. This effect is substantially larger than the effect of an expected interest rate move (see later). The matrix also shows that a 10 Ft (approximately 4 percent) surprise depreciation should lead to a depreciated target expectations by around 3 Ft. The second row determines the effects on the estimated values on the shocks $\mu_{t|t}$ and $\eta_{t|t}$.

The filtered (or one-sided) estimates of the exchange rate target of Hungary only use information available up to the period, and the smoothed (two-sided) estimates use all the available information. The estimates and their standard error bands together with the monthly one-year-ahead exchange rate expectations of market analysts surveyed by Reuters are shown in Figure 4.2, while *Figure 4.3* presents the development of the closely related surprise series $\left(y_t - \widehat{y}_{t|t-1}\right)$ for the exchange rate and the interest rate.

According to the filtered estimates, the exchange rate target gradually appreciated up to the end of 2002, and was fairly in line with the exchange rate development during the second half of 2002. The significant interest rate reductions and exchange rate depreciation in January 2003, however, depreciated the estimated implicit exchange rate target, which dropped further in May and June following the devaluation of the ±15% exchange rate band. It should be noted though that the estimation considers the substantial depreciation of the forint in June mostly as a premium shock, with only limited effects on the exchange rate target. These results are in line with the structural VAR estimation of Vonnák (2005), identifying a significant risk premium shock in June 2003, but no significant monetary policy shock in that month (compare with Figure 4.3). The premium shock was counteracted by the substantial interest rate moves of the Central Bank of Hungary in June and later in November with appreciating effects on the estimated targets. Around the beginning of 2004, the estimated target stabilised around 250 Ft/euro, and in the second half of 2004 it even appreciated somewhat, developing broadly in line with the exchange rate.

FIGURE 4.2 HUF/EUR exchange rate, the estimated targets and the Reuters expectations

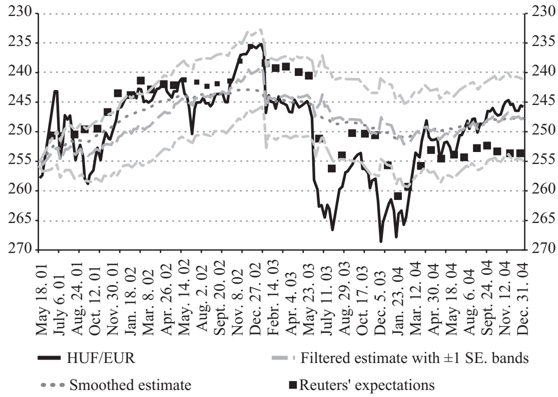
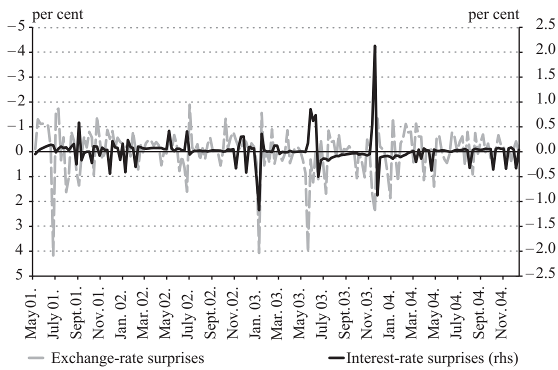


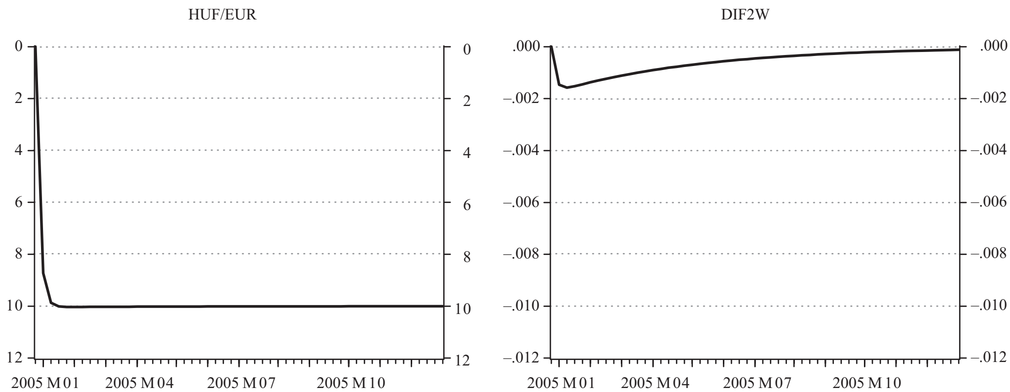
FIGURE 4.3 Forecast errors (surprises) in the observed exchange rate and interest rate developments (May 2001–December 2004, weekly data)



As the market participants are assumed to use at least as many information for developing their expectations about the exchange rate target as the applied model, the estimated exchange rate target is also an estimate for the market expectation of the exchange rate target. Reuters prepare monthly survey in Hungary among market participants about their exchange rate expectations. It might be instructive to compare their average expectations to the estimated targets. The graph contains an implied expected exchange rate 1 year after the survey, which might be considered a proxy for the expected target value. Figure 4.2 shows that the Reuters expectations were more volatile than the estimated implicit target, but the development of the two series are – in most cases – broadly in line, and the framework seems to capture the most important driving forces of these expectations.

The estimated system also allows the assessment of the exchange rate and interest rate responses to known shocks to the exchange rate target (exchange rate target shock), to the interest rate rule (interest rate rule shock), and to the exchange rate equation (premium shock). Consider first a known 10 Ft (approximately 4%) permanent change in the implicit exchange rate target. Figure 4.4 presents impulse responses about the development of the exchange rate and the interest rate.

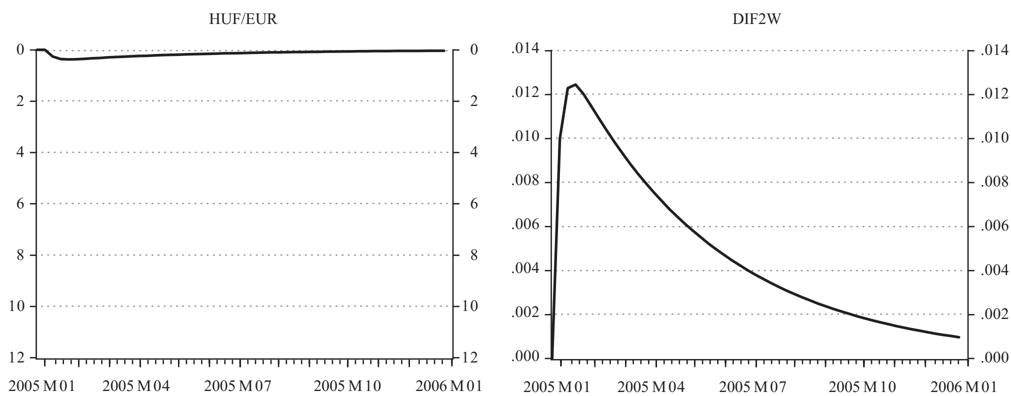
FIGURE 4.4 Exchange rate target shock



The high parameter of the exchange rate target in the exchange rate equation ensures that a known change in the target results in a very fast adjustment of the exchange rate to the new target, and, thereby, the small exchange rate gap will have no significant influence on the interest rate determination. It has to be noted, though, that the central bank might not have direct means to make a target-change fully known, it might need to signal it by observable interest rate – or exchange rate – movements. If it is the case, substantial unexpected interest rate move is necessary to make the public update its previous target estimate. If the interest rate were the only way for the central bank to signal its knew exchange rate target, the order of the necessary move is estimated to be much higher than under a known target change: for a 1% depreciation of the exchange rate, 1.15% surprise interest rate reduction is necessary ceteris paribus.

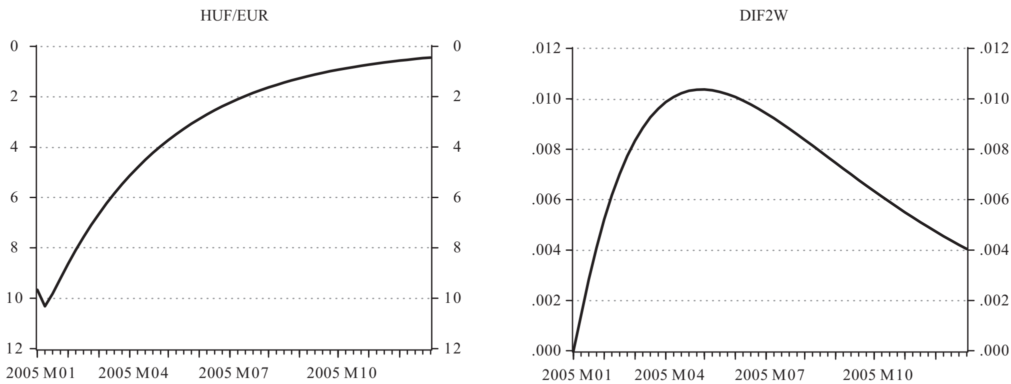
Figure 4.5 shows what happens to the exchange rate and the interest rate, if there is a *known* 1 percentage-point shock to the interest rate unrelated to the exchange rate gap. The graph shows that a shock like that has a very muted estimated effect on the exchange rate (with the wrong sign). The reason is that the shock has no effect on the target-expectations, and the direct effect of the interest rate is estimated to be very small.

FIGURE 4.5 An interest rate rule shock



The third presented shock (in Figure 4.6) is a premium shock hitting the exchange rate and resulting in a 10 Ft immediate depreciation. Afterwards, the shock is allowed to disappear with its estimated average autocorrelation coefficient. The monetary policy responds to the opening of the exchange rate gap (its target is assumed to stay constant) and, as the impulse responses show, the interest rate increase is estimated to reach 50 basis points in the first month and gradually increases over 1 percentage point in the first 4-5 month before it starts decreasing. The behavior of the shock is similar to the obtained impulse responses of a risk premium shock of Vonnák (2005).

FIGURE 4.6 **A premium shock**



4.5 Conclusion

The paper proposed and successfully applied an unobserved variable framework simultaneously estimating an interest rate (differential) rule and an exchange rate equation for Hungary. The framework provided evidence for exchange rate smoothing in Hungary since the widening of the exchange rate band in May 2001 by estimating a smoothly developing unobserved implicit target and showing that the interest rate policy reacted to the deviation of the exchange rate from this target. The model was used to gain estimated interest rate and exchange rate responses to exchange rate target and exchange rate premium shocks. The framework also identified why unexpected interest rate moves have stronger exchange rate effects: they make the market participants update their previous beliefs about the central bank's exchange rate target.

The framework applying the Kalman filter assumes normality of the development of the exchange rate target and interest rate shocks. This assumption seems to be restrictive resulting in an inefficient estimation. Assuming more general – stable – distributions for the error term of the exchange rate target and applying the more general Sorenson-Alspach filter might generate more efficient estimation with estimated exchange rate targets potentially closer to the announced one: with low volatility for prolonged periods with occasional substantial changes.[9] The estimates might also be made more realistic by allowing for ARCH disturbances (see Csiszar, 2005). The framework, furthermore, is flexible enough to include the effects of more fundamental variables – like

[9] The approach was successfully applied to estimate inflation targets of the US Federal Reserve, and forecast US inflation by Bidarkota and McCulloch (1998).

inflation and output gap – on the interest rate rule and exchange rate target developments, which was not possible for the application to Hungary because of the lack of sufficient data. A clear potential route for future research is to apply the framework to a wider set of countries with longer periods of consistent policies.

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4.7 Appendix

Unit root tests

TABLE 4.4 **Unit root tests**

Variables	PP q=4	ADF p=0	ADF p=10	ADF p=20	KPSS	Trend	Process
log(hufeur)	-2.47	-2.32	-2.31	-1.74	0.34	N	I(1)
SIC		-6.62	-6.56	-6.39			
dlog(hufeur)	-12.56***	-12.59***	-4.56***	-2.8*	0.11	N	
SIC		-6.6	-6.55	-6.37			
log(hufeurt)	-0.87	-0.66	-0.92	-1.6	0.49**	N	I(1)
SIC		-8.04	-7.61	-7.28			
dlog(hufeurt)	-9.92***	-9.94***	-4.09***	-1.64	0.24	N	
SIC		-8.05	-7.65	-7.24			
difpr	-1.34	-1.03	-1.64	-1.32	0.81***	N	I(1)
SIC		-8.86	-8.67	-8.35			
d(difpr)	-9.57***	-9.59***	-3.48***	-3.12**	0.11	N	
SIC		-8.97	-8.65	-8.34			
dif3m	-1.31	-1.15	-1.84	-1.5	0.79***	N	I(1)
SIC		-8.43	-8.19	-7.86			
d(dif3m)	-11.96***	-11.93***	-3.08**	-2.63*	0.13	N	
SIC		-8.44	-8.17	-7.84			

**** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

PP is the Phillips-Perron, ADF is the adjusted Dickey-Fuller and KPSS is the Kwiatkowky-Phillips-Schmidt-Shin unit root tests. As the PP and the ADF tests have null-hypotheses of an existing unit root, significant test-statistics signal integration, while the null of the KPSS test is the stationarity of the time-series, so its insignificance shows integration. The q and p parameters show the lags used in the test equations.

Obtaining the starting values

The system was estimated using the Gauss code provided by Hamilton, applying the BFGS algorithm for optimization. The starting values of the parameters and of the forecasts ($\xi_{1|0}$) and mean squared errors ($P_{1|0}$) of the state variables are essential part of the estimation. To obtain the results presented in the paper the starting values were chosen as:

$$\xi'_{1|0} = \begin{bmatrix} \ln(260) & 0 & 0 \end{bmatrix}$$

and

$$P_{1|0} = \begin{bmatrix} 0.001 & 0 & 0 \\ 0 & 0.000001 & 0 \\ 0 & 0 & 0.00001 \end{bmatrix}.$$

The starting parameter values were obtained by running the algorithm in the system, where the value of λ, which determines the proportion of volatility of the exchange rate target shock and the UIP premium shock, were restricted to 0.2. The following two tables show the obtained two sets of parameter values and the values of the log likelihood. It shows that while the estimated interest rate differential rules are fairly similar, there is a substantial difference between the estimated parameter of the effect of the estimated exchange rate target on the development of the exchange rate: in the first estimation the parameter is below 0.1, while it is almost over 0.9 in the second estimation.

TABLE 4.5 **Restricted unobserved variable estimation no. 1. (June 2001 – December 2004, weekly data)**

Dependent	Explanatory variables		Error term	
dif2w	dif2w(-1)	**log(hufeur(-1)/hufeurt)**	ar(1)	log(stdev)
	0.979***	**0.046****	0.281***	-11.96***
stdev	(0.030)	**(0.021)**	(0.074)	(0.102)
log(hufeur)	dif2w(-1)	**log(hufeurt)**	ar(1)	log(stdev)
	0.028	**0.089****	0.146*	-9.54***
stdev	(0.052)	**(0.037)**	(0.080)	(0.102)
Value of log likelihood:		**1505.52**		

**** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

TABLE 4.6 Restricted unobserved variable estimation no. 2. (June 2001 – December 2004, weekly data)

Dependent	Explanatory variables		Error term	
dif2w	dif2w(-1)	**log(hufeur(-1)/hufeurt)**	ar(1)	log(stdev)
	0.994***	**0.037****	0.285***	-11.93***
stdev	(0.010)	**(0.015)**	(0.072)	(0.105)
log(hufeur)	dif2w(-1)	**log(hufeurt)**	ar(1)	log(stdev)
	0.102	**0.867****	0.932*	-9.96***
stdev	(0.184)	**(0.082)**	(0.044)	(0.105)
Value of log likelihood:		**1502.67**		

**** significant at 1% level, ** significant at 5% level, * significant at 10% level.*

This second set of parameters were accepted as initial parameter values for the unrestricted estimates with the values:

$$\begin{pmatrix} \gamma \\ \chi \\ \rho \\ \beta \\ \varsigma \\ \upsilon \\ \lambda \\ \sigma_\phi^2 \\ \sigma_\psi^2 \end{pmatrix} = \begin{pmatrix} 0.102 \\ 0.867 \\ 0.994 \\ 0.037 \\ 0.932 \\ 0.285 \\ 0.200 \\ \exp(-9.66) \\ \exp(-11.93) \end{pmatrix}$$

5. The role of the housing market in monetary transmission

Gergely Kiss and Gábor Vadas

5.1 Introduction

Housing may be considered mundane, an ordinary part of a household's everyday life. However, it can also be a rather complex economic phenomenon, as dwellings can have several functions. Apart from being the traditional 'roof over one's head', a house can serve as a source of wealth accumulation, a valuable item for bequest motives, or a form of investment. Another distinctive characteristic of housing is its sizeable share in household wealth, implying its importance in the household's decision-making process. As a result, shocks to the housing market can have a significant impact on household behaviour, and on the economy as a whole.

The housing market is more complex than the consumption goods market in a number of ways. Not only are the standard economic agents present; other institutions, such as mortgage markets and governmental subsidy/tax regimes, also play a role. Due to the complex interactions among these agents, it is important for policymakers to understand the mechanisms that drive housing market dynamics.

Taking note of the aforementioned distinctive role of dwellings, we attempt to analyse the role of the housing market in the Hungarian monetary transmission, as part of the monetary transmission studies of the Magyar Nemzeti Bank. Section 2 provides stylised facts about the housing markets of developed countries and gives a brief description of the Hungarian housing market. Section 3 provides an overview of the theoretical background of transmission through the housing market. Section 4 presents the empirical estimates, for Hungary, of the effect of interest rates on the behaviour of the household sector. Section 5 discusses the expected effects of the single monetary policy of the eurozone on the Hungarian markets. Finally, Section 6 presents the conclusions.

5.2 Stylised facts

The first part of this section describes the main features of the housing and mortgage markets in a set of developed, mainly European, countries and then attempts to show the relevance of these structural factors in the monetary transmission mechanism. The second part presents a brief history of the Hungarian housing market.

We thank Gábor Kátay, Gábor Kézdi, István Kónya, Balázs Vonnák and the participants of the MNB presentation for discussions and very useful comments.

Housing markets in developed countries

Mortgage regimes play an important role in determining the key indicators of housing markets in developed countries. Three different types of mortgage regimes, namely fixed callable, fixed non-callable and variable, can be found in developed countries. Most countries can be characterised by the dominance of a particular type that has, historically, become the most relevant. Grouping the countries according to mortgage regimes, the following table summarises the major characteristics of the housing and mortgage markets in a number of developed, mainly EU, countries.

TABLE 5.1 Key mortgage and housing indicators in developed countries (2001)

Countries	Dominant type of mortgage	Mortgage/GDP (%)	Average LTV* (%)	Owner occupation (%)
Denmark	Fixed callable	67	80	59
US		58	78	68
Germany	Fixed non-callable	47	70	39
Netherlands		74	112	53
France		22	60	58
Italy		10	55	69
UK	Variable	60	70	68
Ireland		30	60-70	78
Portugal		47	70-80	64
Spain		32	80	85

** Loan-to-value.*
Source: ECB, OECD.

The first observation that can be drawn from the table is that, despite their similarities in terms of recent macroeconomic framework (low inflation, co-ordinated and stability-oriented economic policy), sound and liberalised financial systems, and a high standard of living, developed countries exhibit a surprisingly wide range of key mortgage and housing indicators.

Analysing the countries individually, Denmark and the US belong to the first group, which can be labelled as *fixed callable* mortgage markets. These highly efficient and mature financial markets are able to provide mortgage loans that have fixed interest rates for up to 10-15 years and have the flexibility needed for the early repayment of long mortgage loans. It is not surprising that very few countries belong to this group. Both the US and Denmark have above-average owner-occupation rates, as well as very high mortgage/GDP ratios, indicating the significant role of mortgages in the economy.

The second group consists of countries where the majority of the mortgage loans have *fixed interest rates,* but early repayment is constrained by high fees. Most of the continental European countries belong to this category, which can be further split into two subsets. The first subset is represented by Germany and the Netherlands, with both countries having a high level of mortgage loans. The historical commitment of policymakers to price stability in these countries has created a favourable environment for high turnover at low and fixed long-term interest rates. In other aspects, however, the two countries have some extreme features: the ratio of owner occupation is the lowest in Germany among all the countries in our survey, while the Netherlands has surprisingly high loan-to-value (LTV) ratios, on average exceeding 100% in the case of new mortgages[1].

In the second subset of countries with long fixed interest rates, the mortgage loans do not play an equally significant role in the economy. France and Italy belong to this group, with traditionally low mortgage debt/GDP ratios of 22% and 10%, respectively.

The mortgage markets in the third set of countries are characterised by *variable interest rates*. The UK has been the most traditional example of variable-rate mortgages, with a high mortgage debt/GDP ratio (60%), close to those in the first group. Apart from the UK, the fast growing mortgage markets of Portugal and Spain are also dominated by variable rates. These eurozone members benefit from low interest rates, considering that, prior to the nominal convergence, the high interest rates generated liquidity constraints for the majority of households. In Portugal, the mortgage debt/GDP ratio was 47% in 2001, equal to that of Germany, whereas a decade earlier, it was comparable to that of Italy (12%).

Evolution of the main indicators

The financial deregulation of the 1980s may be considered as a good staring point in examining the dynamics of mortgage markets. In the overwhelming majority of the EU countries, the deregulation of the mortgage markets started in the '80s, proceeding at different speeds across countries. The major steps generally included the abolition of interest rate ceilings on mortgage contracts, as well as the elimination of credit controls and contractual restrictions. Further measures were taken with the aim of liberalising entry into mortgage markets and the securitisation of mortgage loans.

In the short run, however, the quite similar deregulation measures did not lead to similar mortgage markets, but rather widened the set of available choices for new contracts in most countries. The primary reason why mortgage markets could keep their national characteristics for long was the very long maturity of the typical mortgage loan. Apart from the fact that deregulation can take effect only gradually through new contracts, the slow changes may be attributed to other factors as well. One explanation may be that the significantly different histories of inflation, and thus nominal interest rates, still have an impact on household decisions.

In the following sections, we attempt to highlight the most relevant trends of mortgage markets in the last decades and to present the stylised facts illustrating the interplay of mortgage markets with other key macroeconomic variables.

The mortgage debt/GDP ratio has increased substantially during the last 20 years in most of the developed countries. Whereas in the early '80s, the mortgage debt/GDP ratio exceeded 50% in only a few of the countries with the most developed mortgage markets (such as Denmark and

[1] The substantial incentives for mortgage payments in the tax regime provide an explanation for the extremely high LTV ratios in the Netherlands (see further discussion of the impact of tax regimes).

the UK), by 2001, nearly half of the countries in our sample recorded ratios around or above 50%. The average growth rates of mortgage debt/GDP ratios have varied through the different periods and also across countries. As already mentioned, the most dynamic growth in our sample was that of Portugal during the '90s, with an average growth of 15% per annum. During this period, Spain also recorded an annual growth rate above 10%. For the entire period of 1980-2001, the highest growth rate was slightly less, at 10%, also recorded in Portugal. On the other hand, there was basically no growth in the mortgage debt/GDP ratio of France during the entire period.

Analysing the dynamics of the mortgage debt/GDP ratios in a macroeconomic context, the changes can, to a large extent, be attributed to three major macroeconomic factors: changes in real house prices and interest rates, and the deregulation of the mortgage markets.

It is interesting to examine the interrelation between mortgage debt and house price growth in different countries (see Figure 5.1). The EU countries provide a wide set of combinations. In Portugal, for instance, the most dynamic growth of the mortgage debt/GDP ratio was not accompanied by any growth in real house prices in the '90s. By contrast, in Germany, where the mortgage debt/GDP ratio was already high in the '80s, real house prices were rather decreasing in the second half of the '90s, parallel with a mild increase in the mortgage debt/GDP ratio. Italy and the Netherlands show a third type of relationship: house prices and mortgages have been positively correlated. In Italy, house prices and the mortgage debt/GDP ratio showed a cyclical pattern following the economic cycle, the correlation having been broken by the yield convergence prior to the euro adoption which resulted in a pronounced growth of the mortgage debt/GDP ratio. In the Netherlands, the two indicators were growing basically parallel during the entire period, with a faster house price growth at the end of the period.

Changes in nominal mortgage rates had a clear effect on mortgage dynamics. The nominal interest rate of mortgage debt plays a crucial role in determining the liquidity constraint of households in EU countries, as loan indexation (see Section 3 for more details) had never been popular, for historical reasons, in these countries. Mortgage interest rates declined during the '90s in all countries, reaching historically low levels in a number of countries. The decrease in the nominal rates could be attributed partly to cyclical effects, which generated very low real interest rates globally from 2002 and, more importantly for a number of countries, to a drop in inflation rates and risk premium. The latter was especially significant in the case of South European eurozone countries during the nominal convergence process (see Figure 5.2).

The effect of the change in mortgage interest rates on liquidity constraints can be best illustrated by an example. Using the interest rates prevailing in 1995 and 2002 in different countries, given the example of a 20-year loan with fix nominal instalments, where 1/3 of the disposable income is spent on amortisation, we calculated the maximum amount of loan a household could take out. The change in the liquidity constraint, which is the difference between the maximum loan amounts in 1995 and 2002, can be expressed in terms of monthly income. The following table shows that the easing of the liquidity constraint was significant in all countries, and it had the greatest effect in the case of Portugal, Spain and Italy, explaining to a large extent the growth in the mortgage debt/GDP ratio.

The relevance of the effect of the nominal interest rate on mortgage dynamics can also be seen in the debt service of mortgage loans compared to disposable income. As Figure 5.5 (ECB 2003)

TABLE 5.2 Effects of decreasing yields on the liquidity constraint

Country	Change in the liquidity constraint (monthly income)
Portugal	20.6
Spain	20.2
Italy	19.6
Denmark	10.1
UK	9.8
Germany	6.8

Source: Own calculations.

shows,[2] despite the more dynamic growth of mortgage debt/GDP ratios, the mortgage debt service/disposable income ratio has increased only modestly in most countries due to the substantial easing effect of the lower nominal interest rates. As regards the effect of decreasing nominal and real interest rates, the BIS study by Debelle (2004) came to a similar conclusion based on calculations of the ratio of debt service of total household debt to disposable income.

Thus far, we could, to a large extent, explain the dynamics of mortgage debt/GDP ratios in an economic context in recent decades. However, the marked differences in the level of mortgage indebtedness across countries suggest that other factors (e.g. institutional, cultural) also play a role.

Mortgage regulations are basically not yet harmonised in the EU. There are still barriers to further integration, as identified by the Forum Group on Mortgage Credit (2004), and the level of cross-border activity is low compared to other segments of the financial sector. The regulatory and institutional differences appear to be due to differences in characteristics of mortgage regimes; rather surprisingly, these differences are less reflected in mortgage interest rates across regimes in the eurozone member countries. Due to yield convergence in the second half of the '90s (see Figure 5.3), the standard deviation of mortgage rates within the eurozone have dropped significantly and euro mortgage rates have recently been very similar across member countries.

It is worth noting the difference in household preferences between Portugal and Italy. While both countries had experienced significant liquidity constraints prior to eurozone membership, and now as euro area members face low and very similar interest rates and economic policy frameworks, households in these two countries responded entirely differently to the easing of liquidity constraints. In contrast to the situation in Portugal, families in Italy do not have a strong tendency to rely on the financial system to solve housing problems, as indicated by the country's permanently low mortgage debt/GDP ratio.

House Equity Withdrawal

House equity withdrawal has become an important channel of monetary transmission in a number of developed countries in the past decades, parallel with the liberalisation of the mortgage markets. There are very different patterns in housing equity withdrawal, and both significantly positive

[2] This is only an estimate of the debt-servicing-to-income ratio, particularly as it applies the mortgage interest rate of new contracts to the whole stock of mortgage debt

and negative values can be found in the EU. This might look less than straightforward given that housing as an asset has a relatively stable ratio to total household wealth in the four biggest EU countries[3]. On the one hand, house equity withdrawal was equal to 3% of disposable income in the UK during the '80s and the '90s. According to the OECD (2004), house equity withdrawal was also positive in the Netherlands and was around zero in Denmark in the '90s. On the other hand, in Germany, Italy and France during the '90s, households increased housing wealth on average by 6% of disposable income, implying that house equity withdrawal was significantly negative.

The experience of the UK shows that house equity withdrawal became significant after the beginning of the liberalisation of the mortgage markets in the early 1980s, rising during the entire decade to reach 8% of disposable income by 1989. Apart from the liberalisation of the mortgage markets, the UK experience also supports the concept that the number of transactions also plays an important role in house equity withdrawal. In the UK, the ratio of transactions to owner-occupied housing is about twice as high as the EU average. It is also above average in the Netherlands and Denmark.

During the cyclical downturn in the past years, house equity withdrawal became an important macroeconomic issue in a number of economies. In the US, which can be considered as one of the best examples for house equity withdrawal, equity extracted from owner-occupied housing reached $700bn, or around 9% of disposable income, in 2002. A large part of this extraction, almost $200bn, was related to the refinancing of existing callable loans. Low and decreasing mortgage rates undoubtedly motivated refinancing, particularly given the low cost prepayment options in the US mortgage market. An even greater part of house equity withdrawal, $350bn, was related to the transactions of existing homes. It is not surprising, then, that a record number of existing home sales, strongly encouraged by the low mortgage rates, was behind the very high level of transaction-related house equity withdrawals. According to Fed estimates (Greenspan 2003), mortgage originations for existing home purchases reached $600bn, after subtracting repayment of home sellers, resulting in a net increase of $350bn in mortgage debt, of which a considerable part was spent on goods and services. By and large, evidence from the US in the last years illustrate that, provided a sufficiently developed and efficient mortgage market exists in the economy, monetary policy through housing equity withdrawal can have a greater impact on household behaviour, and thus on economic activity, than previously thought.

Transaction costs, tax regimes

Considering that dwellings answer a basic human need, housing is also an important area for economic policy. Governments in most countries take measures to influence the housing market, to pursue social goals, such as improving the housing conditions for low-income households. Government intervention also has implications for the monetary transmission. In the following discussion, which is based on the ECB (2003) survey, we focus on the interaction between government policies and monetary transmission.

[3] The ratio, according to HM Treasury (2003), is between 0,31 (in Italy) and 0,4 (in France), with Germany (0,32) and the UK (0,34) in between. In assessing these ratios, it should be kept in mind that the definition of households' total asset cannot be compared strictly across countries due to, for instance, differences in pension schemes and, therefore, the size of pension funds.

Government policies pertaining to housing include, on the one hand, subsidies (such as provision of tax exemptions for housing-related expenses and direct subsidies to certain households) and transaction-related taxes, on the other. Theoretically, government measures have an impact on the housing market at three levels of household decision-making: first, on the choice between investment in housing and moveable assets; second, the choice between owner-occupied and rented housing; and finally, the choice between new and existing housing.

Most EU countries have traditionally supported home ownership through direct subsidies and the granting of tax exemptions for mortgage interest payments, and by not taxing imputed rents. Measures favouring owner occupation can have an adverse effect on the single monetary policy, as they decrease labour mobility within the eurozone, an important adjustment mechanism in the monetary union. The total amount of public expenditures on housing policies in the EU countries has not changed significantly since 1980, averaging 0.6-1.3% of GDP[4]. While public expenditures remained generally stable, there were important changes in the structure of housing policy measures in most EU countries. A number of countries have moved towards a more neutral stance in terms of influencing investment decisions between housing and movable assets. At the same time, some countries have increased the incentives towards owner-occupied housing.

Transaction costs do not only generate income for the government in the form of stamp and registration duties and inheritance taxes; they also provide a means for containing speculative price movements. However, higher transaction costs can also have adverse effects. Higher transaction costs tend to decrease the number of transactions in the housing market, as shown by EU data. Belgium, which has the highest stamp duties, reaching 10-12%, has one of the lowest transaction figures, while the UK with very low stamp duties (1-4%) has the highest transaction figures. Relating housing transactions to house equity withdrawal, it can be concluded that government policies can constrain monetary transmission if these rely heavily on transaction-related incomes.

Short history of the Hungarian housing market

The Hungarian housing market experienced a number of shocks in the last two decades. In the late '80s and the early '90s, Hungarian households, wary of an economic breakdown, turned to real estate as the most important form of saving. This resulted in rising house prices. A few years into the transition, concerns regarding economic stability began to subside, paving the way for the restoration of portfolio balance between real and financial saving. This led to the so-called financial savings' miracle in Hungary in the mid-'90s[5].

At the beginning of the transition in the early 1990s, there was no mortgage market to speak of in Hungary. Although there was a considerable amount of outstanding subsidised housing loans during the socialist regime, the government decided to abolish the subsidy on account of the rising budget deficit, which attended the collapse of the centrally planned economy. Following the legal disputes over the termination of the subsidy for existing, long-maturity loans, the subsidised housing loans were converted into market-rate loans, significantly increasing the debt-servicing

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[4] These figures are not strictly comparable across countries, as some countries include forgone revenues in public expenditures, while others do not.

[5] For a more detailed description of this period see Zsoldos (1997).

obligations of households. However, debtors were given the option to repay the debt fully at highly advantageous discounted rates. Since many households chose the prepayment option, the outstanding amount of housing loans dropped to less than HUF 150 bn by 1991, equivalent to 6% of GDP. It dropped further in nominal terms, becoming insignificant, from a macroeconomic point of view, for almost a decade (see Figure 5.6).

There were basically no new housing loans during the years when inflation was high and volatile. In 1991, the inflation rate peaked at 35%, remaining above 15% until 1998. In light of this, and considering the 1/3 prudential limit on debt service/disposable income, households could thus not raise loans exceeding their two-year income[6], even with nominal interest rates close to 15%. High and volatile rates of inflation in the first half of the '90s also led to the shortening of business contracts. Economic agents did not want to get tied down to long nominal contracts. This was particularly true in the financial markets. Even the Hungarian government could not issue long-term forint bonds: the 5-year government bond appeared in the market only in 1996. Considering that mortgage loans cannot have maturities longer than benchmark government bonds, the short yield curve also significantly constrained the potential growth of the mortgage market. In short, a confluence of factors hampered the growth of the mortgage market in the first years of the transition: high and volatile inflation, as well as low household demand for mortgages owing to declining real wages and rising unemployment.

The next period of development in the Hungarian housing market may be considered to have started in the late '90s[7]. Economic consolidation began in the mid-'90s, accompanied by the increasing credibility of an economic policy that was openly committed to the fast nominal convergence path. As a result, long yields and the inflation rate declined continuously from 1997, parallel with the gradual extension of the benchmark government yield curve to longer maturities of 10 and 15 years in 1999 and 2001, respectively. These developments created the necessary financial background for the functioning of a mortgage market in Hungary.

Alongside these developments was the establishment of the legal framework for the Hungarian mortgage market. In 1997, the Parliament passed the Act on Mortgage Institutions. In line with this, new regulations in related areas, such as loan origination, foreclosure and prudential limits, were harmonized with the EU legal framework. However, despite improving macroeconomic and financial conditions and the institution of a legal and regulatory framework, the mortgage market remained stagnant until 2000 when the government introduced mortgage-related subsidies.

In 2000, more than 10 years after the loan subsidies were abandoned in the last years of the socialist regime, the government introduced interest subsidies to long mortgage loans for new housing constructions. The main rationale for instituting the new housing policy measures was the fact that the number of new housing constructions had been declining throughout the '90s. This decline was, to a large extent, due to the lack of house financing: households could rely only on their savings to finance housing investment.

Early governmental measures promoting only new housing constructions facilitated the development of a mortgage regime similar to many EU countries, with the dominance of fixed non-callable

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[6] Due to the effect of high interest rates on the liquidity constraint of a household, assuming a 20-year maturity and that 1/3 of disposable income is spent on the loan amortisation.

[7] The early stage of this period is discussed in Valkovszky (2000).

mortgage loans. Although these measures did not have a major macroeconomic impact, they gave an impetus to the previously inert mortgage market. In 2000, the households' mortgage debt/GDP ratio started to post some growth. To further foster this growth, although to a smaller extent, the government extended the subsidy to buying existing dwellings as well. Meanwhile, macroeconomic conditions had also become favourable: the inflation rate dropped below the 7% target at end-2001, while the yield curve showed a steep negative slope, reflecting investors' confidence in the profitability of the convergence play strategy in the Hungarian government bond market. The new government measures, along with the favourable macroeconomic conditions, resulted in a gradual increase in mortgage loans, with a monthly average of HUF 15 bn of new loans granted in 2001. However, the outstanding stock by the end of the year still did not exceed 2% of GDP.

The year 2002 brought dramatic changes to the mortgage market. Government subsidies directly targeting households were increased significantly at the beginning of the year. Moreover, through subsidies linked to funding costs, bank margins climbed to 8%. Meanwhile, the subsidy scheme was exhibiting a rather unusual feature: the interest burden of households was not sensitive to market rates; all interest rate risk was with the central budget. The most general mortgage type was a 15-20 year loan, with the interest rate fixed for 5 years and a cap on interest paid by households at 6% for existing dwellings and even lower for new constructions. These rates were even significantly lower than benchmark government yields at that time.

The subsidy scheme was clearly not going to be sustainable. Under the scheme, even households that would otherwise not have considered taking out a mortgage loan in the near future, were applying for loans simply to take advantage of the favourable conditions. This resulted in such a sudden and significant rise in mortgage loans that, by the middle of 2002, the mortgage market had started to post exponential growth. In the second half of the year, the volume of new loans originated in 2 months exceeded the total volume originated in the previous year. However, the government was slow to respond. It decided to cut the subsidies substantially only in December 2003, amidst serious concerns about the external and internal stability of the Hungarian economy.

The tightening measures primarily attempted to cut the budget expenditures on interest rate subsidies. Given the lower subsidies for the new loans, banks' profit margins declined, parallel with the significant increase in the interest burden of households. Furthermore, the changes to the subsidy scheme gave rise to two new features: mortgage rates became partly linked to market rates, and the difference between subsidies for new and existing housing widened from 1 to around 3 percentage points.

From the transmission point of view, the most relevant change was the establishment of the link between the mortgage rate faced by households and the market rate. The immediate and strong impact of the tightening measures on the demand for new loans may be attributed not only to the fact that subsidies were cut significantly but also to unfavourable market developments. As concerns about the external and internal equilibrium of the Hungarian economy increased in 2003, the long segment of the yield curve started to increase significantly, putting an end to the yield convergence that characterised long yields in the previous years.

Loan origination dropped significantly in 2004 as a natural consequence of the tightening measures and the high long rates. At the same time, a new product appeared in the market: foreign exchange-denominated (FX) mortgage. Faced with the high forint mortgage rate, a growing number of households opted for mortgages with a lower nominal rate, notwithstanding the imminent exchange rate risk.

5.3 The theoretical foundations of transmission

This section discusses the three main theoretical channels through which the housing market and related economic forces influence the behaviour of households: (1) the interest rate channel; (2) the asset price and wealth effect; and (3) the credit channel. The interest rate channel is important in that the changing mortgage interest rate alters the amount of monthly repayment, thereby influencing households' disposable income. As regards the asset price and wealth effect, dwellings may be considered as an asset class; thus, their prices and investment volume can be determined like that of any other asset. Moreover, a rise in house prices implies increasing wealth, which makes higher consumption possible through the wealth effect. Finally, the credit channel has a fairly similar effect: a rise in house prices increases housing wealth and, consequently, the available collateral for the loan, which, in turn, induces higher consumption expenditure.

Interest rate channel

Monetary policy can have a direct impact on the behaviour of households through the interest rates on mortgage loans, providing a significant channel of monetary transmission. There are three main characteristics of mortgage loans that are relevant for monetary transmission. The most important characteristic is the low risk of a mortgage loan, which is reflected in the low risk premium. The physical characteristics of the dwellings, serving as collaterals, explain the low level of risk: dwellings are immobile and have a very long lifetime. The second characteristic is related to the size of the loans. Usually the mortgage loan is the largest loan in the portfolio of a household, representing a high ratio both compared to the value of the house and to disposable income. The third characteristic is long maturity which, on the one hand, is feasible due to the safety of the collateral but which, on the other hand, requires a long amortisation period due to the large volume of debt.

Despite the low level of risk, financial intermediaries have nevertheless set up prudential limits on mortgage loans. Due to the volatility of house prices and the costs related to liquidating the dwelling of non-servicing debtors, limits were introduced to maximise the loan-to-value ratios. For the monetary transmission, however, another limit is of greater interest: the one determining the ratio of monthly instalments to disposable income. As a general rule, monthly instalments should not exceed one-third of disposable monthly income.

The nominal interest rate on a mortgage loan can be broken down into three components: inflation compensation, risk-free real interest rate, and the risk premium of mortgage loans. For debtor households, the real interest rate prevailing in the economy and the risk premium are equally relevant; together they determine the real cost of a mortgage loan. Inflation compensation also has an impact on the behaviour of the households. In other words, for the households it is not simply the net present value of the cash flow that is important, but also the duration of the loan.

If the nominal interest rate is high due to high inflation, then the ratio of inflation compensation would be increasing within the monthly instalment and, ceteris paribus, the ratio of capital amortisation would be decreasing. This implies that, in case of higher inflation, higher nominal monthly instalments are required to serve a mortgage loan with the same net present value. Monetary policy has to take into consideration that, with the increase in nominal interest rates, more and more households would face a liquidity constraint due to the amortisation/income ratio.

Similar to calculations in Section 2, Figure 5.4, taking the example of a 20-year loan with fixed nominal instalments and a 1/3 amortisation/income ratio, shows the maximum amount of loan, expressed in terms of monthly income, as a function of the nominal interest rate. In case of a 19% interest rate, the maximum loan is less than two years' income, roughly one third of what is available at a 3% nominal interest rate.

So far we have argued that the nominal interest rate is important due to its impact on liquidity constraints. However, the indexation of monthly instalments could also result in higher loan amounts, as it allows monthly instalments to grow nearly parallel with monthly income. While indexation can be useful in the financial markets as long as the inflation uncertainty is not too high, it can easily have a counter-effect on long-run inflation. The more widespread indexation is in an economy, the more permanent inflationary inertia can turn out to be, making disinflation more costly in the future.

In what follows, we group the different kinds of mortgage loans, discussed in Section 2 above, according to the link between the key interest rate and mortgage rates. The long-maturity mortgage loans can be divided into two major sets based on whether mortgage rates are fixed or variable within the time horizon (2-3-years) relevant for monetary policy.

The shorter the interest rate period of a loan, the stronger the effect of the key interest rate on the mortgage rate. In case of variable rate mortgages, first, re-pricing occurs faster, and second, changes in the key interest rate have a stronger effect on short rates. Thus, variable rate mortgages provide a direct and efficient channel for monetary transmission.

If, on the other hand, rates are fixed for longer periods (for instance, 5 years), then changes in the key interest rate would have only an indirect effect, in two stages. The first step involves the impact of changes in the key interest rate on the yield curve at maturities relevant for mortgage loans. It is important to note that, in general, the effect will be declining at longer maturities. The second step is related to the length of the period with a fixed rate. Market rates are relevant only at the beginning of a new interest rate period. Thus, while having an immediate impact on new loans, they exert only a gradual effect on the outstanding stock of existing loans.

Another feature that should be considered in the case of fixed loans is the possibility of early repayment. If debtors can refinance with low transaction costs (having callable loans), then the transmission mechanism becomes asymmetric. During periods of declining interest rates, debtors will take advantage of lower rates, reducing monthly instalments and/or increasing the amount of the loan. This is an immediate reaction to lower rates. Increasing rates, on the other hand, do not imply any changes in the behaviour of households, as debtors keep servicing their loans with the original fixed rates. Monetary tightening has no immediate effect on household behaviour; its impact can be discerned only at the beginning of the new interest rate period, as discussed above.

Asset price and wealth effect

In theory the price of an asset is the net present value of future dividends *(D)* that it can earn, that is, $P_0 = \sum_{t=1}^{\infty} E[D_t]/(1+r)^t$. However, before we apply asset price theory to housing investment, we should re-examine the role of dwellings.

In the microeconomic sense, a house is not simply a 'roof over one's head'. Arrondel and Lefebvre (2001) define the dual aspect of the households' housing decision-making process: as a source of housing services and as an asset, i.e., housing is also taken into consideration in investment decisions. Xiao Di (2001) examines the role of dwellings in the USA, where housing investment is treated as a form of investment, at par with financial investment.

By and large, although housing investment has several special characteristics (e.g., a considerable amount of initial down-payment, large transaction costs, uncertainty about quality, uniqueness of every unit, relative illiquidity, long implementation time, etc.), it can be regarded as an investment form. The owner of a house can realise income from tenants and from changes in house prices. Increasing house prices can provide a higher return on real estate than does financial investment, and thus force households to reallocate their portfolios. In general, households are willing to buy or sell assets as long as they are profitable, irrespective of the type of the asset in question.

The determinants of house prices are examined in empirical literature as well (for instance, see Cho, 1996; Mayer and Somerwille, 1996). Muellbauer and Murphy (1997) introduced the following equation for house prices:

$$P_t = g(H / POP, y, r, \Delta P / P, M, \ldots) \tag{1}$$

where *H, POP , y, r* and *M* denote demand for housing, population, average real income, interest rate, and a proxy for credit/mortgage rationing, respectively. Two points are worthy of note. First, Muellbauer and Murphy (1997) show a fairly stable house price-to- income ratio. Second, recall that return on housing investment *(R)* equals $R = (E[D_{t+1}] + E[\Delta P_{t+1}])/P_t$ in asset price theory, which suggests that this return could be related to returns from any other investment form. Chen and Patel (1998) made this explicit by using the form

$$p_t = \alpha + \beta y_t + \gamma E[r_{t+1} - \Delta p_{t+1}] + \delta DV_t \tag{2}$$

where DV and the small letters denote demographic variables and the logarithm of the corresponding variables, respectively. It should be noted that equation (2) can be considered as the long-term component of the error correction model. The Bank of England (2000) (hereafter BoE) model uses a similar form in the long-run house price equation, restricting the long-run elasticity of income to one.

At first glance, it would appear that these empirical shortcuts have no connection with asset price theory. However, Vadas (2003) showed that if one considers housing as an asset, the theoretical price relation of the portfolio choice model can be captured by the error correction form. Based on the aforementioned considerations, we can examine the effect of the interest rate on house price by using the error correction form, keeping in mind the underlying asset price implications.

Obviously, changing house prices influence households' decisions, that is, those pertaining to housing investment and consumption. As far as dwelling investment is concerned, we can apply the portfolio choice approach described in Vadas (2003). This paper argues that the choice of investment between real and financial assets can be compared to the choice between two financial assets. Based on this, the ratio *(τ)* between dwelling investment and gross saving[8] can be explained by the excess return (ER) of holding real estate over holding a financial asset[9]:

$$\tau_t = \frac{1}{1+\exp\left[-(\eta + \Phi(L)\,\tau_t + \Theta(L)ER_t)\right]} + \varepsilon_t. \tag{3}$$

Given τ, dwelling investment can be computed by multiplying τ by gross saving.

In the case of consumption, the BoE model (2000) uses the modified version of the error correction consumption equation originally suggested by Hendry and Ungern Sternberg (1981). In the BoE model, households' wealth consists not only of net financial but also housing wealth. When house prices rise, total housing wealth does so too, which implies a positive adjustment to consumption through the error correction mechanism. Case et al. (2001) and Girouard and Blöndal (2001) also found an empirically significant positive relationship between housing wealth and household expenditure. Based on this, the consumption function can be formed the following way:

$$\Delta c_t = \alpha_0 + \alpha_1\left(c_{t-1} - \beta_1 y_{t-1} - \beta_2 w^f_{t-1} - \beta_2 w^h_{t-1}\right) + \alpha_2 \Delta c_{t-1} + \alpha_3 \Delta y_t + \varepsilon_t, \tag{4}$$

where c, w^f and w^h denote consumption expenditure, financial and housing wealth, respectively.

In order to simulate the wealth effect on consumption in Hungary, we use the Hungarian Quarterly Projection Model (MNB, 2004a) in which the consumption function contains housing wealth, and the housing investment function is based on the aforementioned portfolio choice approach.

Credit channel

If mortgage repayment is tied to the value of the collateral, namely dwellings, changes in house prices alter the amount of monthly repayment by changing the risk premium. Increasing house prices reduce, while decreasing house prices increase, the risk premium. Thus, changes in house prices either increase or decrease the amount of monthly repayment, thereby influencing the ability to repay, and the possibility of default.

Several theoretical and empirical studies seek to incorporate these effects into their models. Westaway (1992) provides a comprehensive general equilibrium model, which incorporates the flow of housing services into the utility function. Aoki et al. (2002) go one step further and not only use housing services in the utility function, but also apply the financial accelerator model developed by Bernanke et al. (2000). The main point of the financial accelerator is that house prices influence housing wealth which households can use as collateral in borrowing. If house prices increase, housing wealth and available collateral do so as well. Consequently, households can borrow at a lower financial premium and/or increase their indebtedness.

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[8] Gross saving equals households' disposable income minus consumption expenditure.

[9] Since the ratio of housing investment to gross savings must be between 0 and 1, the study suggests the logistic function, which fulfills this requirement.

The financial accelerator can be captured in two ways in empirical modelling. First, the financial premium on households' loans should be linked to housing wealth. Although this would be the better option, identifying the premium on the consumer loan can prove to be very difficult. The other method involves linking households' consumption to housing wealth directly. However, in this case, the wealth effect and the financial accelerator or credit channel cannot be separated. Even so, we employ this latter approach in empirical investigation due to the measurement difficulty of the first approach.

5.4 Transmission in the Hungarian housing market

In this section, we show, apart from the standard transmission channels (namely, the interest rate channel and, as indicated above, the joint wealth effect-credit channel), two other effects which influence the monetary transmission in the Hungarian housing market.

Interest rate channel

We expect mortgage loans to have a weak direct impact on households' disposable income in Hungary, for two reasons. First, despite dynamic growth in recent years, the outstanding stock of mortgage loans is still low compared to that in developed countries. Second, the key interest rate affecting the yield curve has had only a minor impact on the interest burden of mortgage loans due to the features of the government subsidies effective until 2003. Apart from the government subsidies, the fixed non-callable mortgages dominating the Hungarian market result in a delayed effect of interest rate changes, similar to many eurozone countries.

Based on the evolution of the mortgage market and the government subsidy scheme discussed in Section 2, the following table summarises the direct effect of interest expenditure on disposable income and the effect of a change in the market interest rate.

Table 5.3 Sensitivity of disposable income to changes in the mortgage interest rate

Year	Households' disposable income (bn HUF)	Mortgage interest expenditure (bn HUF)	Interest payments/ Disposable income (%)	Sensitivity of interest expenditures to change (+100 bps) of the market rate (bn HUF)
2001	8913	18.4	0.21	0.8
2002	9742	53.4	0.55	2.2
2003	10863	95.4	0.88	3.9
2004*	11950	132.2	1.11	5.5

* *Forecast.*
Source: Own calculations.

As is apparent from Table 5.3, a one-percentage-point change in the market rate induces a negligible change in the disposable income of the household sector and, thus, in aggregate consumption expenditure.

Due to the high domestic interest rates, FX mortgages are becoming more popular, creating a new channel for monetary transmission. First, monetary tightening occurs when the exchange rate is depreciating, as household income after mortgage payments falls; the converse is true when the exchange rate is appreciating. Another very important feature of this channel of monetary transmission is the speed of adjustment: monthly instalments are immediately affected by changes in the exchange rate regardless of the interest conditions (variable or fixed) of the mortgage loan.

Asset price, wealth effect and credit channel

In order to determine the wealth effect of monetary policy on housing investment and private consumption, we first have to estimate the relationship between the interest rate and house prices. Using the resulting price elasticity coefficient, we can then simulate the following: (1) the effect of interest rates on house prices, and thus on dwelling investment, and (2) the effect of altered housing wealth on consumption.

As previously discussed, house prices can be modelled within an error correction framework. Previous studies used simple time-series techniques. However, due to the short sample period, this is not feasible for Hungary. Instead of using aggregated time series we apply panel data where the cross-sectional variance comes from the geographic separation[10]. The economic rationale for using national cross-sectional data lies in the fact that the mobility of Hungarian households between regions is very low. Thus, regional time series are not explanatory variables for each other.

A further adjustment to equation (2) is the exclusion of demographic variables. Demographic variables are certainly essential to explaining house prices when significant demographic fluctuations can be observed. However, our sample is too short (quarterly observations for the period of 1997-2002) to demonstrate such effects. Moreover, we also know that there has been no considerable movement in Hungarian demography in the past few years. As a result, we can proceed with our estimation process using the following equation:

$$\begin{aligned} p_{i,t} &= \mu_i + \gamma_1 p_{i,t-1} + \gamma_2 p_{i,t-2} + \beta_0 y_{i,t} + \beta_1 y_{i,t-1} + \alpha_0 r_t + \alpha_1 r_{t-1} + \alpha_2 d_{00} r_t \\ &\quad + \alpha_3 d_{00} r_{t-1} + \varepsilon_{i,t} \end{aligned} \tag{5}$$

where i represents the capital and the 19 counties of Hungary, while p, y, r and d_{00} denote house prices, GDP per capita, the interest rate of housing loan, and a dummy variable which equals 0 before 2000 and 1 otherwise, respectively. The dummy variable is supposed to test whether government measures easing access to mortgage loan has an effect on monetary transmission[11]. Equation (5) can be rewritten in the following form, which is a frequently used form of the ECM:

$$\begin{aligned} \Delta p_{i,t} &= \mu_i + \theta_0 \left[p_{i,t-1} - \theta_1 y_{i,t-1} - \theta_2 r_{i,t-1} - \theta_3 d_{00} r_{i,t-1} \right] - \gamma_2 \Delta p_{t,t-1} + \beta_0 \Delta y_{i,t} \\ &\quad + \alpha_0 \Delta r_t + \alpha_2 \Delta d_{00} r_t + \varepsilon_{i,t} \end{aligned} \tag{6}$$

[10] For details about the data set, see Appendix, Data set section.

[11] Since government actions take place in stages, no single date can be pinpointed. As we argued earlier, 2000 was the first year when subsidy measures were introduced. It was thus only after that when households' mortgage debt/GDP ratio started growing.

where $\theta_0 = \gamma_1 + \gamma_2 - 1$, $\theta_1 = -(\beta_0 + \beta_1)/(\gamma_1 + \gamma_2 - 1)$, $\theta_2 = -(\alpha_0 + \alpha_1)/(\gamma_1 + \gamma_2 - 1)$ and $\theta_3 = -(\alpha_2 + \alpha_3)/(\gamma_1 + \gamma_2 - 1)$. This specification allows us to test numerous assumptions, among them: that the ratio of house price to income is constant *(θ_2 = 1)*; that the interest rate has a significant effect on house prices *($\theta_2 \neq 0$)*; that government measures altered the transmission *($\theta_3 \neq 0$)*; that house price growth has been sluggish *($\gamma_2 \neq 0$)*, etc. In order to avoid the estimation bias that may arise from using a single estimator, we apply three different approaches.

Firstly, since our sample has a cross-sectional dimension, we apply panel estimators. We apply a fixed-effect estimator as a starting point since the lagged dependent variable is correlated with the error term, making the estimation biased. To handle this problem, we apply the IV (instrumental variables) of the Arellano and Bond (1991) dynamic panel estimator.

Secondly, panel estimators can have two weaknesses in our case. On the one hand, they are appropriate when $T \to \infty$, so they are not fully suitable to our sample. On the other hand, they assume all parameters to be homogeneous in a cross-sectional dimension. However, if this assumption does not hold, the following would be the more appropriate equation:

$$\begin{aligned}\Delta p_{i,t} = \mu_i + \theta_0 \left[p_{i,t-1} - \theta_1 y_{i,t-1} - \theta_2 r_{i,t-1} - \theta_3 d_{00} r_{i,t-1} \right] - \gamma_{i,2} \Delta p_{t,t-1} + \beta_{i,0} \Delta y_{i,t} \\ + \alpha_{i,0} \Delta r_t + \alpha_{i,2} \Delta d_{00} r_t + \varepsilon_{i,t}\end{aligned} \tag{7}$$

Time-series estimators, such as 3SLS, can handle the second problem. However, they are appropriate only when $T \to \infty$.

In order to handle these weaknesses, we consider a 'mid-solution' when the cross-sectional and time dimensions are roughly equal and allow heterogeneous parameters. Pesaran et al. (1999) suggest an estimator for this special case, which is called the pooled mean group estimator (PMGE). To ease comparison, we also apply the simple mean group estimator (MGE). Finally, for the sake of completeness, we also employ three-stage least squares (3SLS), which is frequently used in time-series studies, keeping in mind its aforementioned weakness.

In order to understand the estimation results, one has to recall the significant discrepancy between estimators. While panel estimators use equation (5) and assume all parameters – namely, that all α, β and γ are equal across counties – the pooled mean group estimator uses equation (7) and restricts only long-run parameters *(θ_s)* to be equal, allowing different short-run dynamics, i.e., α_0, α_2, β_0 and γ_2. Since the latter assumption is more acceptable, we design the 3SLS estimation in the same way. The estimated parameters using the various estimation methods are shown in Table 5.4 below.

According to the estimation results, the long-run relationship between house price, income and interest rate seems to be an acceptable assumption. Every estimator indicates unit elasticity between house price and income, i.e., the ratio of house price to income is constant. The only discrepancy between the panel estimator and the other two estimators is the speed of adjustment. While it is reasonable in the case of 3SLS and Pesaran-Shin-Smith, the Arellano and Bond estimator indicates too rapid an adjustment (θ_0 = -0.473).

The interest rate elasticities before 2000 seem to be reasonable and are also close to each other. More worthy of note, however, are the results from the dummy variable estimations. Contrary to our expectations, the increasing interest rate elasticity after the introduction of government subsidies is not supported by the estimation results. Each of the methods implies a declining interest

Table 5.4 Estimation results

	Fixed effect		Arellano-Bond			MGE		PMGE		3SLS	
	Coef.	**t stat**	**Coef.**	**Z stat**		**Coef.**	**χ^2 stat**	**Coef.**	**t stat**	**Coef.**	**$P(\theta_i=0)$**
γ_1	1.330	34.3	0.820	4.02	θ_0	-0.255	203.2	-0.068	-1.06	-0.153	0.00
γ_2	-0.502	-14.3	-0.293	-2.47	θ_1	0.977	102.2	0.972	10.06	1.065	0.00
β_0	0.441	2.7	0.860	3.85	θ_2	-0.031	71.6	-0.028	-9.38	-0.031	0.00
β_1	-0.323	-2.1	-0.403	-1.76	θ_3	0.013	190.4	0.010	6.73	0.004	1.00
α_0	-0.002	-0.9	-0.003	-1.07							
α_1	-0.005	-2.3	-0.007	-2.71							
α_2	0.006	9.2	0.006	7.12							
α_3	-0.004	-5.8	-0.002	-1.56							
Long-run income elasticity											
θ_1	0.69		0.966			0.977		0.972		1.065	
$P(\theta_1) = 1$	0.165		0.787			0.263		0.775		0.317	
Long-run interest rate elasticity											
before 2000	-0.037		-0.020			-0.031		-0.028		-0.031	
after 2000	-0.027		-0.012			-0.019		-0.018		-0.027	

In the case of Arellano-Bond, the Hansen J statistic is $\chi^2(4) = 4.41$, $P = 0.353$, while AR(2) test is $z = 1.37$, $P = 0.171$. Exogenous instrument variables are $p_{i,t-3}$, $p_{i,t-4}$, $y_{i,t-2}$, $sh_{i,t-1}$, $sh_{i,t-2}$ and $fh_{i,t-2}$ where sh and fh denote new house stars and finished house constructions. In the case of 3SLS, we applied the Monte Carlo method to obtain proper distribution.

rate parameter, although its magnitude is fairly small. On the other hand, it is not significant in every estimator, e.g. 3SLS strongly rejects the change in the interest rate parameter.

There could be several reasons for obtaining such a result. Firstly, government subsidies were gradually increasing. They can thus be considered as being a series of measures rather than one single measure. Due to the relatively short sample period, we did not want to extend the number of dummy variables, as this would have distorted the estimation results. Instead, we chose the approximate start of the effect of government actions (see footnote 11). Secondly, the drop in the mortgage loan rate occurred at the end of the sample. Obviously, the adjustment of house prices takes longer, likely continuing through the ensuing years. Since the full effect of the sharp decrease in interest rate cannot be detected in the sample, the estimations cannot capture its effect properly. Finally, and most importantly, the changing variables do not imply different deep parameters. Note that the lower interest rates do not alter household behaviour by themselves. They simply increase the demand for credit. By and large, we believe that the whole sample should be considered, although greater attention should be paid to the more significant parameters.

Based on the estimation results, we are able to simulate the effect of the interest rate on relevant household variables, such as housing investment and consumption expenditure. To achieve this, we use the Hungarian Quarterly Projection Model, extended with our new house price equations. In order to obtain a complete interval, we use the lowest (Arellano-Bond) and the highest (3SLS) estimation results. It should be recalled, however, that the most probable outcome is likely to be within this interval, as the more appropriate Pesaran-Shin-Smith estimator suggests.

TABLE 5.5 Transmission through the wealth and credit channel

	House prices		Housing investment		Consumption	
long-run interest elasticity rate	**-0.012**	**-0.031**	**-0.012**	**-0.031**	**-0.012**	**-0.031**
1st year average	-0.60	-1.14	0.00	0.00	0.00	-0.01
2nd year average	-1.22	-2.89	-0.39	-0.56	-0.05	-0.11
3rd year average	-1.19	-3.07	-0.70	-1.13	-0.11	-0.26
4th year average	-1.19	-3.05	-0.70	-1.02	-0.14	-0.34
5th year average	-1.19	-3.05	-0.69	-0.88	-0.13	-0.35

** 1 percentage-point permanent increase in mortgage loan rate. Results are displayed as the percentage differences from baseline.*

Table 5.5 shows the simulation results of a one percentage-point permanent increase in the mortgage loan rate. Evidently, house prices decrease by 1.2 and 3.1 percentage points. Declining house prices are only one source of decreasing housing wealth. Higher interest rates and lower house prices also discourage housing investment. According to the simulation, this effect could be around 1 percent. Lower house prices and dwelling investment alter the real wealth position of households, which should influence consumption decisions. Since a consumer loan secured by dwellings is not very common in Hungary, it is not surprising that declining housing wealth has a rather moderate effect on consumption. It should be noted that the changes in consumption expenditure shown above stem merely from the housing market; we ignore any other relationship between interest rate and consumption.

'Borrow more' effect – a form of house equity withdrawal

In recent years, house equity withdrawal has become an important macroeconomic feature, despite the unsophisticated mortgage products offered in the Hungarian market. The main reason for this was the combination of the previously binding liquidity constraint on households and the generous subsidies made available for existing dwellings.

The existence of the housing equity withdrawal involving housing transactions can be illustrated with an example. Households who would like to purchase a more expensive apartment sell their old one and take out a mortgage loan with the highly advantageous interest rates. On the aggregate level, if the transaction involves only existing dwellings, there is no change in the net financial position of the household sector, as the mortgage loan equals the increase in the savings of the seller. However, due to the low interest rate, the household taking up the mortgage might consider taking out a bigger loan to finance consumption, for instance, to furnish the new apartment. If LTV and debt service/income ratios are at manageable levels, households could significantly ease the liquidity constraint. Our previous calculations (MNB Inflation Report 2004 February, MNB, 2004b) showed that 15-30% of mortgage loans raised for existing housing could finance consumption during 2001-2003. The estimation was based on the unexplained consumption growth by standard factors such as income, financial and housing wealth, and the consumer confidence index.

In order to determine the possible amount of this excess loan demand, we invoke the theoretical aspect of the interest rate channel. According to Figure 5.4, a one-percentage- point increase in the nominal mortgage rate around 5% decreases the maximum loan amount by an equivalent of 5 months' income. Using the above-mentioned 15-30% ratio of excess consumption to mortgage loan, the 15-30% of 5 months' income, that is the tightening of the liquidity constraint, leads to a 25-50% drop in quarterly income. Considering that the ratio of mortgage loan origination to personal disposable income was 6% in 2002, the one-percentage-point increase in nominal mortgage rate implies a 1.5-3% decrease in quarterly income in the whole household sector. Using this computation we can simulate the 'borrow more' effect. It is therefore an important characteristic of the Hungarian mortgage market that housing equity withdrawal could exist despite the fact that households could choose only from an array of unsophisticated mortgage products.

TABLE 5.6 **'Borrow more' effect***

	Consumption	
Decrease in income	**1.5%**	**3%**
1st year average	-0.9	-1.9
2nd year average	-1.5	-3.0
3rd year average	-1.4	-2.9
4th year average	-1.3	-2.6
5th year average	-1.2	-2.4

**1 percentage-point permanent increase in mortgage loan rate around 5 percentage nominal rate. Results are displayed as percentage differences from the baseline.*

The evolution of the number of housing transactions also supports the growing importance of house equity withdrawals (see Figure 5.7). The number of housing transactions has almost doubled in the last seven years, and by 2003 the Hungarian figure has already exceeded the German and Belgian levels.

Renting market

The renting market can have important implications for monetary transmission. Rental costs are usually included in the consumer basket. The housing market therefore has a direct effect on inflation. The Hungarian situation is rather special in this regard since there are hardly any apartments rented at market price, as reflected in the very high level (92%) of owner occupation. One reason behind the very high level of owner occupation is the fact that the majority of state-owned apartments were sold to tenants in the early '90s for a symbolic amount. Another possible reason why official statistics register a very small renting market is tax evasion. Landlords are obliged to pay a 20% tax after rental income. According to anecdotal evidence, however, rental income hardly ever appears in the tax reports.

The non-existence of a statistically observable renting market has led to a situation where rental costs are substituted with different items in the Hungarian consumer basket. Market rents are substituted with a regulated price, the rents charged by local municipalities on dominantly social housing. The imputed rents of owner-occupied housing are approximated by a weighted average of goods and services related to house repair and maintenance. From a monetary policy point of view this substitution is rather controversial, as largely different macroeconomic factors determine regulated prices, housing repair and maintenance goods and services on the one hand, and house-price-linked rental costs on the other. Thus, the full effect of transmission cannot yet be captured by recent statistics. A switch to actual rental costs in the consumer basket is therefore necessary to reflect the real transmission effects.

Another important point to consider is the difference between the weight of rents in the Hungarian and the HICP baskets: while the weight of housing rents is around 6% in the HICP excluding imputed rents, in Hungary, the regulated rent and the imputed rent account for 0.1% and 5.5%, respectively, of the consumer basket.

Adding effects

The previous subsections examined different transmission channels. Since these shocks are fairly small, the linear approximation of combined effects should not cause considerable bias. We summarise these results in Table 5.7 below.

TABLE 5.7 Summary of transmission effects*

	House prices	Housing investment	Consumption
1st year average	-0.60 – -1.14	0.00 – 0.00	-0.9 – -1.91
2nd year average	-1.22 – -2.89	-0.39 – -0.56	-1.55 – -3.11
3rd year average	-1.19 – -3.07	-0.70 – -1.13	-1.51 – -3.16
4th year average	-1.19 – -3.05	-0.70 – -1.02	-1.44 – -2.94
5th year average	-1.19 – -3.05	-0.69 – -0.88	-1.33 – -2.75

** 1 percentage-point permanent increase in mortgage loan rate. Results are displayed as percentage differences from the baseline.*

At first glance, it would appear that the mortgage rate has a disproportionately large impact on consumption compared to housing investment. However, it should be recalled that while housing investment is influenced by standard transmission channels, consumption is likewise influenced by the ‘borrow more’ effect. Considering the huge consumption boom, parallel with extensive mortgage loan demand in 2002 and 2003, our results appear to be consistent with the facts and also seem to offer an additional explanation for the observed consumption growth.

5.5 On the way to the eurozone

Prior to accession to the eurozone, it is important for the conduct of Hungarian monetary policy to understand in detail the transmission mechanism in the eurozone. Focusing on eurozone experiences is particularly important in trying to analyse a channel that is relatively new to the Hungarian economy, such as the interaction between monetary policy and the housing and mortgage markets. Given the nominal convergence process of Hungary, the experiences of the less developed eurozone countries can serve as useful benchmarks for expected future dynamics, both during the last years of the convergence process and for the expected effects in the early years in the eurozone. Furthermore, understanding the main features of the transmission mechanism in the eurozone could help policymakers to facilitate the convergence of the Hungarian housing and mortgage markets to structures prevailing in the eurozone.

The first characteristic of the transmission mechanism in the eurozone is related to the dominance of long-term, non-callable bonds in the mortgage markets of the biggest member countries. As discussed previously, the dominance of long non-callable bonds results in a rather weak link between the key interest rate and interest burden of the mortgage debt in the eurozone, and leads to a slow convergence of the main parameters of the existing mortgage stock across the different countries.

The heterogeneity of the structural factors, along with the differences in house price and mortgage dynamics, has important implications for the monetary transmission in the eurozone. Prior to the launch of the single currency, some economists had serious concerns about the risks stemming from the differences in the transmission mechanism between interest rates and housing markets, given the heterogeneity of institutional and market characteristics. Maclennan, Muellbaurer and Stephens (1999) argue that, apart from initial heterogeneity, there could be considerable blockages to the convergence of the mortgage and housing markets in the unified financial markets even in the longer run. These could slow down the process, and probably eliminate the prospect of convergence entirely in some countries.

It is interesting to note in this regard that an assessment of the structural factors in the EU housing markets based on the four-year experience of the monetary union (ECB 2003) highlighted the fact that, due to the liberalisation of the markets, the heterogeneity prevailing in the mortgage markets of the eurozone countries had moved from the country level to the household level. This implies that the transmission through the mortgage and housing markets in the eurozone will retain its heterogeneity in the long run. However, in contrast to the situation before the adoption of the euro, it will change from household to household, as households can have access to a wider range of mortgage products in choosing what fits their preferences the best.

The ECB conducted a comprehensive analysis of the monetary transmission mechanism in the eurozone (Angeloni et al. 2002), summarising the experiences of the first years of the single currency. The analysis took into account the difficulties related to the short time series since the implementation of the euro, as well as the structural changes that might have happened due to the change in the monetary regimes of the member countries. Having these caveats in mind, the study found that the interest rate channel is a very important channel of monetary transmission, although it is not exclusive in many countries. The bank lending channel was found to be significant in Italy and Germany, countries with more rigid mortgage markets, although at the eurozone level, the results were contrary to the presumption of a widespread and strong bank lending channel.

The study also found that the overall effect of monetary policy on the real economy is comparable between the US and the eurozone. However, the components of GDP most sensitive to monetary policy are different. It is investment that drives output changes in the eurozone, whereas in the US, much of the output adjustment seems to stem from changes in consumption. These qualitative findings are consistent with the assumption that flexible mortgage markets, such as those in the UK and the US, can strengthen the monetary transmission mechanism operating through households' consumption behaviour.

Among the most developed EU mortgage markets, the UK and Denmark are not part of the eurozone, as both countries have an opt-out from becoming a full member of the EMU. However, both countries have thorough analyses of how their transmission mechanism through the housing and mortgage markets would be affected by the adoption of the euro. What makes the comparison of the situations in the two countries even more interesting is the fact that they are basically at the opposite ends of the spectrum in terms of mortgage regimes.

In the UK, HM Treasury (2003) prepared a study on the implications of the housing market for the transmission mechanism as part of the very comprehensive assessment of the five economic tests for determining whether adoption of the euro would be in the interest of the economy. The study concluded that, due to the structural differences between the UK and the eurozone housing and mortgage markets, the interest-rate sensitivity of households in the UK is greater than in the eurozone. Thus, the optimal monetary policy for the enlarged eurozone might not be optimal for the UK. The study identifies four main structural differences: housing supply elasticity, level of mortgage debt combined with the dominance of variable rate mortgages, owner-occupation rate and the level of competition and liberalisation of mortgage markets. The last point is the main reason behind the difference in house equity withdrawal, which has probably the most important macroeconomic effect for the difference between the consumption behaviour of UK and eurozone households.

Denmark has a rather different view of the possible effects of adopting the euro. Despite the structural differences between the housing and mortgage markets of Denmark and the eurozone countries, there are no serious concerns about the possible effects of adopting the euro. One reason for this is the set-up of the current monetary policy framework: the Danish crown is pegged to the euro with a narrow band in the ERM II regime, and the interest rate policy of the ECB is rather closely followed by the Danish National Bank. Due to the monetary regime, the adoption of the euro would mean only slightly lower interest rates, given the 20-30 bps spread of Danish yields above euro benchmark levels. Based on the fixed exchange rate regime market, participants can hedge prepayment risk in the euro market without needing to hedge currency risk, although, the single currency could make hedging even easier in the Danish market.

Another reason behind the pro-euro stance is the limited difference between the transmission effects of the long callable Danish bonds and the non-callable eurozone bonds in empirical terms. As discussed earlier, an asymmetry arises between callable and non-callable types when the long rates are decreasing, making the re-mortgaging of callable bonds profitable. This happens usually when the economy is below the potential growth rate and the monetary policy stance is accommodative. In these cases the asymmetry would lead to faster recovery through the higher consumption generated by the more favourable terms of re-mortgaging. However, it would not lead to overheating as there are basically no differences between the two mortgage types in times of increasing yields, leading to tighter monetary conditions.

While it is important to pay attention to the national characteristics influencing monetary transmission even in a monetary union, global forces should also be kept in mind. A recent study (IMF 2004) argues that house prices are globally synchronised to a large extent, despite the extreme non-tradable nature of dwellings. The study, which used the dynamic factor model, has found that in a set of 13 developed countries, global factors explained, on average, 40% of house price movements between 1980 and 2004. One theoretical explanation for the important role of global factors in determining house prices is that, apart from housing assets, a significant part of household wealth consists of internationally traded assets, causing rates of return to move in a coordinated fashion globally. Another reason, confirmed by the econometric results of the IMF (2004), is that interest rates and mortgage debt/GDP ratios are correlated with the global housing factor, which captures common shocks affecting house prices in all countries of the sample. These results highlight the importance of monetary policy and the mortgage market in the housing markets of developed countries, strengthening the transmission mechanism of the single monetary policy in the eurozone.

By and large, there is a sizeable outstanding stock of mortgage loans and the mortgage debt/GDP ratio has been growing steadily in the eurozone, not least due to the effects of the convergence of nominal yields. However, the transmission effect of residential mortgage loans is rather limited, as the bulk of the loans in the biggest countries are made up of long, non-callable loans. Mortgage markets are liberalised, as reflected in the growing heterogeneity of the new contracts across countries. However, on an aggregate level, the competitiveness of the eurozone mortgage market is well behind that of the UK market, where households have a better opportunity for housing equity withdrawal and can thus significantly ease liquidity constraints to smooth consumption.

Future dynamics of Hungarian mortgage market

In light of the international experiences discussed above, it is important to consider the possible dynamics coming into play in the Hungarian market in the coming years and decades. In the following section, we focus mainly on the mortgage market for two reasons. First, the most rapid change in the structural factors is related to the mortgage market. Second, the adoption of the euro will certainly exert the most direct impact through mortgage loans.

As we look forward to the adoption of the euro, it is logical to assess the future of the Hungarian mortgage market in light of the experiences of current eurozone members. We have seen in section II that Portugal and Italy are the two extremes in terms of mortgage market developments. Portugal is the typical example of a liquidity-constrained market where demand for mortgage loans grew extremely fast, alongside interest rate convergence. In Italy, on the other hand, there was a rather moderate increase in demand during the years of convergence.

However, apart from the foregoing, another factor should be considered in studying a small open economy using its national currency, such as Hungary. Since a significant part of the transmission mechanism through the housing market is related to the indebtedness of the household sector, the net financing position of the household sector also needs to be taken into account. In other words, apart from structural features, the sustainability of the net position of the domestic sectors, as reflected in the current account, can also influence the speed of adjustment in the run-up to euro adoption.

If there were only forint-denominated loans available in the mortgage market, the dynamics of the new loan provision would depend primarily on long-yield convergence. Given the loan conditions after the tightening of the subsidy scheme, the benchmark rates should drop some 300-400 basis points, so as to be comparable with the levels during the heavily subsidised period of 2002-2003. This would also imply that, due to the gradual process of yield convergence, the growth in the mortgage market would be rather limited in the coming years, contrary to the exponential dynamics in 2003. In this scenario, the Hungarian mortgage market would become similar through time to those in most continental EU countries. Given the dominance of long fixed loans in these countries, monetary policy has had only a weak impact on the disposable income of households, although there is still a substantial growth in the mortgage debt/GDP ratio.

The response of the household sector to the tightening of the subsidies points, however, to a somewhat different path. As earlier mentioned, FX loans became increasingly popular in 2004 among households facing the higher forint mortgage rates. The strong mortgage demand suggests that Hungarian households were willing to pay a high price, namely the imminent exchange risk, to loosen liquidity constraint. The growing popularity of FX mortgage loans provides an additional transmission channel on the one hand, as high domestic rates rather shift mortgage demand to FX loans, and leads to the build up of the non-hedged FX position of households, raising stability-related concerns, on the other.

Looking from a longer perspective, however, the increased importance of FX loans in the mortgage market is only temporary. As earlier noted, the rationale for the FX loans from a household's perspective, lies mainly in the high domestic rates at long maturities, which are directly related to macroeconomic fundamentals. Given the still existing government subsidies for housing loans, the mechanism by which a credible convergence path can decrease the popularity of FX loans is clear: improving fundamentals are reflected in decreasing risk premium, leading to lower domestic yields, thus giving less incentive for FX loans. At the same time, it is less than straightforward to determine the level to which the stock of FX loans will rise before domestic yields become once again more favourable to households. It will depend partly on domestic economic policy, when it can commit itself to a credible convergence path and also on international market conditions, which, due to the historically low short interest rates and rather steep yield curve, recently make variable rate FX mortgages highly attractive for liquidity-constrained households.

Short term simulation

In light of recent dynamics, it is a relevant question for monetary policy to see what could potentially be the size and composition of mortgage loans at the time eurozone accession. To answer this question we performed a simple simulation until 2010, the official target date for eurozone accession.

Although it is still quite early, just a few years after the start of mortgage lending, to forecast the mortgage/GDP level which could be considered as the long-run equilibrium for Hungary after euro adoption, the popularity of FX loans points toward high equilibrium mortgage levels. Considering that Hungarian households have gotten so easily used to the wide range of mortgage products, encouraging them to take on significant exchange rate risk to improve access to mortgage loans, Hungary will likely not follow the moderate path observed in Italy. Rather, mortgage developments in Hungary will, more likely, mirror the dynamics observed in Portugal, where mortgage loans rose to almost 50% of GDP in less than ten years.

5.6 Conclusions

Based on the international experiences and the evolution of the Hungarian mortgage and housing markets, the following conclusions can be drawn regarding the monetary transmission mechanism.

- While monetary policy has a quite significant effect on consumption, it exerts a rather limited impact on housing investment and house prices in Hungary.
- The transmission through the interest rate channel is negligible at the macroeconomic level, for two major reasons. First, notwithstanding its exponential growth in the last years, the ratio of mortgage indebtedness to GDP in Hungary (8%) is still low compared to those in developed countries (40-60%). Second, the Hungarian mortgage market is dominated by long, non-callable loans, which creates a weak and delayed link between key policy interest rate and mortgage rates.
- The wealth and credit channel could be discerned in the Hungarian data, with theoretically consistent parameters, although transmission effects on house prices, housing investment and consumption are rather limited.
- A further transmission channel related to house equity withdrawal, the 'borrow more' effect, has had a significant impact on household consumption in recent years.

There are various factors determining the future dynamics of mortgage markets until and after the adoption of the euro. During the convergence process, the sustainability of the net saving position of the domestic sectors can constrain the growth of household indebtedness. Recent experience shows that high domestic mortgage rates shift demand towards FX loans, rather than decrease the overall demand for mortgages.

It could take decades after euro adoption to reach the equilibrium mortgage debt/GDP level. Given the fast growing loan demand of households, particularly the popularity of FX loans, the possible dynamics in the Hungarian market might mirror those of Portugal, where the mortgage debt/GDP ratio increased from 10% to almost 50% in less than a decade.

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Appendix

Data set

House prices: Data on house prices constitute the most problematic data set. The Hungarian Central Statistical Office (CSO) publishes house prices based on contracts submitted to the Land Registry Office. On one hand, this implies great cross-sectional detail. However, CSO data are available only on a yearly basis. In order to increase the information content, we thus generated a quarterly database based on the raw monthly database of the Hungarian CSO (2003). During the generation process, we applied the following data-check filters:

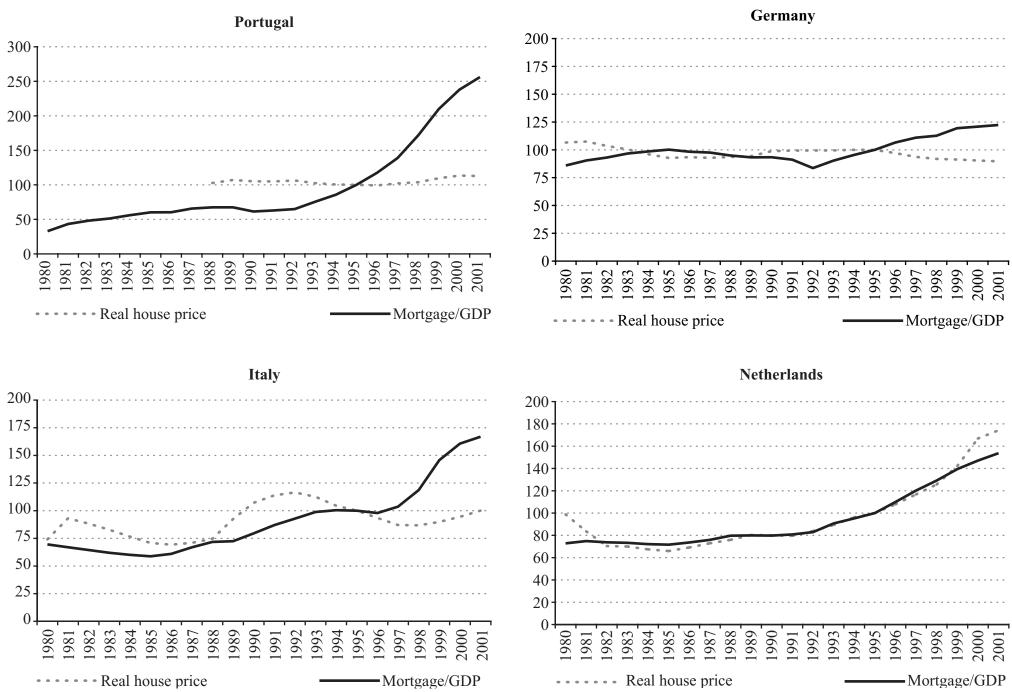
- the total area of dwellings should be between 20 and 600 m^2 square meter
- the price per square meter of dwellings should be between € 200 and 4000.

Income. Theoretically, the appropriate income variable should be the disposable income of households, which would consist of average net wages. However, average net wages available at the county level have two problems. First, average wages are only roughly half of households' disposable income. Second, the wage data are published in terms of headquarters rather than the actual working site. This means that part of the income reported under a certain county may not really be attributable to that county, as it may lodge merely the headquarters and not the actual place of work of the employee concerned. However, considering that GDP figures are also published in terms of headquarters, the available data may still serve as a proxy for the entire amount of households' incomes. It is thus reasonable to use data on GDP per capita instead of average wages.

Interest rate: We use a composite mortgage interest rate of subsidised loans, market loans and FX loans, weighted by their respective shares in loan origination. Since official interest rate statistics incorporate data on government subsidies in the time series, we therefore used the maximum APRC set by government regulations in case of subsidised loans.

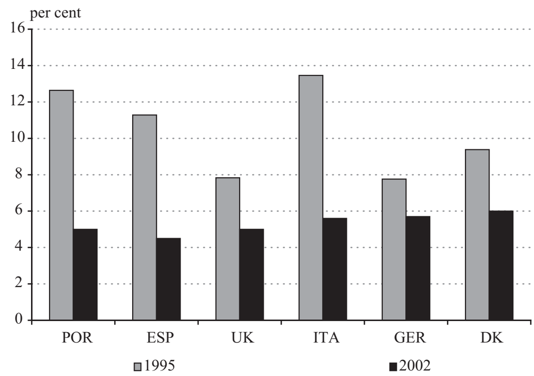
New house starts and finished house constructions: We use new house starts and finished house construction by county as exogenous instruments. The first one denotes the number of house building permits issued by local governments. The latter shows the number of permits to reside that are granted to newly built houses.

FIGURE 5.1 **Real house prices and mortgage/GDP growth in selected eurozone countries (1995=100)**



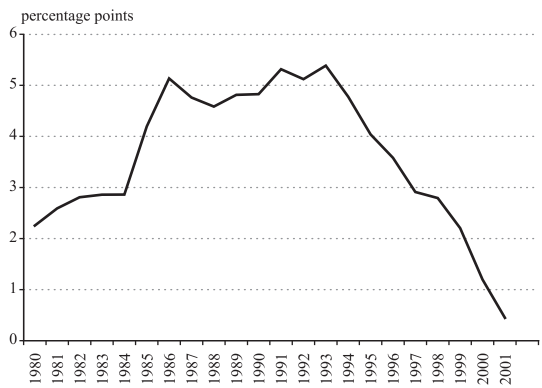
Source: ECB.

FIGURE 5.2 Convergence of mortgage interest rates



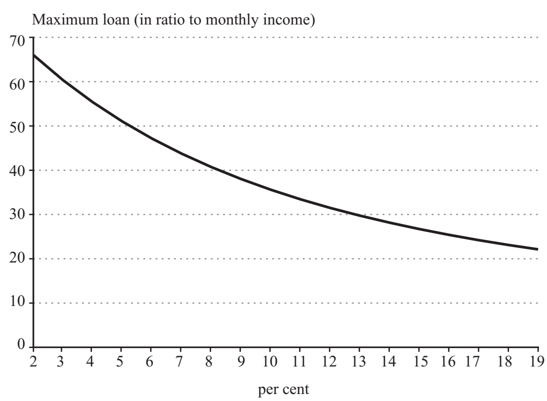
Source: ECB, HM Treasury.

FIGURE 5.3 Standard deviation of mortgage rates in eurozone member states



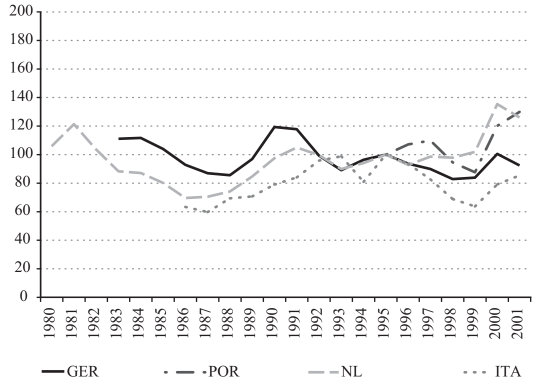
Source: ECB.

FIGURE 5.4 Credit constraint and nominal interest rate



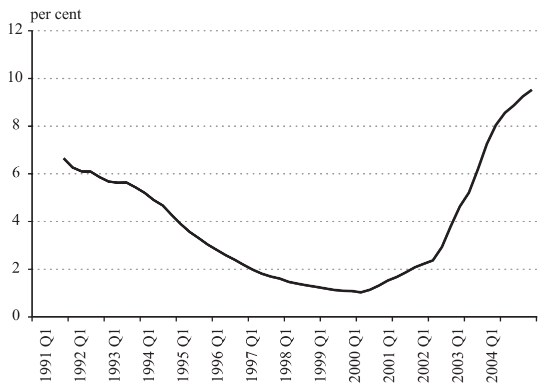
Source: Own calculations.

FIGURE 5.5 Debt servicing to disposable income (1995=100)



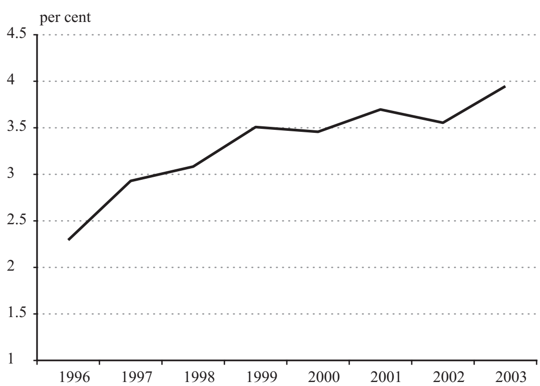
Source: ECB.

FIGURE 5.6 Mortgage/GDP in Hungary



Source: MNB.

FIGURE 5.7 Housing transaction/housing stock in Hungary



Source: Ministry of Finance.

6. Is there a bank-lending channel in Hungary? Evidence from bank panel data

Csilla Horváth, Judit Krekó and Anna Naszódi

6.1 Introduction

The bank lending channel emphasizes the behavior of financial intermediaries in effecting the quantity of loans and therefore the real economy. The theory of bank lending channel suggests that the state of financial sector may have a strong influence on the transmission of monetary policy. The implication of this theory on the euro zone is that a common monetary policy shock in the euro zone may induce asymmetric reactions in countries with different conditions on the financial market. Since the beginning of the EMU, a large body of empirical analysis had been devoted to the credit channel. These find weaker or stronger evidence of credit channel for the analyzed countries (see Table A. in the Appendix). The book edited by Angelioni et al. (2003) summarizes the main findings for the European countries. In this paper we investigate whether bank lending channel plays a role in the transmission mechanism in Hungary. We discuss and investigate whether and to what extent the conditions for the working of the bank lending channel are fulfilled, review the conditions of the Hungarian financial sector, outline the expected future tendencies based on some country- and region-specific characteristics. In the empirical examination of the bank lending channel we use the generally applied approach suggested by Kahsyap and Stein (1995) which relies on discovering asymmetries in changes in the amount of loans to monetary actions in order to isolate supply and demand effects. We estimate an ARDL model where the asymmetric effects are captured by interaction-terms.

According to this approach, however, asymmetries can only be attributed to supply decisions if loan demand is homogeneous across banks. A novelty of the paper is that we make an attempt to test whether demand of loans can be considered homogeneous across banks with respect to some bank-characteristics. Additionally, we also investigate an intermediate step in the process of the bank-lending channel. Namely, whether monetary tightening induces asymmetric increases in external financing, which is in line with the theory.

This approach tests the existence of bank lending channel only indirectly, but not directly. The most reliable and direct way to test this hypothesis in an environment of interest rate controlling monetary policy would be the comparison of bank lending with alternative external funding of

We are grateful for the useful comments of Péter Benczúr, Katalin Bodnár, Zsolt Darvas, Marianna Endrész, Márton Nagy, Zoltán Szalai, and Balázs Vonnák.

firms.[1] This direct test is not feasible in Hungary because of the poorly developed equity and corporate bond market. Although we do not test directly whether the Hungarian financial system amplifies the traditional effects of monetary policy actions, based on some stylized facts we conclude that the conditions for the functioning of the bank lending channel are fulfilled. Moreover, we find significant asymmetric adjustment of loan quantities along bank characteristics suggested by the bank lending literature. In addition, we do not find any sign for asymmetric loan demand adjustment along these variables. According to these findings, we cannot rule out the existence of the bank lending channel in Hungary.

The rest of the paper is organized as follows. In Section 2 we discuss the theoretical background of the bank lending channel. In Section 3, in order to get an overall picture of the bank lending channel, we list several stylized facts about the financial system of Hungary. Section 4 describes the econometric model and presents the results. Section 5 concludes. In this paper we not only present indirect evidence for the bank lending channel but also predict some important future changes in the transmission mechanism in Hungary.

6.2 Bank lending channel: theoretical and methodological background

In this section we provide a concise discussion of the theories for the bank lending channel. First, we shortly introduce the credit channel and explain the functioning of its two sub-channels: the balance sheet channel and the bank lending channel.

The starting idea of the theory of *credit channel* is that there are frictions on the financial markets. These frictions arise from asymmetric information that exists among economic agents that lead to adverse selection and moral hazard behavior.[2] Due to these frictions, internal and external sources of finance are not perfect substitutes of each other (in contrast with the I. theory of Modigliani-Miller) but there exists a gap between the costs of internal (e.g., retained earnings) and external financing (issuing equity or debt), which is called the external finance premium. Monetary policy can influence the external finance premium; monetary tightening increases and monetary loosening decreases its magnitude. Due to this additional effect of policy on the external finance premium, the impact of monetary policy on the cost of borrowing may be amplified (Bernanke and Gertler, 1995). Bernanke and Gertler (1995) emphasize that the so-called credit channel should not be considered a free-standing alternative to the traditional transmission mechanism, but rather as a set of factors that magnify conventional interest rate effects.

While the functioning of the credit channel would magnify the effects of monetary policy, there are theories that suggest that banks may decide to smooth their interest rates, hereby reducing the effect of monetary policy. Adverse selection, moral hazard problems, and relationship lending may, for example, induce banks to increase their loan interest rates at a smaller extent than the

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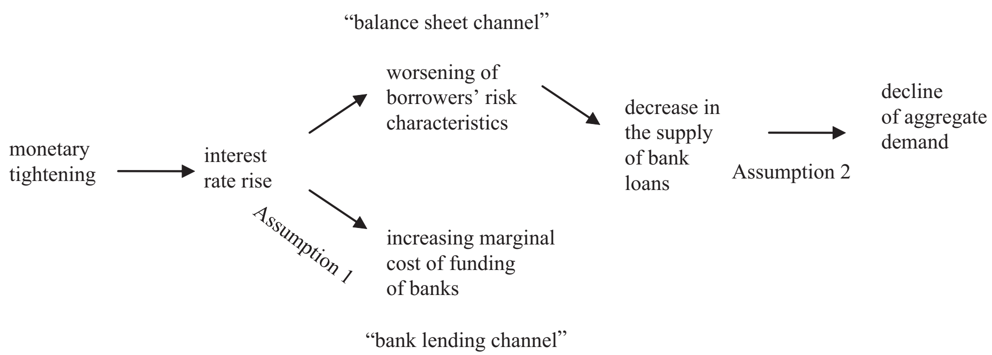
[1] Kashyap, Stein and Wilcox (1993) found evidence for this hypothesis. Their results show that the ratio of commercial papers of bank loans rises following a monetary policy contraction.

[2] Adverse selection means that borrowers with higher risk are more involved in searching for loans and therefore, they have a higher probability of obtaining them than borrowers with lower risk. Moral hazard problem on the other hand arise after granting of credit. Given granted credit, borrowers may be more inclined to start riskier activities increasing the risk of their credit. As a result, in case of higher moral hazard and adverse selection, creditors may decide to decrease the amount of credit or when considering every borrower identical, they may make the conditions for borrowing stricter.

raise in their cost of funding due to monetary tightening. So, it is ambiguous whether the banking system amplifies or weakens the functioning of monetary policy relative to the case when the banking system was not considered (and certain aspects of its behavior were not modeled) in the transmission mechanism. It depends on which of these two mechanisms dominate in an economy. The net effect of the banking sector depends on characteristics of the banking system (such as degree of competition, easy access to external financing of firms and banks) and on characteristics of the economy itself (distribution of good and risky borrowers and the relevance of adverse selection behavior).

The credit channel is interesting and important for several reasons. First, if the credit view is at work, it implies that monetary policy can affect the real economy without much variation in the policy rate. Second, the view can explain how monetary contraction influences investment and inventory behavior. In addition, understanding the credit channel will offer insights on how innovation in financial institutions might affect the potency of monetary policy. Furthermore, the credit channel can explain the distributional effects of monetary policy on both lenders and borrowers while the conventional view cannot. Finally, the credit view also implies that the impact of monetary policy on economic activity is not always the same. It is sensitive to the state of firms' balance sheet and health of the banking sector. That is, it has obvious implications for the ability of monetary policy to offset particular sorts of adverse shocks.

FIGURE 6.1 **Stylized description of the functioning of the credit channel**



Two mechanisms have been suggested to explain the effects of monetary policy actions on economic activity based on changing external finance premium (see Figure 6.1). One is the *balance sheet channel* (also referred to as net worth channel) that stresses the potential impact of monetary policy actions on borrowers' balance sheets, net worth, and cash-flow. The other is the *bank lending channel* that focuses on the loan supply decisions of banks.

Balance sheet channel

The balance sheet channel of monetary policy arises because monetary policy actions affect not only market interest rates but also the financial positions of borrowers, both directly and indirectly. A tight monetary policy directly weakens borrowers' balance sheets in at least two ways. First, rising interest rates directly increase interest expenses, reducing net cash flows and weakening the borrower's financial position. Second, rising interest rates are also typically associated with declining asset prices, which among other things shrink the value of the borrower's collateral. Indirect effect of tight monetary policy on net cash flows and collateral values is due to deterioration in consumers' expenditure. The firm's revenues will decline while its various fixed or quasi-fixed costs do not adjust in the short run. The financing gap, therefore, erodes the firm's net worth and credit worthiness over time.

Lower net worth means that lenders in effect have less collateral for their loans, and so are more exposed to problems arising from asymmetric information. A decline in net worth, which raises the adverse selection problem, thus leads to decreased lending to finance investment spending. Lower net worth of business firms also increases the moral hazard problem because it means that owners have a lower equity stake in their firms, giving them more incentive to engage in risky investment projects. Since taking on riskier investment projects makes it more likely that lenders will not be paid back, a decrease in business firms' net worth leads to a decrease in lending and hence in investment spending. This mechanism may explain why the impact of the credit channel on spending, particularly on inventory and investment spending, may persist well beyond the period of the initial monetary tightening.

Bank lending channel

The bank lending channel focuses on possible effects on the supply of loans of banks. The bank lending channel is based on the idea that the cost of funding of the banks increases in response to restrictive monetary policy shocks. There are several reasons why the marginal cost of funding may increase. First, if there is some degree of asymmetric information[3] between banks and their investors, adverse selection problems will arise. This tends to make marginal cost of external funding an increasing function of the risk free interest rate. Second, secured deposits function as money, and therefore reduce as a response to a monetary restriction. If a bank wants to compensate or partly compensate a drop in liabilities, it acquires more uninsured external funding. Due to the decreasing share of secured funding investors consider the bank more risky and require higher risk premia or limit their lending to banks. Third, when aiming to obtain more external funds the banks face additional costs, such as search costs, cost of advertising. As a response, banks may be inclined to increase the spread due to the increasing average cost of funding.

So, the idea behind the theory of bank lending channel is that monetary policy affects not only loan demand, but also banks' loan supply, which in turn, further influences the monetary policy on investment and consumption. According to the bank lending literature there are two necessary assumptions for the functioning of the bank lending channel. First, the marginal cost of funding increases as a response to the interest rate hike (assumption 1 on Figure 6.1). Second, a significant number of firms are dependent on bank loans, i.e., these firms are unable to perfectly substitute between bank loans and other forms of finance (assumption 2).

[3] Evidence that commercial banks face adverse selection problems when raising external funding have been provided by the event studies of Cornett and Tehranian (1994) and Poloncheck, Slovin and Sushka (1989).

Theoretical model for the bank lending channel

There are several models that address the working of bank lending channel. Early models, like those of Bernanke and Blinder (1988) and Kashyap and Stein (1994), were developed for the case where central banks control money supply either by direct interventions or by changing the reserve requirement of commercial banks. Nowadays, the main policy instrument of the central banks is the interest rate. Ehrmann at al. (2003) distilled a model for the bank lending channel where central bank operates via the base rates. Consequently, below we focus on a simplified version of this model.[4]

The model

An essential building block of this model is that external finance premium of banks increase due to moral hazard and adverse selection problems when interest rate rises. This increase may vary across banks that have different characteristics.[5]

In this model the loan market is assumed to be characterized by monopolistic competition. The demand for (nominal) loans of bank i (L_d^i)is:

$$L_d^{\,i} = -a_0 r_{L,i} + a_1 y + a_2 p\,, \tag{1}$$

where $r_{L,i}$ refers to the bank-specific loan rate, y to aggregate real output, p to price level and a_0, a_1 and a_2 are positive coefficients. Banks choose the bank-specific loan rate ($r_{L,i}$) in order to maximize their profit under the constraint of balance sheet identity:

$$L_i + S_i = B_i + C_i\,. \tag{2}$$

Loans granted by the bank plus the banks' holding of securities (S_i) should be equal to the liability side consisting of external funding (B_i) including deposits and capital (C_i).

Further assumptions are that bank capital is proportionally related to the level of loans in order to meet the regulatory minimum capital requirement:

$$C_i = kL_i\,. \tag{3}$$

Banks' holding of liquid securities is linked to the external funding (B_i) in order to meet a liquidity requirement:

$$S_i = sB_i\,. \tag{4}$$

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[4] The only simplification we make on the Ehrmann et al. (2003) model is that we do not distinguish between secured and non-secured external funding of the banks.

[5] See for example Lowe and Rohling (1992).

Banks finance the assets not only by internal sources (capital), but also by interest bearing external sources (B_i). The interest rate paid by bank i for its external finance is denoted by $r_{B,i}$. The external finance premium over the risk free rate is likely to be bank-specific:

$$r_{B,i} = r_S \cdot (\mu - c \cdot x_i) \qquad\qquad 1 < \mu - c \cdot x_i, \tag{5}$$

where x_i refers to observable characteristics of banks, like its capital adequacy ratio, size, or liquidity position. These are indicators of the banks' stability.

The spread between the interest rate paid by bank i for its external finance ($r_{B,i}$) and the risk free rate (r_s) might vary across banks for two reasons.

First, the interest rate elasticity of deposits might vary across banks, just like the preferences of depositors. To exemplify this, banks with more affiliations or with more customer oriented services are likely to attract on average less interest rate sensitive deposits. Both the number of affiliations and the sensitivity of the deposits of the banks are likely to correlate with observable characteristic of the bank (x_i), like size.

Second, the external funds of the banks are supplied at a risk premium over the risk free rate and the risk-premium increases when r_s rises making the funding of loans more expensive for the banks.

Bank i has the following profit function:

$$\Pi_i = L_i \cdot r_{L,i} + S_i \cdot r_S - B_i \cdot r_{B,i} - \Psi_i \tag{6}$$

where Ψ_i denotes bank specific administrative costs.

Each bank maximizes its profit given by (6) under the constraints of (1)-(5). After solving the constraint optimization problem of bank i, we get the following expression for the optimal amount of loans:

$$L_i = \frac{a_1}{2} \cdot y + \frac{a_2}{2} \cdot p - \frac{a_0 \cdot \mu \cdot (1-k)}{2} \cdot r_S + \frac{a_0 \cdot c \cdot (1-k)}{2} \cdot x_i \cdot r_S - \frac{a_0}{2} \cdot \frac{\partial \Psi_i}{\partial L_i}. \tag{7}$$

As we can see from the expression, the optimal amount of loans granted by a bank will be a function of its observable characteristics (x_i), such as capitalization, liquidity, share of foreign ownership, and size.

As discussed later in more detail, in most empirical literature the regression of concern is a version of equation (3) and the investigation whether the parameter of $x_i \cdot r_S$ is significant and has the expected sign is the way to identify loan-supply movements. We rely on a slightly modified version of equation (7) for the investigation of the bank-lending channel in Hungary. The identification, however, relies on the homogeneity assumption of loan demand across banks (that L_d^i does not depend on x_i). The accuracy of this assumption will be tested in the empirical part of the paper.

Empirical approaches for the identification of the bank lending channel

Several empirical approaches have been used to investigate the functioning of bank lending channel. As already pointed out, the difficulty arises from separating the supply and the demand effect of monetary actions. Earlier papers tried to examine the bank lending channel based on aggregate data, while in more recent papers identification rely on asymmetries in the loan supplies of individual banks.[6]

Identification based on aggregate data

Bernanke and Blinder (1992) rely on aggregate balance sheet data and use vector autoregressive models to see how monetary policy affects real economy and via what transmission mechanism. They find that tighter monetary policy results in an immediate reduction of bank deposits and bank holdings of securities with little immediate but larger delayed effect on loans. Finally, aggregate output also falls. While the authors' finding is certainly in line with the idea of bank lending channel, it may as well be purely due to the standard interest rate channel.

In order to overcome this identification problem, Kashyap, Stein and Wilcox (1993) consider relative fluctuations in bank lending and in commercial papers that are lending substitutes for bank loans. They conclude that tighter monetary policy leads to a rise in the ratio of commercial papers to bank loans. The commercial paper is a proxy for the changes in the firms demand for loans. Hence, changes in the composition of the firms' external finance indicate that loan reduction is due to a shift in the relative marginal cost of loans to that of commercial papers, as suggested by the bank lending theory. However, this identification implicitly assumes that monetary policy shocks affect demand for alternative funds the same way.

Identification based on asymmetric movements in firm behavior

Several researchers used micro-level data to test for some cross-sectional implications of the bank lending theory. Gertler and Gilchrist (1994), for example, investigate whether the influence of monetary policy is larger for small firms that are supposed to be more bank-dependent. Their empirical finding for such an asymmetry however can also be due to the functioning of the balance sheet channel.

Nilsen (1999) takes this approach a step further. He not only investigates asymmetry in loan usage of firms but also analyses whether the cutback found is voluntarily. Namely, he investigates the use of a less desirable alternative credit: trade credit. He finds an increase in the use of trade credit and takes this as a support for bank lending channel.

Identification based on asymmetric movements in loan quantity

Kashyap and Stein (1995) investigate bank lending behavior at the individual bank level. Kashyap and Stein (1995) suggest that smaller banks might have steeper increasing external finance premium than larger banks because large banks have better access to non-deposit funding, as they are less exposed to information asymmetry problems. Based on this, they suggest identifying shifts in supply by seeking for differences in loan quantity adjustment for *larger and smaller banks.*

[6] Some of these approaches have mostly been applied to countries and periods with interest rate controlling monetary policy, while others have been used where and when monetary authorities control the money supply. Although, we are interested in the first case, the empirical investigations and results in the second case might be relevant to the first case as well.

Kashyap and Stein (2000) point out other possible asymmetric adjustment of banks. They argue that a bank with more *liquid* assets can relatively easily protect its loan portfolio in case of decreasing liabilities, simply by drawing down on its larger buffer stock of securities. The authors find that size and liquidity might be interrelated. Kakes and Sturm (2002) when analyzing bank lending in Germany conclude that in fact, smaller banks tend to hold a larger buffer of *liquid* assets to offset monetary shocks.

Kishan and Opiela (2000) add another factor to the possible distributional effects of monetary policy. They argue that *capital's* role in absorbing shocks to asset markets makes it an indicator of bank health and therefore an indicator of a bank's ability to raise alternative funds.

Based on Haas and Naaborg (2005), in line with the ideas of Kishan and Opiela (2000) we also include *foreign ownership* among bank characteristics and argue that higher foreign ownership might lead to lower marginal cost of financing because banks that are subsidiaries of foreign banks can get relatively cheap foreign funds from their parent banks. Therefore, smaller reaction of loan supply to monetary shocks is expected at banks with foreign ownership due to the working of bank lending channel.

In our empirical analysis we follow the approach of Kashyap and Stein (1995 and 2000), Kishan and Opiela (2000), and Haas and Naaborg (2005) and seek for asymmetries in the adjustment of loan quantity to changes in money market rate among banks with different size, liquidity, capitalization, and foreign ownership characteristics.

6.3 How much the theory applies for Hungary: looking at stylized facts

In order to get an overall picture of the bank lending channel in Hungary, we first list several stylized facts about its financial system and examine the relevance of these conditions for the bank lending channel. A thorough overview of the financial conditions in Hungary is especially important when investigating the bank lending channel because of several reasons. First, this overview might help to identify and separate the loan supply and the demand effect, which is a rather complicated empirical problem. Moreover, the changing economic environment makes the empirical analysis more difficult. Second, data on past and present behavior of loan supply cannot provide us with ideas about how important the role of financial institutions will be, for example, by the time Hungary joins the EMU. Here we present some stylized facts and investigate the possible future tendencies.

The reaction of external finance premium of banks to monetary shocks (Investigation of Assumption 1)

The functioning of the bank lending channel has a starting point that monetary tightening leads to increase in the external finance premium of banks. Using our dataset we find, that indeed, the 3-month Forint money market rate (MMR) and average cost of financing[7] (ACF) are highly correlated (0.63), which suggests that an interest rate increase results in higher costs of financing for banks. However, this can still be mainly due to the working of the classical interest rate channel. A more informative measure would be to see whether average cost of funding increases (addition-

[7] Average cost of financing is computed as interest rate payments per interest-bearing liabilities.

ally to the effect of interest rate channel) when MMR increases. More precisely, whether the spread between MMR and ACF is higher when MMR is higher. This correlation is positive and relatively high; 0.33.

The identification of the bank lending channel that we follow is based on identifying asymmetries according to theoretically plausible characteristics of banks that are outlined in the previous section. To investigate whether according to these factors indeed we see a difference in the financing of banks, we compute the correlation of size, liquidity, capitalization, and foreign ownership with average cost of financing.[8] We find, in accordance with the theory of Kashyap and Stein (1995 and 2000), and Haas and Naaborg (2005), that size, capitalization, and foreign ownership (see the first column of Table 6.1) are negatively correlated with the average cost of financing. The correlations, however, are quite low in most of the cases.

TABLE 6.1 Correlation matrix of size, liquidity, capitalization, and foreign ownership, and average cost of financing

	ACF	Liquidity	Size	Capit1	Capit2	For. own.
ACF	1	0.05	-0.05	-0.06	-0.02	-0.23
Liquidity	0.05	1	-0.07	-0.005	0.13	0.10
Size	-0.05	-0.07	1	-0.16	-0.14	-0.07
Capit1	-0.06	-0.005	-0.16	1	0.79	0.21
Capit2	-0.02	0.13	-0.14	0.79	1	0.23
For. own.	-0.23	0.10	-0.07	0.21	0.23	1

Note: Calculated for all banks and for the entire sample period, see data description in the empirical part of the paper
We obtain alternative measures of capitalization.
Capit1 is computed as equity divided by total assets and Capit2 is the capital adequacy ratio.
In our further analysis we use Capit2.

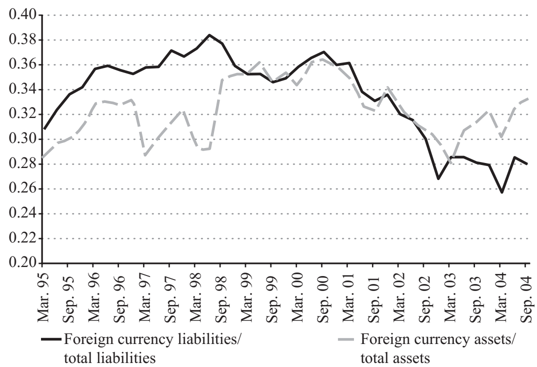
The correlation does not necessarily mean that an increase in money market rate results in a larger increase in the marginal cost of funding, for example, for smaller banks, but might just capture a difference in the cost *levels*. We investigate this question in a more sophisticated way in the empirical part of the paper by regressing changes in ACF on changes in different macroeconomic variables, changes in the MMR, and on interaction-terms of changes in MMR with bank-specific characteristics. The results support that an increase in MMR or in the euro interest rates (3-month EURIBOR) induces significant increase of ACF of an average bank, which supports the working of interest rate channel.

[8] Of course, average cost of funding among banks may differ due to differences in other characteristics of the liability side, such as average maturity. In this simple exercise we assume these other factors to be uncorrelated with the bank characteristics we focus on. One concern might be the relationship for ownership. If foreign-owned banks are more likely to have funding in foreign currency, an increase in domestic interest rate might have a lower influence on their average cost of funding, biasing our parameter of the interaction term with foreign ownership to negative values. At the same time, larger banks have proportionally larger deposit base. As this base is not exposed to the external finance premium an increase in MMR will lead to a lower increase in the average cost of funding. However, this asymmetry is in line with the idea of bank lending channel.

Availability of foreign (currency) funds

The forint yields contain a significant currency risk premium while the country risk premium is almost negligible. Therefore, there is a wide gap between the cost of Forint and foreign currency funds, and even the correlation between domestic and foreign interest rates is low (e.g. euro, Swiss francs). The Figure 6.2 shows the significance of foreign (currency) funds in liabilities, as of foreign currency denominated liabilities to total liabilities amounted to more than 26% between 1995 and 2004. The share of assets denominated in foreign currency in total assets is even higher in Hungary, it is around 30% during the observed period. It seems that the deepening of the monetary system in Hungary did not affect this proportion; it seems rather stable despite that total assets increase monotonically.

FIGURE 6.2 Currency denomination structure of assets and liabilities of the banking sector



Source: MNB.

Additionally, the majority of Hungarian banks are owned by foreign financial institutions. Foreign involvement in the banking market has increased over the observed period, which is a general characteristic of the new EU countries (Schmitz, 2004). Consequently, a significant and increasing proportion of the Hungarian banks can get relatively cheap foreign funds from their parent banks. These banks may face fewer financing constraints if they can receive additional (cheap) funding, equity or debt, from their parent banks (Haas and Naaborg, 2005) due to reduced asymmetric information problems. A bank with foreign parent bank that is facing problems with raising new capital may, for example, receive funds from the parent bank in exchange for (new) shares and when this bank needs additional liquidity the parent bank may provide it with funds in exchange for debt titles. Bonin et al. (2003) find that in countries in Central Europe and Baltic States (CEB) privatized banks experienced a decrease in net interest rate margins after their privatization. They argue that this provides evidence that foreign ownership made access funds less expensive. Haas and Naaborg (2005) find, analyzing CEB countries as well, that all parent banks interviewed in their study operate some form of internal equity market in which they influence the capital levels of their subsidiaries. Parent banks provide their CEB subsidiaries with debt funding; long-term debt or short-term cash support. However, in general, parent banks cannot fund their subsidiaries in the host-country currency. An example they come up with is that of ING Hungary that receives some euro liquidity from Amsterdam but does all of its funding locally because its business is mainly in Hungarian forint.

This implies that Hungarian banks can substitute domestic funds with relatively cheap foreign funds easily. This weakens the significance of the bank lending channel. The adoption of the euro in Hungary and the common monetary policy will reduce such possibilities for substitution since a significant share of the foreign parent banks and foreign funds are in the euro area.

Trends in liquidity and capitalization of the banking sector

The most commonly used bank characteristics applied to capture the existence of the bank lending channel are capitalization and liquidity position of banks. The banking sector has been characterized by excess liquidity in the last few years, as a consequence of heavy capital inflows in the late nineties, which was sterilized by the central bank. In other words, the increase in funds were more intense, then the lending possibilities of the banks. However, the share of liquid assets of the banking sector has been decreased continuously in the last few years, which might contribute to the increasing relevance of the bank lending channel at an aggregate level over time. The ratio of liquid assets has declined and the loan to deposit ratio has increased, and has approached the euro area's level (according to our dataset, on average, the ratio of liquid assets to total assets decreased from 50% to 23% in the period of 1998 and 2004). Similarly, capitalization of the banking sector has been also almost continuously declining from the late nineties, the capital adequacy ratio lowered significantly (it reduced from about 18% to 11% between 1995 and 2004); in case of some banks it is near the regulatory minimum. It is important to point out, these trends in liquidity and capitalization cannot be regarded an unfavorable developments. The Hungarian banking sector is now converging to 'normal' levels (see Table 6.2). The reduction of excess liquidity and overcapitalization might enhance the bank lending channel, i.e. the effect of monetary policy shocks on banks' lending decision might become stronger.

TABLE 6.2 Some characteristics of the banking sector in Hungary and the Eurozone in 2003

	Hungary	Eurozone
Capital adequacy ratio	11.5	12.3
Liquid assets/total assets	19.6	18

Source: MNB, ECB (2003).

However, the above mentioned bank characteristics are not independent from each other. Theory of bank lending channel suggests that banks, which face asymmetric information problem to a greater extent, for example smaller banks, have larger difficulties accessing cheap funds. Consequently, these banks are more inclined to hold more liquid assets and also to be better capitalized. In other words, higher liquidity and capitalization might be an endogenous response from smaller banks to counterbalance their financing difficulties resulting from higher asymmetric information problem. Additionally, limited access to cheap non-deposit funding might be captured by the liability structure of the banks, i.e. that smaller banks are notably more dependent on deposit financing than larger banks, and also better capitalized. According to Kashyap and Stein (2000), data of American banks support this hypothesis. Hernando and Pages (2003) also find that small Spanish banks tend to have more liquid assets and capital, which might be an endogenous response for asymmetric information problems and difficulties resorting uninsured sources of funds.

The Hungarian banking sector seemingly also underpins this hypothesis: smaller banks tend to have higher liquidity and capital adequacy ratio, than that of the larger banks (see Table 6.3). However, in contrast with the traditional story, the ratio of deposits to total external funds is lower, and the ratio of money market funds in total liabilities is higher at smaller banks than that of the larger banks. This data questions that smaller banks gather more deposits due to limited access to cheap non-deposit funding.

TABLE 6.3 **Selected indicators of Hungarian banks by size (2003)**

	Banks		
	small	medium	large
Liquid assets/total assets	33.8	39.7	19.6
Capital adequacy ratio	19.1	19.6	10.3
Loan/deposit ratio	126.6	140.7	105.1
Deposit/external funds	66.4	48.4	78.5
Money market funds/external liabilities	19.0%	20.3%	5.8%

Source: MNB.

The structure of the Hungarian financial system (Investigation of Assumption 2)

The second assumption for the working of the bank lending channel is that banks dominate the financing of firms, namely that (at least some) firms cannot substitute bank loans by other non-bank sources. From this point of view the picture in Hungary is rather mixed.

The Hungarian financial system is clearly bank-dominated, which creates a ground for the bank lending channel. Capital markets play a marginal role in corporate financing (see Table 6.4). In Hungary, the ratio of the market capitalization of the stock market to GDP is less than 30% of the average ratio of the EMU countries. Moreover, financial systems of EMU countries are also dominated by banks. In Hungary, the corporate bond market is especially underdeveloped and we do not expect substantial progress in the near future. On the other hand, although the financial intermediation is continuously deepening (loan/GDP ratio rose from 18.3 to 38.2 in the period of 1998-2004), domestic credit per GDP is significantly lower in Hungary than in the Euro-zone, which reduces the significance of bank loan supply effect on the corporate sector. Another important feature of the financial system is that direct foreign loans account for a significant share of total corporate debt. Consequently, corporations, especially large corporations, can substitute their domestic bank loans by foreign loans relatively easily (see Table 6.5), of which interest rate is not affected by domestic monetary policy. This fact mitigates the importance of Hungarian banks in the transmission mechanism in the present, but as majority of these loans come from EU banks, the effect of the common monetary shocks might become stronger after adopting the common currency.

TABLE 6.4 International comparison of channels of financial intermediation to enterprises (per cent of investment)

	Hungary		Portugal	Spain	Germany	USA
	1998[1]	2000[2]	1998[1]	1998[1]	1998[1]	1998[1]
			Domestic liabilities			
Bank credit[3]	20.4	18.9	32.8	19.9	17.0	6.8
Bond issues	1.2	0.1	3.5	1.4	..	..
Equity issues[4]	0.4	0.0	7.6	4.8	3.8	14.3
			Foreign sources			
Inter-company loans	4.1	3.1	2.8	2.1	..	..
Bank loans	3.2	13.6	2.2	2.3	..	..
Bond issues	0.3	0.1	0.3	0.0	..	..

[1] *1998: average of 1997 and 1998.*
[2] *2000: average of 1999 and 2000.*
[3] *Credit of domestic banks contains credit provided for corporate sector (including credit in foreign currency) by the resident banks (including foreign owned).*
[4] *Equity issues: capital-raising public offers on the stock exchange.*
Source: Schardax and Reininger (2001), Table 21, page 25.

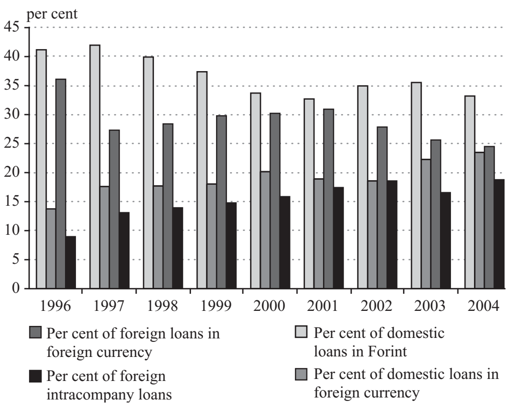
TABLE 6.5 Distribution of corporate and household loans and deposits by currency denomination in 2003 (per cent)

	Non-financial corporations		Households	
	Loans	Deposits	Loans	Deposits
Domestic banks, HUF	44	54	97	87
Domestic banks, foreign currency	29	12	3	13
Foreign banks, foreign currency	27	34	-	-
Total	100	100	100	100

Source: MNB.

Figure 6.3 clearly shows that the decomposition of corporate loans has changed significantly since 1996. The share of intercompany loans in foreign currency has doubled (increased from 9 to 19%) that might be partly due to the sharply increasing foreign ownership in the corporate sector in this period. At the same time, companies in Hungary appear to be more inclined to substitute their foreign currency denominated loans from abroad with those from banks in Hungary (their total share stays around 50% in the period, but the share of the first drops from 36% to 25% while the share of the second increases from 14% to 23%). The most important trend with respect to the working of the bank lending channel is that the share of loans denominated in Hungarian Forint fell from 41% to 33% from 1996 to 2004 with some cyclical variation in the period between. This tendency suggests a decreasing importance of the bank lending channel in Hungary. However, it may not necessarily continue even in the near future, because the domestic interest rate is expected to converge to the euro interest rate. The diminishing interest rate differ-

FIGURE 6.3 Decomposition of corporate loans in Hungary



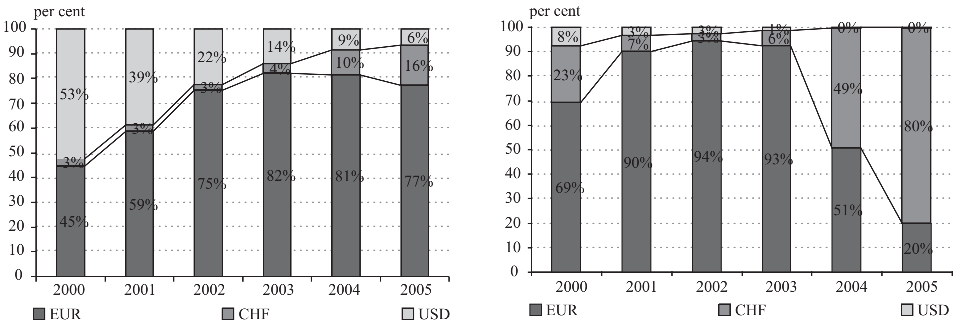
ential will make the domestic currency denominated loans more attractive for corporate and retail borrowers than before.

Regarding the expected entrance to the EMU the currency denomination decomposition of loans is also interesting. Figure 6.4 shows an increasing share of Swiss Franc both in consumer loans and corporate loans, and therefore of total loans in foreign currency. Holding of consumer loans in Swiss Franc increased rapidly in the past two years, to 80% of all domestic consumer loans in foreign currency. This happened at the expense of euro consumer loans, whose share dropped from 93% to only 20% in between 2003 and 2005. Since 2003 the share of corporate loans in euro also shows a declining pattern. As we mentioned earlier, a significant share of euro loans would suggests a rapid increase in the importance of the bank lending channel by the time of the EMU entry. The observed displacement of the Euro loans by the Swiss Franc denominated loans works against this change. At the same time, as the Report on Financial Stability October (2005) points out, due to risk management considerations banks may start to shift their foreign currency loans from Swiss Franc loans to euro loans.

Implications for the future

Although the majority of the above mentioned factors imply a weak bank lending channel, some expected future developments in the factors suggest its increasing significance. Most importantly, the dominance of foreign, mostly European, ownership of banks, and the substantial share of euro denominated assets and liabilities of banks imply that with the adoption of the common monetary policy – the share of liabilities and assets sensitive to domestic monetary policy will increase substantially. This will strengthen the bank lending rate channel. We do not expect a quick improvement of the equity market in Hungary. So, possibility of companies to substitute bank loans with other sources of financing continues to stay limited in Hungary thereby not showing a tendency that would weaken the bank lending channel.

FIGURE 6.4 Currency decomposition of domestic corporate loans in foreign currency (left) and Currency decomposition of domestic consumer loans in foreign currency (right)[9]



Source: MNB. Data for 2005 is only available until October.

Since financial markets in Europe are also bank-dominated, we do not expect that bank dependence of borrowers would decline substantially as the Hungarian economy integrates more into and becomes more similar to the European economy.

The banking sector has been characterized by excess liquidity in the last few years, as a consequence of heavy capital inflows in the late nineties, which was sterilized by the central bank. However, the share of liquid assets of the banking sector has been decreased continuously in the last few years, which might contribute to the increasing relevance of the bank lending channel at an aggregate level over time. Similarly, capitalization of the banking sector has been also declining considerably from the late nineties almost continuously, the capital adequacy ratio lowered significantly. The continuously diminishing of excess liquidity in the banking system and the decreasing capitalization due to the increasing efficiency in the banking system outlines the possibility of strengthening of the bank-lending channel in the future in Hungary.

At the same time, increasing tendency has been observed in the foreign ownership that increased the possibility of banks to get relatively cheap foreign funds from their parent banks. Domestic deposit insurance protection covers additional components since January 2003. The National Deposit Insurance Fund of Hungary included bank bonds and certificates of deposits issued by banks after 1 January 2003 among the insured items. These changes imply a reduction in the possible effectiveness of bank lending channel.

We believe that among these diverse processes the effect of Hungary's EMU entry will be the most influential.

1.4 Econometric analysis

In this section we describe the data and the empirical approach that we use for the investigation of the bank lending channel in Hungary and discuss the results. Our empirical analysis of the bank lending channel in Hungary uses data on individual bank balance sheets and applies panel-econometric techniques to exploit the heterogeneity among banks and over time.

[9] We thank Katalin Bodnár for providing us detailed data on the currency decomposition of corporate and consumer loans.

Data

We use quarterly data for the period of January 1995 – 2004 September. In order to get comparable results with Ehrmann et al. (2003) we treated the data the same way whenever it was possible. Most mergers have been treated by a backward aggregation of the entities involved in the merger. However, for banks, which merged at the end of our sample period, in 2004, we trimmed the observations after the mergers. We opted for this approach due to its advantages; namely, that we could make use of a larger information set for estimation and that we could avoid the possible bias induced by aggregation. Due to this merger treatment the number of cross-sections might vary over sample periods. The number of banks in a sub sample period ending before some mergers exceeds the number of banks in the whole sample period by the number of these mergers.

After the merger treatment we discarded those banks from the sample which existed for less than two years during the sample period. We also discarded those banks, which had either no deposits, or their loan to total asset ratio was less than 1% over the entire sample period. We trimmed the time series of those banks which had either no deposits or of which the lending activity was negligible for a few quarters during the sample period. Most of these banks have just stated in these periods or were about to close. So, the deletion of these observations eliminated those periods where the functioning of the bank was lead by unusual financial activities. Our final database contains 25 commercial banks. All balance sheet variables are seasonally adjusted.

Normalization of bank-specific variables

An important issue is to normalize the variables that capture possible asymmetries across banks in order to have proper interpretation for the c_j parameters. By demeaning the bank-specific terms their expected value becomes zero so, the c_j parameters can be interpreted as the average effect of monetary policy on loans.

One approach is to define variables that capture possible bank-specific asymmetries as deviations from their cross-sectional means as follows (like in Ehrmann et al. 2003 and Topi and Vilmunen 2001):

$$x_{it}^{*} = x_{it} - \frac{1}{N}\sum_{j=1}^{N} x_{jt}$$

This formulation removes a general trend characterizing the financial sector, for example general deepening of the financial sector. Size is usually defined this way. However, liquidity and capitalization are usually measured as (Ehrmann et al. 2003 and Brissimiss et al. 2003)

$$x_{it}^{*} = x_{it} - \frac{1}{TN}\sum_{t=1}^{T}\sum_{j=1}^{N} x_{jt}$$

This specification removes the overall average (across banks and over time) from each observation. This way we obtain the interpretability of parameters c, but we do not remove a trend from a possibly changing financial market. We chose this approach regarding the liquidity, capitalization, and foreign ownership variables, as we assume that the above mentioned general trends of decreasing liquidity and capitalization, and increasing trend in foreign ownership might be relevant from the point of view of the transmission. An argument for using the second normalization for non-size variables is as follows. The definition of a large bank may differ with changing market conditions, i.e., a bank which is considered to be small on a market with deeper financial sector may be regarded as medium or large in a smaller market. Contrary to size, liquidity and capitalization are less relative measures. This way, we make use of the variability of these characteristics not only across banks, but also over time.

Empirical approach to test asymmetric adjustment of cost of funding

In the beginning of Section 6.3 we started to check whether monetary tightening leads to increase in the external finance premium of banks by looking at the correlations between the ACF and the different bank-specific variables, respectively. Here we investigate whether an increase in money market rate results an increasing average cost of funding in the banking sector. This hypothesis is similar to assumption 1, however assumption 1 states a relationship between *marginal* cost of funding and money market rate, and not between *average* cost of funding and money market rate.[10] Moreover, we test the hypothesis that there is some asymmetry across banks in the reaction of their average cost of funding to the higher money market rate. This hypothesis is closely related to one of our assumptions in the theoretical model, namely, $0<c\cdot x_i$ in equation (5).

We regress changes in ACF on changes in different macroeconomic variables, changes in the MMR, and on interaction-terms of changes in MMR with bank-specific characteristics and estimate the following equation:

$$\begin{aligned}\Delta\log(ACF_{it}) = a_i + \sum_{j=1}^{J_1} b_j \Delta\log(ACF_{i,t-j}) + \sum_{j=0}^{J_2} c_j \Delta r_{t-j} + \sum_{j=0}^{J_3} d_j \Delta\log(GDP_{t-j}) + \sum_{k=1}^{n}\sum_{j=0}^{J_4} e_j z_{k,t-j} \\ + f x_{i,t-2} + \sum_{j=0}^{J_5} g_{ij} x_{i,t-2}\Delta r_{t-j} + \varepsilon_{it}, \qquad (8)\end{aligned}$$

where r_t refers to changes in interest rate at time t; L_{it} to of nominal loans of bank i at time t; GDP_t to GDP at time t; $z_{k,t}$ defines the kth macro variable at time t which we control for, such as inflation, exchange rate, foreign interest rate; $x_{i,t}$ captures bank-specific variables (in addition to the usual variables: size, liquidity, capitalization we also consider foreign ownership) of bank i at time t; and ε_{it} is the error term. We focus on the significance and the sign of cross-terms when seeking evidence for asymmetric effect of monetary policy on the external cost of funding of banks with different risk characteristics. This expression can be considered as an empirically-extended version of Equation (5) in the theoretical model.

[10] We have data only on the average cost of funding but not on the marginal cost of funding and therefore rely on this variable as a proxy.

The columns of Table 6.6 show the results of the five estimated equations.[11] The results in Table 6.6 show that an increase in MMR or in the euro interest rates (3-month euribor) induces significant increase of ACF of an average bank, which supports the working of interest rate channel. Exchange rate depreciation also leads to higher costs of funding. With respect to the interaction-terms that are our main interest, we have similar results to that of the correlation; an increase in the interest rate induces a larger change in average cost of funding for smaller, less capitalized banks, and for banks with higher domestic share. The fact that the parameter of the interaction-term for liquidity is positive does not contradict with the theory. Additionally, since the Hungarian banking sector has been characterized by excess liquidity, variation in liquidity among banks and over time is not likely to be informative for the functioning of the bank lending channel in Hungary in the investigated period. At the same time, banks that are aware of being exposed more to increasing cost of external funding (higher ACF) may decide to hold more liquid assets in order to protect their portfolio. Our results are in line with the theory and make us somewhat confident that if we find significant asymmetry for a specific bank-characteristic might indeed identify the functioning of bank lending channel.

Empirical approach to test asymmetric adjustment of credit quantities

Due to the ongoing debates about the bank lending channel, researchers use very different approaches to assess this channel of the monetary transmission mechanism as pointed out in section 6.2. In our investigation we apply the most frequently used approach of Kashyap and Stein (1995 and 2000) that relies on finding asymmetries in the reaction of loan quantity to monetary policy actions. This method was followed by majority of researches in the Transmission Network in the euro zone.

The empirical model

We rely on the usual approach of assessing the existence of bank lending channel, namely, we test the existence of distributional effects of monetary policy among banks, by introducing interaction-terms: based on Ehrmann et al. (2003) and Kashyap and Stein (1995) and followers, we use the following reduced form model to test for the existence of bank lending channel:

$$\Delta \log(L_{it}) = a_i + \sum_{j=1}^{J_1} b_j \Delta \log(L_{i,t-j}) + \sum_{j=0}^{J_2} c_j \Delta r_{t-j} + \sum_{j=0}^{J_3} d_j \Delta \log(GDP_{t-j}) + \sum_{k=1}^{n} \sum_{j=0}^{J_4} e_j z_{k,t-j} + fx_{i,t-2} + \sum_{j=0}^{J_5} g_{ij} x_{i,t-2} \Delta r_{t-j} + \varepsilon_{it}, \tag{9}$$

[11] In each version of equation (8) we only include one bank-specific variable (x_i). So, we estimate five separate equations. The results of the equation that contains, for example, size as bank-specific variable can be seen in column two, the results for liquidity in column 3, etc. All tables in this section can be interpreted the same way.

where r_t refers to changes in interest rate at time t; L_{it} to of nominal loans of bank i at time t; GDP_t to GDP at time t; $z_{k,t}$ defines the kth macro variable at time t which we control for, such as inflation, exchange rate, foreign interest rate; $x_{i,t}$ captures bank-specific variables (in addition to the usual variables: size, liquidity, capitalization we also consider foreign ownership) of bank i at time t; and ε_{it} is the error term. So, in order to proxy loan demand and monetary changes as closely as possible, we regress the loan growth of banks on GDP growth, inflation rate, domestic interest rate change, foreign interest rate change and focus on the significance and the sign the parameter of

TABLE 6.6 **Results of regressions for ACF**

ACF	**GMM, lag2, 1995 Q1-2004 Q3**				
Asymmetry (A)	Size	Liquid	Capit1	Capit2	For. own.
Interest rate	1.33***	1.53***	1.54***	1.55***	1.57***
	(7.79)	(9.83)	(13.13)	(9.28)	(11.41)
GDP	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
	(-6.23)	(-6.29)	(-8.22)	(-5.98)	(-8.95)
Exchange rate	0.18***	0.19***	0.19***	0.23***	0.19***
	(5.21)	(5.60)	(8.03)	(5.09)	(5.80)
Euro interest rate	0.00**	0.01***	0.01***	0.00	0.01***
	(2.04)	(3.67)	(3.77)	(1.17)	(5.29)
Inflation	-0.10	-0.11**	0.02	0.05	0.09
	(-1.45)	(-2.00)	(0.35)	(0.86)	(2.06)
A*interestrate	**0.00*** **	**1.28*** **	**-2.38*** **	**-0.84*** **	**-0.27**
	(-5.53)	**(2.94)**	**(-3.60)**	**(-2.41)**	**(-1.31)**
A	0.00	-0.01	0.01	0.04	-0.03
	(-1.36)	(-0.07)	(0.05)	(0.34)	(-0.53)
No. of obs.	855	855	841	841	847
Adjusted R^2	0.53	0.53	0.54	0.54	0.54
J-statistics	511.81	505.52	497.96	493.42	535.87
	(0.43)	(0.38)	(0.47)	(0.39)	(0.28)
D-Hansen test	20.46	33.09	27.04	29.16	44.04
	(0.97)	(0.52)	(0.78)	(0.69)	(0.11)

** significant at 10%, ** at 5%, *** at 1%.*
For GMM we only could use the White 1-step GMM weights. Below the J-statistics and the D-Hansen statistics, the numbers in parentheses are the corresponding p-values. The standard errors of the long-run coefficients are computed by delta method.[12]

[12] As long-run parameters are non-linear functions of the short-term parameters, we need to apply delta method for the estimation of the variance of the long-run parameters. Delta method is a general approach to compute confidence intervals of functions of maximum likelihood estimates that would be too difficult to compute analytically. In essence, it uses a linear (first order Taylor) approximation of the function and uses this to compute the variance of the simpler linear function.

cross-terms (g_{ij}) when seeking evidence for loan-supply effects. The interpretation of the long-run value of the g_{ij} s can be summarized as follows:

I. If loan demand can be considered homogeneous across banks:
  1. Significantly positive g shows genuine difference in loan supply behaviour.
  2. If g is not statistically different from zero, there is a common loan supply reaction across banks.
  3. Significantly negative g suggests that the selected x_i variable does not capture loan supply behavior or the basic identification condition is not true.

II. Under heterogeneous loan demand across banks:
  1. A significant g can capture aggregate effect of heterogeneous demand and supply side reaction of individual banks.

We use asymmetric variables lagged two times to avoid possible endogeneity. If the bank lending channel operates and loan demand is homogeneous across banks then we anticipate the coefficients of cross terms to be significantly positive, as monetary policy changes have a weaker effect on larger, more liquid and better capitalized banks and banks with larger share of foreign ownership according to the bank lending channel theory.

However, the aggregate coefficient of the monetary policy variable (c_j) also gives important information: it shows the aggregate effect of policy change on credit aggregates; a negative coefficient of interest rate implies that loans fall after a monetary tightening. This coefficient includes the demand and supply effects as well.

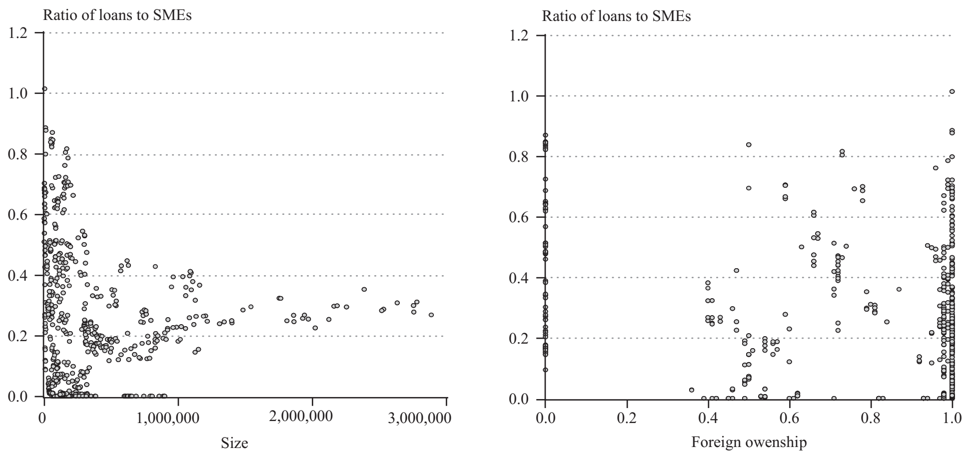
Testing homogeneity of loan demand

In order to properly disentangle the loan supply reaction to monetary policy actions, the Kashyap and Stein model assumes homogeneous reaction of loan demand with respect to the analyzed bank-specific variables.

However, if larger banks tend to lend more to larger companies, whose loan demand is less sensitive to interest rate changes than smaller ones', then the possible positive asymmetry with respect to the size variable might arise from the asymmetric adjustment of loan demand. To check whether it is plausible to assume homogeneity of loan demand for banks with different size we look at how the ratio of loans to small- and medium-size enterprises (SMEs) varies over banks with different size. Figure 6.5 shows that the ratio varies a lot among small banks while the conditional variance reduces as the size of banks increases and there seems to be a tendency for the ratio to increase with size. This figure shows panel observations, namely several observations (over the investigated period) for the analyzed banks. The correlation between the two variables is slightly negative (-0.07). When we run simple regressions to measure the relationship between these two variables, the parameter of size is never significant and sometimes it even has a positive sign. So, based on this simple investigation we find that the necessary assumption of homogeneous demand for loans for the identification of the bank lending channel is plausible.

Another concern may be a possible demand asymmetry due to the lending decomposition of foreign versus domestic banks. Empirical evidence has been found that foreign (which are also possibly larger) banks lend less to SMEs. The studies of Berger et al. (1995), and DeYoung et al. (1999) show that in the US foreign and large banks tend to supply less loans to small firms while Berger et al. (2001) have similar finding for Argentina. Haas and Naaborg (2005) investigate how foreign bank entry influences credit accessibility for SMEs and find that only those foreign banks whose parent bank is headquartered on another continent lend less to SMEs. Figure 6.5 also suggests no obvious relationship between the lending to SMEs and foreign ownership. The correlation between the two variables is -0.18. When we run simple regressions to measure the relationship between these two variables, we find negative coefficients for foreign ownership; however, they are never significant. Although we have no economic theory that would suggest a relation between the share of loans to SMEs and either capitalization or liquidity of banks, we checked the possible correlation. Again, the assumption of homogenous demand turns out to be plausible.

FIGURE 6.5 **Scatter plot of bank size and share of loans to SMEs in total loans (left) and of foreign ownership share and share of loans to SMEs in total loans (right)**



Besides the possible heterogeneity of loan demand across banks due to the heterogeneity in size of corporate clients of banks, there might be other concerns as well. The possible demand asymmetry might be due to some other heterogeneity across clients of banks, like the risk characteristics and the sectoral characteristics of the clients.

The size of the banks or other endogenous bank specific characteristics (denoted by x in Equation (9)) may be correlated with the sectoral characteristics of the clients or with the quality of the portfolios, i.e. the risk characteristics of the clients. In case of high correlations, a significantly positive g parameter in Equation (9) cannot be interpreted as empirical evidence of bank lending channel, because the assumption on homogeneity of loan demand is not fulfilled.

Moreover, if smaller banks tend to finance more riskier clients, in the case of a rate hike, the smaller banks' loan supply is expected to decrease faster than that of the large banks due to the larger deterioration of portfolio or/and higher increase of marginal cost of funding. This mechanism is a mixture of the balance sheet channel and the lending channels. Thus, under such portfolio-heterogeneity one cannot distinguish between the two.

In order to rule out the above mentioned concerns we measure the correlations between some bank characteristics (size, liquidity, capitalization, share of foreign ownership) and the ratio of non-performing loans (as a proxy for different risk characteristics) and the share of corporate loans in the loan portfolio (as a proxy for sectoral characteristics of the clients). We find, that these correlations are relatively small, and non of them exceed 0.3 in absolute term.

To sum up, even if the loan demand elasticity of companies might vary over the size of companies, the share of loans to SME-s does not seem to vary over banks with different size. The same can be concluded when analyzing the relationship between the proportion of loans to SMEs and foreign ownership. Moreover, there is no close relationship between some bank characteristics (size, liquidity, caitalization) and the ratio of non-performing loans and the share of corporate loans in the loan portfolio. So, we have no evidence against the assumption that banks with different size, liquidity position, capitalization and with different share of foreign ownership are facing homogenous loan demands and hence, asymmetric reaction of the quantity of loans with respect to these variables can be mainly attributed to asymmetry in loan supply reactions.

Results

In this section we investigate whether an interest rate increase is associated with a decrease of bank loan supply. We investigate this by the method Kahsyap and Stein (1995) which relies on discovering asymmetries in changes in the amount of loans to monetary actions in order to isolate supply and demand effects. We report the results on long-run effects.[13] For testing the significance of long-run parameters that are in general non-linear functions of the estimated short-run coefficients we again use the delta method. We use lag 2 for each variable that was suggested by Akaike and Schwartz criteria.

When estimating the parameters of the empirical model, we include all variables in nominal terms (in Forint). By including CPI and the exchange rate[14] as explanatory variables, we control for inflationary effect as well as revaluation effect addition to their effect on loan demand in real terms.

Table 6.7 to Table 6.14 show the estimation results of equation (4) for the different loan aggregates; total loans, corporate loans, total loans in domestic currency, and corporate loans in domestic currency. The most essential loan aggregate with respect to the functioning of the bank lending channel is the total loans, however, asymmetric reaction with respect to less aggregated loan categories may provide us with interesting insights as well. Moreover, the analysis of sub-markets makes the assumption of similar demand elasticities of banks more plausible since the characteristics of clients on on particular market can be considered as to be more homogeneous compared to the aggregate level. However, the theoretical model is based on the profit maximalisation condition of banks on an aggregate level, which may not be true on sectoral level or in case of different denomination of loans. So, in case of the disaggregation on the one hand the basic assumption is

[13] Regression results with short-run parameters can be acquired from the authors.

[14] As we have seen in Section 6.3 the proportion of loans in other currencies than euro of all domestic loans in foreign currency was still very significant even in 2000 and this ratio has changed within the observed period. Unfortunately, we do not have available data on the decomposition of currency-denominated loans at the bank level for the entire sample period. So, normalization with respect to the euro/huf exchange rate would also lead to biased parameter estimates of exchange rate.

more tenable, but on the other hand the theoretical foundation of the empirical model is less established.

First, we estimate equation (4) with only one interaction-term. Then, in order to control for possible correlations in the bank-specific variables, we also estimate equation (4) including two interaction-terms at the same time.

Results for total loans

In this section we investigate of the possible asymmetric reaction of total loans to monetary policy actions. Table 6.7 and Table 6.8 show the results when we include one and two interaction-terms, respectively. The coefficient of the nominal interest rate has the expected sign and is significant in all of the specifications, that is a one percentage point change in the 3-month benchmark rate results in a nearly 1 percent decline in the credit aggregates ranging from 0.82% to 1.01% according to different estimations for the regression with one interaction-term. This value is in between 0.72% and 1.28% for the regression with two interaction-terms. The parameter of the nominal exchange rate proved to be significantly positive, that is, a depreciation of Forint relative to Euro increases total loans due to the revaluation effect. The parameter of GDP also shows the expected positive sign and is significant. The effect of foreign interest rate (3-month euribor) appears to be almost always negative and sometimes even significant. This coefficient captures two effects; reduction in euro denominated credit due to an increase in this policy variable and substitution effect. Table 6.7 shows that when we include only one asymmetric cross-term, we find that the sign of all asymmetric effects are in line with the bank-lending channel theory.

As the different bank-characteristics may be correlated with each other, in order to better disentangle the asymmetric effects with respect to each other, we control for two of such characteristics at the same time. Results of such regression can be seen in Table 6.8 for total credit. We have robust findings for the significant and positive coefficient of foreign ownership and capitalization. Size turns out to be positive in most regressions, except for when controlling for capitalization. The parameter of the interaction-term of liquidity is not significant, and its sign is not robust.

Table 6.7 Estimation results with long-run coefficients for total loans

Total loan	**GMM, lag2, 1995 Q1-2004 Q3**			
Asymmetry (A)	Size	Liquid	Capit	For. own
Interest rate	-0.92***	-0.82***	-1.01***	-0.88***
	(-14.38)	(-8.27)	(-10.76)	(-14.48)
GDP	0.01***	0.01***	0.01***	0.01***
	(10.92)	(5.68)	(7.42)	(11.15)
Exchange rate	0.19***	0.14***	0.15***	0.18***
	(8.00)	(8.49)	(6.88)	(8.66)
Euro interest rate	0.00***	0.00	0.00	0.00***
	(-2.79)	(-0.44)	(-0.34)	(-2.34)
Inflation	0.12***	0.19***	0.09***	0.12***
	(4.65)	(4.74)	(2.48)	(3.26)
A(-2)*interestrate	**0.00**	**0.23***	**2.96*****	**0.15****
	(1.00)	**(1.72)**	**(6.78)**	**(1.95)**
A(-2)	0.00	0.11*	0.08	0.00
	(-1.34)	(1.89)	(0.40)	(-0.16)
No. of obs.	854	854	844	846
Adjusted R^2	0.15	0.16	0.13	0.15
J-statistics	580.55	589.53	569.69	584.33
	(0.47)	(0.37)	(0.60)	(0.43)
D-Hansen test	47.75	49.73	28.58	46.10
	(0.06)	(0.04)	(0.72)	(0.08)

Notes: For GMM we only could use the White 1-step GMM weights. Below the J-statistics, the numbers in parantheses are the corresponding p-values. The standard errors of the long-run coefficients are computed by delta method.

TABLE 6.8 Estimation results with long-run coefficients for total loans with two asymmetric effects and cross-terms

Total loan	**GMM, lag2, 1995 Q1-2004 Q3**					
A1	Liquid	Capit	For. own.	Capit	For. own.	For. own.
A2	Size	Size	Size	Liquid	Liquid	Capit
Interest rate	-1.08***	-1.28***	-0.92***	-1.03***	-0.72***	-0.88***
	(-12.87)	(-10.41)	(-9.25)	(-8.42)	(-7.41)	(-7.08)
GDP	0.01***	0.01***	0.01***	0.01***	0.01***	0.01***
	(6.87)	(7.92)	(11.55)	(3.90)	(5.47)	(6.93)
Exchange rate	0.22***	0.17***	0.18***	0.12***	0.16***	0.14***
	(10.12)	(6.36)	(9.14)	(3.69)	(6.01)	(6.74)
Euro interest rate	0.00	0.00	-0.01***	0.00	0.00	0.00
	(-1.40)	(-0.07)	(-2.33)	(0.79)	(0.50)	(0.17)
Inflation	0.15***	0.12***	0.11***	0.17***	0.18***	0.12***
	(4.31)	(3.18)	(3.41)	(3.96)	(5.07)	(2.54)
A1(-2)*ir	**-0.02**	**0.41**	**0.44*** **	**2.45*** **	**0.61*** **	**0.02**
	(-0.10)	**(0.76)**	**(4.91)**	**(11.03)**	**(2.68)**	**(0.06)**
A2(-2)*ir	**0.00**	**0.00*** **	**0.00*** **	**-0.09**	**0.32**	**3.11*** **
	(0.67)	**(-4.19)**	**(3.89)**	**(-0.26)**	**(1.44)**	**(3.01)**
A1(-2)*A2(-2)*ir	**0.00*** **	**0.00*** **	**0.00*** **	**12.92*** **	**2.19*** **	**2.03**
	(-6.88)	**(-6.35)**	**(7.80)**	**(7.72)**	**(2.23)**	**(0.47)**
A1(-2)	0.00***	0.00***	0.00***	0.10***	0.10***	0.08***
	(-12.53)	(-4.32)	(-2.62)	(17.53)	(29.31)	(9.59)
A2(-2)	0.12***	0.01	0.00***	0.06***	0.00	-0.01***
	(20.54)	(1.38)	(-2.19)	(9.85)	(-0.26)	(-2.22)
A1(-2)*A2(-2)	0.00***	0.00***	0.00	0.27***	-0.09***	-0.04
	(3.16)	(-16.96)	(-1.00)	(10.14)	(-10.48)	(-1.23)
Adjusted R^2	0.17	0.14	0.15	0.16	0.17	0.13
No. of obs.	854	844	846	844	846	844
J-statistics	576.98	558.73	595.30	591.36	577.49	590.68
	(0.52)	(0.72)	(0.31)	(0.35)	(0.51)	(0.36)
D-Hansen test	22.72	17.06	29.87	31.38	44.26	45.26
	(0.93)	(0.99)	(0.66)	(0.59)	(0.11)	(0.09)

Results for corporate loans

As corporate loans are the most important in influencing investment activity, we also investigate the working of bank-lending channel with respect to corporate loan aggregates (see Table 6.9 and

Table 6.10). We use the same approach as for total credit and obtain similar results. The coefficients of interest rate are negative and significant, GDP growth appear to influence corporate credit quantity positively. The sign of interaction-terms with size and foreign ownership are in line with the bank-lending theory, while for liquidity we find opposite sign (see Table 6.9). These results are very robust to the inclusion of the second interaction-term (see Table 6.10).

TABLE 6.9 Estimation results with long-run coefficients for corporate loans

Corporate loan	**GMM, lag2, 1995 Q1-2004 Q3**			
Asymmetry (A)	Size	Liquid	Capit	For. own
Interest rate	-0.61***	-0.71***	-0.66***	-0.92***
	(-4.78)	(-3.35)	(-2.95)	(-6.96)
GDP	0.01***	0.00	0.01**	0.01***
	(3.01)	(1.21)	(2.05)	(4.20)
Exchange rate	0.71***	0.80***	0.68***	0.72***
	(15.08)	(19.08)	(14.24)	(13.01)
Euro interest rate	0.01**	0.01*	0.01	0.01*
	(2.04)	(1.88)	(1.50)	(1.80)
Inflation	0.16***	0.30***	0.04	0.13***
	(2.38)	(5.50)	(0.49)	(2.33)
A(-2)*interestrate	**0.00*** **	**-6.38*** **	**2.55*** **	**1.42*** **
	(7.70)	**(-15.38)**	**(45.49)**	**(4.32)**
A(-2)	0.00	0.05	0.08*	0.01
	(0.42)	(0.32)	(1.77)	(0.17)
No. of obs.	856	856	845	848
Adjusted R^2	0.38	0.39	0.38	0.38
J-statistics	568.28	569.75	570.64	560.01
	(0.62)	(0.60)	(0.59)	(0.71)
D-Hansen test	26.05	31.60	23.76	20.88
	(0.84)	(0.60)	(0.90)	(0.96)

Notes: For GMM we only could use the White 1-step GMM weights. Below the J-statistics, the numbers in parantheses are the corresponding p-values. The standard errors of the long-run coefficients are computed by delta method.

TABLE 6.10 **Estimation results with long-run coefficients for corporate loans with two asymmetric effects and cross-terms**

Corporate loan	**GMM, lag2, 1995 Q1-2004 Q3**					
A1	Liquid	Capit	For. own.	Capit	For. own.	For. own.
A2	Size	Size	Size	Liquid	Liquid	Capit
Interest rate	-0.87***	-0.02	-0.86***	-0.81***	-0.95***	-0.45***
	(-3.82)	(-0.16)	(-4.37)	(-4.63)	(-4.95)	(-2.77)
GDP	0.00	0.01***	0.01***	0.00	0.00*	0.01***
	(1.58)	(2.84)	(3.22)	(1.47)	(1.64)	(2.95)
Exchange rate	0.77***	0.66***	0.70***	0.78***	0.74***	0.66***
	(13.88)	(11.39)	(11.00)	(18.61)	(17.35)	(13.96)
Euro interest rate	0.00	0.01*	0.01*	0.00	0.00	0.01*
	(0.89)	(1.87)	(1.62)	(0.64)	(0.73)	(1.80)
Inflation	0.23***	-0.03	0.11**	0.17***	0.15***	0.03
	(4.61)	(-0.51)	(1.97)	(2.80)	(2.57)	(0.56)
A1(-2)*ir	**-6.15*** **	**6.93*** **	**1.47*** **	**2.82*** **	**1.79*** **	**0.03**
	(-14.45)	**(9.37)**	**(5.04)**	**(3.99)**	**(3.35)**	**(0.11)**
A2(-2)*ir	**0.00*** **	**0.00*** **	**0.00*** **	**-7.48*** **	**-6.19*** **	**4.89*** **
	(4.31)	**(10.29)**	**(8.20)**	**(-8.92)**	**(-8.29)**	**(5.14)**
A1(-2)*A2(-2)*ir	**0.00*** **	**0.00*** **	**0.00*** **	**-5.80**	**3.12**	**-14.92*** **
	(-6.47)	**(9.29)**	**(5.44)**	**(-1.21)**	**(1.45)**	**(-3.53)**
A1(-2)	0.00***	0.00	0.00	0.07***	0.07***	0.04***
	(-3.39)	(-0.53)	(0.34)	(7.50)	(8.35)	(2.32)
A2(-2)	0.07***	0.07***	0.01	0.01	0.02***	0.02*
	(6.84)	(5.00)	(0.94)	(1.48)	(2.64)	(1.94)
A1(-2)*A2(-2)	0.00	0.00***	0.00***	0.39***	-0.06**	0.19***
	(0.71)	(-4.58)	(-2.31)	(6.26)	(-2.08)	(3.66)
Adjusted R^2	0.39	0.38	0.37	0.40	0.39	0.38
No. of obs.	856	845	848	845	848	845
J-statistics	568.18	578.25	563.28	572.86	553.37	563.28
	(0.62)	(0.50)	(0.67)	(0.56)	(0.77)	(0.67)
D-Hansen test	15.51	18.00	16.04	22.53	15.61	17.13
	(1.00)	(0.99)	(1.00)	(0.93)	(1.00)	(0.99)

Results for total loans in domestic currency

In this sub-section we investigate the reaction of the Forint denominated total loans to domestic monetary shocks. Domestic monetary policy might have different effect on forint and foreign currency denominated loans; as a consequence the bank lending channel might also differ for the two categories. For quantities in domestic currency we only have a shorter sample available for estimation, starting from the first quarter of 1998. We apply the usual procedure to test for possible asymmetries that would indicate adjustment in loan demand. Table 6.11 shows some evidence that an interest rate increase results in a decline of loans in domestic currency. Almost all control variables, even GDP and Euro interest rate, have negative but insignificant sign. With respect to the interaction-terms, we find results that confirm the presence of asymmetries that are in line with the bank lending theory for all investigated variables. When including two cross-terms (see Table 6.12), we now find robust parameters for size, liquidity, and capital.

TABLE 6.11 **Estimation results with long-run coefficients for total loans in domestic currency**

Total loans in HUF	**GMM, lag2, 1998 Q1-2004 Q3**			
Asymmetry (A)	Size	Liquid	Capit	For. own
Interest rate	-0.40**	-0.26	-0.36*	-0.38**
	(-1.98)	(-1.45)	(-1.87)	(-2.14)
GDP	0.00	0.00	0.00	0.00
	(-1.04)	(-0.50)	(-0.84)	(-0.79)
Exchange rate	-0.09	-0.07	-0.05	-0.05
	(-1.51)	(-1.27)	(-0.87)	(-0.82)
Euro interest rate	-0.01	-0.01**	-0.01*	-0.01
	(-1.60)	(-1.94)	(-1.79)	(-1.29)
Inflation	0.24**	0.31**	0.24**	0.13
	(2.13)	(2.19)	(2.00)	(1.13)
A(-2)*interestrate	**0.00**	**3.44*** **	**1.97*** **	**0.72*** **
	(1.07)	**(7.45)**	**(4.13)**	**(3.49)**
A(-2)	0.00	0.08	0.05	-0.05
	(-0.10)	(0.45)	(0.43)	(-0.80)
No. of obs.	548	548	548	548
Adjusted R^2	0.29	0.30	0.29	0.29
J-statistics	287.97	282.24	280.93	282.95
	(0.05)	(0.08)	(0.09)	(0.07)
D-Hansen test	21.63	27.43	27.12	11.45
	(0.48)	(0.19)	(0.20)	(0.97)

Notes: For GMM we only could use the White 1-step GMM weights. Below the J-statistics, the numbers in parantheses are the corresponding p-values. The standard errors of the long-run coefficients are computed by delta method.

TABLE 6.12 Estimation results with long-run coefficients for total loans in domestic currency with two asymmetric effects and cross-terms

Total loan in HUF	**GMM, lag2, 1998 Q1-2004 Q3**					
A1	Liquid	Capit	For. own.	Capit	For. own.	For. own.
A2	Size	Size	Size	Liquid	Liquid	Capit
Interest rate	-0.27	-0.34	-0.24	-0.20	-0.03	0.19
	(-1.72)	(-1.41)	(-1.07)	(-0.89)	(-0.16)	(0.75)
GDP	0.00	0.00	0.00	0.00	0.00	-0.01
	(-0.45)	(-0.96)	(-0.93)	(-0.60)	(-0.46)	(-1.22)
Exchange rate	-0.08	-0.06	-0.03	-0.05	-0.03	0.00
	(-1.45)	(-1.13)	(-0.56)	(-0.88)	(-0.56)	(-0.06)
Euro interest rate	-0.01*	-0.01	-0.01	-0.01	-0.01	0.00
	(-1.93)	(-1.21)	(-1.02)	(-1.83)	(-1.07)	(-0.26)
Inflation	0.20	0.25**	0.07	0.31**	0.18	0.16
	(1.44)	(2.19)	(0.59)	(2.21)	(1.27)	(1.28)
A1(-2)*ir	**3.49*** **	**2.48*** **	**0.49** **	**1.41* **	**0.07**	**-0.98* **
	(9.35)	**(3.33)**	**(2.04)**	**(1.92)**	**(0.15)**	**(-1.80)**
A2(-2)*ir	**0.00*** **	**0.00* **	**0.00**	**2.76*** **	**3.23*** **	**4.69*** **
	(3.38)	**(1.71)**	**(0.91)**	**(4.68)**	**(4.86)**	**(4.14)**
A1(-2)*A2(-2)*ir	**0.00*** **	**0.00**	**0.00**	**0.91**	**-3.50**	**-15.60*** **
	(-4.97)	**(0.54)**	**(0.08)**	**(0.21)**	**(-1.43)**	**(-2.76)**
A1(-2)	0.00***	0.00	0.00***	0.08***	0.09***	0.05***
	(-3.37)	(-0.81)	(2.35)	(8.88)	(9.38)	(2.45)
A2(-2)	0.10***	0.02**	-0.05***	0.04***	-0.05***	-0.04**
	(6.26)	(2.24)	(-4.42)	(2.45)	(-3.56)	(-2.29)
A1(-2)*A2(-2)	0.00	0.00***	0.00***	-0.03	-0.14***	0.00
	(0.61)	(-6.17)	(-3.43)	(-0.80)	(-4.34)	(0.03)
Adjusted R^2	0.29	0.28	0.28	0.29	0.30	0.31
No. of obs.	548	548	548	548	548	548
J-statistics	287.37	285.78	278.49	280.99	264.28	280.08
	(0.25)	(0.27)	(0.38)	(0.34)	(0.62)	(0.36)
D-Hansen test	25.80	19.98	9.48	25.99	14.82	27.51
	(0.26)	(0.58)	(0.99)	(0.25)	(0.87)	(0.19)

Results for corporate loans in domestic currency

Here, we investigate the reaction of the Forint denominated corporate loans to monetary shocks. The results (in Table 6.13) suggest that, among the analyzed credit quantities, this is the most elastic to changes in domestic interest rate. Our results on the possible asymmetries are mostly in line with what we found above, the sign of the coefficients of size and foreign ownership point towards the existence of bank lending channel, however, the coefficient of the interaction-term with not only liquidity but also capitalization has a negative coefficient. The adjusted pseudo R^2 is the highest for these among the least aggregate quantities.

The results with single interaction terms are less robust than for previous loan quantities (see Table 6.14). While the coefficients of the interaction term of size are always positive and significant, and are always negative and significant for liquidity, the parameter of the interaction-term for foreign ownership and for capitalization is positive and significant only in two cases.

TABLE 6.13 **Estimation results with long-run coefficients for corporate loans in domestic currency**

Corporate loans in HUF		**GMM, lag2, 1995 Q1-2004 Q3**		
Asymmetry (A)	Size	Liquid	Capit	For. own
Interest rate	-0.96***	-1.31***	-0.91***	-1.20***
	(-8.45)	(-8.47)	(-6.15)	(-10.16)
GDP	0.00*	0.00	0.00	0.00**
	(1.63)	(1.23)	(0.90)	(1.99)
Exchange rate	0.14***	0.18***	0.17***	0.16***
	(4.29)	(4.98)	(5.02)	(4.82)
Euro interest rate	-0.01**	-0.01***	-0.01*	-0.02***
	(-2.51)	(-2.93)	(-1.86)	(-3.45)
Inflation	-0.01	0.06	-0.02	0.00
	(-0.13)	(1.09)	(-0.36)	(0.06)
A(-2)*interestrate	**0.00*** **	**-3.33*** **	**-6.43*** **	**0.15**
	(8.62)	**(-14.42)**	**(-20.78)**	**(0.66)**
A(-2)	0.00	0.01	0.06	-0.02
	(-1.07)	(0.12)	(0.54)	(-0.55)
No. of obs.	849	849	849	849
Adjusted R2	0.53	0.53	0.53	0.53
J-statistics	583.62	588.73	587.41	585.72
	(0.44)	(0.38)	(0.40)	(0.41)
D-Hansen test	31.89	21.04	37.57	32.96
	(0.51)	(0.94)	(0.25)	(0.45)

TABLE 6.14 Estimation results with long-run coefficients for corporate loans in domestic currency with two asymmetric effects and cross-terms

Corporate loans in HUF			**GMM, lag2, 1995 Q1-2004 Q3**			
A1	Liquid	Capit	For. own.	Capit	For. own.	For. own.
A2	Size	Size	Size	Liquid	Liquid	Capit
Interest rate	-1.16***	-0.06	-1.07***	-0.80***	-0.88***	-0.19
	(-4.66)	(-0.36)	(-8.63)	(-4.26)	(-5.73)	(-0.96)
GDP	0.00	0.00	0.00	0.00	0.00	0.00
	(1.26)	(0.46)	(1.64)	(1.40)	(0.77)	(-0.03)
Exchange rate	0.15***	0.08**	0.15***	0.18***	0.12***	0.15***
	(4.04)	(2.00)	(4.95)	(3.62)	(2.56)	(3.74)
Euro interest rate	-0.02***	-0.01***	-0.02	-0.02***	-0.01*	-0.01***
	(-3.18)	(-2.82)	(-3.49)	(-3.48)	(-1.73)	(-2.40)
Inflation	0.05	-0.15***	0.04	-0.01	0.02	-0.03
	(0.72)	(-4.16)	(0.66)	(-0.16)	(0.30)	(-0.68)
A1(-2)*interestrate	**-3.95*** **	**2.74*** **	**0.37**	**-3.56*** **	**0.79** **	**-3.20*** **
	(-13.12)	**(2.70)**	**(1.43)**	**(-7.28)**	**(2.21)**	**(-6.36)**
A2(-2)*interestrate	**0.00*** **	**0.00*** **	**0.00*** **	**-0.91**	**-3.23*** **	**3.67*** **
	(8.16)	**(6.96)**	**(4.62)**	**(-1.37)**	**(-6.30)**	**(2.81)**
A1(-2)*A2(-2)*ir	0.00***	0.00***	0.00	-41.41***	9.19***	-38.30***
	(-9.11)	(8.94)	(1.40)	(-8.20)	(6.74)	(-7.64)
A1(-2)	0.00***	0.00	0.00	0.01**	0.03***	0.07***
	(-2.67)	(1.19)	(-0.27)	(2.34)	(4.92)	(8.69)
A2(-2)	0.00	0.11***	-0.03***	0.03***	-0.01	-0.04***
	(0.04)	(12.73)	(-4.28)	(4.42)	(-1.35)	(-4.60)
A1(-2)*A2(-2)	0.00*	0.00***	0.00***	0.03	-0.17***	-0.10***
	(-1.82)	(2.92)	(-3.51)	(0.73)	(-6.59)	(-2.86)
Adjusted R^2	0.53	0.54	0.53	0.54	0.54	0.54
Number of observations	849	839	841	839	841	839
J-statistics	582.06	580.90	584.61	579.45	577.19	569.89
	(0.46)	(0.47)	(0.43)	(0.49)	(0.51)	(0.60)
D-Hansen test	29.40	34.20	41.70	34.08	33.22	30.21
	(0.69)	(0.44)	(0.16)	(0.44)	(0.49)	(0.63)

6.5 Conclusions

In this paper we investigate the working of bank lending channel in the case of Hungary. In the spirit of the theory of bank lending channel, we apply the generally used approach of Kashyap and Stein (1995, 2000) that relies on discovering asymmetric movements of loan quantities with respect to certain bank-characteristics.

In addition to the usual bank-specific variables (such as size, liquidity, and capitalization), along which asymmetry is derived from the theory bank lending channel, we consider foreign ownership as well. We find heterogeneity among banks in the majority of cases with different model specifications. However, this heterogeneity could be associated with heterogeneous loan demand functions across banks. The novelty of the paper is that we make an attempt to test whether demand of loans can be considered homogeneous across banks with respect to some bank-characteristics. We find empirical evidence that demand of loans can be considered reasonably homogeneous across banks with respect to the share of foreign ownership and size of banks. Also, we find that an increase in policy rate induces a larger increase in average cost of funding for smaller, less capitalized banks, and for banks with higher domestic share. This suggests that such banks incur larger increase in their external financing premium in the period of monetary tightening. According to these findings, we cannot rule out the existence of the bank lending channel in Hungary.

At the same time in our previous work (Horváth et al., 2004), we find average long-run pass-through parameters of 0.98 and 0.95 based on our analysis on aggregate and panel data, respectively. Also, we could not reject the null of complete pass-though. This finding suggests that the banking system does not amplify the effect of monetary policy and therefore the real economy and what we find is simply heterogeneous reaction of banks due to the bank lending channel.

We find that a rise in the nominal short-term interest rate results in a decrease in the credit growth. Although the average effect of interest rate is negative on the credit growth it cannot only be attributed to the bank lending channel but may arise from the demand effect due to the traditional interest rate effect and the balance sheet channel.

Some expected future developments outline a changing significance of the bank lending channel. The dominance of foreign, mostly European, ownership of banks and the substantial share of euro denominated assets and liabilities of banks imply that with the adoption of the common monetary policy the share of liabilities and assets, sensitive to domestic monetary policy will increase substantially. Since financial markets in Europe are bank-dominated, we do not expect that that bank dependence of borrowers would decline as the Hungarian economy integrates more into and becomes more similar to the European economy. Additionally, the continuously diminishing of excess liquidity in the banking system and the decreasing capitalization due to the increasing efficiency in the banking system outlines the possibility of strengthening of the bank-lending channel in the future in Hungary.

Appendix

TABLE A List of empirical research on the bank-lending channel

	Country	Approach used	Policy instrument	Results
		EURO AREA		
Brissimis et al. (2003)	Greece	KS and BB	Athibor 3M	Compatible with the existence of bank-lending channel, but not satisfactory
Ehrmann et al. (2003)	EURO area	KS (interaction-terms)	Nominal short-term interest rate	Inconclusive (depends on the data and method used)
Farinha and Marques (2003)	Portugal	KS modified (level)	Short-term MMR	Exists, effect is stronger for less-capitalized banks
Hernando and Martínez-Pagés (2003)	Spain	KS	MMR 3M	Most evidence rejects the bank-lending channel
Gambacorta (2003)	Italy	KS	Repo	Evidence
De Haan (2003)	The Netherlands	KS	MMR 3M	Evidence for effect on non-secured bank debt
Kaufmann (2003)	Austria	KS (Markov switching specification)	3 months interest rate	Weak evidence
Loupias et al. (2003)	France	KS	3 months interbank interest rate	Weak evidence
Topi and Vilmunen (2003)	Finland	KS (interaction-terms)	SVAR shock	Weak evidence
		CEECs		
Horváth et al. (2005)	*Hungary*	*KS*	*Bubor (3 month)*	*Weak evidence*
Juks (2004)	Estonia	KS	Euribor	Evidence
Pruteanu (2004)	Czech Republic	KS	2-weeks repo rate and Pribor 1Y	Evidence
Wróbel and Pawłowska (2002)	Poland	KS	Unclear	Evidence

Variables definition

GDP: qoq growth rate of GDP from seasonally adjusted GDP data.
Inflation: we used the yoy index calculated from trend price level.
Forint interest rate: 3-month benchmark rate.
Euro interest rate: 3-month euribor rate.

The **size** variable is defined as the total assets of the bank at book value.

The **loans** are the total loans at book value.

The **liquidity ratio** is defined as the ratio of liquid assets to total assets, where the liquid assets includes cash, short-term government securities and short-term interbank deposits and short-term deposits at the central bank.

Capitalization is defined as the capital adequacy ratio.

The **share of foreign ownership** is defined either as the share of foreign ownership in the bank. In case of missing data we use the share of foreign voting rights as a fairly good proxi.

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7. Estimating the effect of Hungarian monetary policy within a structural VAR framework

Balázs Vonnák

7.1 Introduction

During the 1990s many researchers attempted to estimate the effect of monetary policy on output and prices using the structural VAR approach. The purpose of the research was often to find the monetary general equilibrium model most consistent with the data. Despite the effort devoted to this issue there remained some unresolved problems, although some consensus results also emerged.

From the central banker's point of view, especially if he is an inflation targeter, the most important thing is perhaps the behaviour of prices in the wake of a monetary policy action. Unfortunately, the reaction of prices has shown the largest variability across models. Nevertheless, as Christiano, Eichenbaum and Evans (1998) (henceforth CEE) claim, the impulse response of some other variables, like that of output, had proven to be very robust to specification.

Even if we have a consensus view about the impulse responses, it is useful to clarify first what we can learn from structural VARs about the effect of monetary policy. The standard SVAR approach involves identifying monetary policy shocks and quantifying their consequences. These shocks are unexpected deviations from the systematic behaviour of monetary policy, from the so-called 'monetary policy rule'. But since these deviations usually explain a small part of the policy instrument's variation, the question naturally arises: are these shocks important in understanding the transmission of monetary policy? Why do we not simply regress changes in output and prices on changes in the policy instrument, for example, in the short interest rate?

The answer is because interest rate changes are mainly endogenous (i.e. consistent with the policy rule) reactions of monetary policy to other types of shocks coming from the economy. If we trace the development of prices following that particular change in interest rate, we only get a picture about the consequences of that particular shock which, among others, caused the interest rate movement. Clearly, the endogenous reaction of monetary policy is only one channel through which disturbances exert their influence on prices. It is therefore crucial to separate autonomous disturbances coming from monetary policy from other types of shocks.

Even if we are aware of the advantages of identifying pure monetary policy shocks, their interpretation is not yet straightforward. Some possible versions are listed in CEE (1998). I would like to cite two of them here. The first is perhaps the most often used 'exogenous shift in preferences' term. Since shocks are one-off deviations from the rule, and the rule can be derived from the deci-

I am grateful to Ágnes Csermely, Zsolt Darvas, Csilla Horváth, Zoltán Jakab M., Marek Jarociński, Péter Karádi and János Vincze for useful comments. Any remaining errors are mine.

sion maker's preferences, this explanation may not be very convincing. If one would like to model changing monetary policy preferences, policy rule with time-varying coefficients may better describe the actual behaviour.

Another approach is to assume saying that those shocks are due to imprecise measurement, lack of reliable real-time data, or statistical error. Although this seems to undermine the claimed usefulness of monetary policy shocks at first glance, I would prefer the latter interpretation in a linear modelling environment. Despite being small and unintended, these 'errors' help us to unveil the reaction of macro variables when the only source of the disturbance is the monetary policy. When a decision maker has an erroneous picture about the state of the economy, he or she deviates from systematic behaviour involuntarily and makes the economy reveal the difference in its response from the 'normal' course. Of course, these errors are small relative to the predictable actions. Put in another way, *the investigation of monetary policy shocks does not help much characterise the monetary policy, but rather the response of variables to monetary policy, the transmission mechanism.*

The identification of these monetary policy shocks is not straightforward. Special care should be taken in choosing the appropriate approach when working with data like our Hungarian time series. The bulk of the literature has dealt with large, closed economies with stable institutions; hence the adoption of known methods to small open economies just having undergone some transition processes should be coupled with critical modifications. Two principles are recommended: (1) one should seek the identification that uses the least structural knowledge about the economy and (2) one should check the robustness of the results by using alternative approaches, too. These recommendations are not orthogonal to each other.

This paper tries to meet these requirements. The first is taken into account by imposing sign, or more generally, inequality restrictions instead of concrete values. The second is fulfilled by using two independent sets of assumptions: in the baseline identification I impose sign restrictions on impulse responses similarly to Uhlig (2005) and Jarociński (2006). The alternative strategy is to some extent related to the 'narrative approach' of Romer and Romer (1989) and to the approach of Rudebusch (1998) and Bagliano and Favero (1997, 1999). The basic idea in all these papers is to use historical evidence regarding monetary policy shocks. My identification scheme, however, is more liberal, since I only specify the date of the largest contractionary and loosening monetary policy shocks, and I do that using only inequality restrictions.

One of the main conclusions drawn after having experimented with several specifications is that using data between 1995 and 2004 produces results more comparable to the consensus of the SVAR literature than using longer sample beginning in 1992. The second important technical observation is that the results are quite robust to the identification strategy.

As far as transmission mechanism is concerned, a typical monetary policy shock during the past nine years caused roughly an immediate 25 basis points short interest rate rise and a one per cent appreciation of the nominal exchange rate. The output declines very quickly after the shock, reaching its minimum at -0.3% within the first 3 years. The reaction of consumer prices is much more protracted, but somewhat smaller: the maximum reduction is 0.1-0.15% between the 4th and 6th years after the shock.

The structure of the paper is as follows: in section 7.2 the issue of identification is discussed. In sections 7.3 and 7.4 the baseline and the alternative estimates are presented. The last section concludes.

7.2 Identification of monetary policy shocks

In the following subsections typical identification schemes are outlined[1]. Identification of structural shocks, such as monetary policy shocks, involves the imposition of some restrictions. These strategies can be more or less classified either by the statistics that are restricted or by the precision of the restrictions, namely whether they require the target parameter to equal some real number, or just to be greater or less than certain values. This section follows the latter grouping but in the subsection 'Restrictions on implied structural shock series' the former aspect is also touched on. The subsection afterwards justifies the identification strategy adopted in this paper.

Major aspects of identification

Within a structural VAR framework one estimates first the reduced form model, which is approximated by a vector-autoregressive specification:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_p y_{t-p} + Bz_t + u_t \quad ,$$

where y stands for the vector of n endogenous variables, z contains intercept, deterministic trend and other exogenous variables, p is the number of lags included, and vector u is the unexplained part of the vector process. B is the matrix of coefficients of exogenous variables, while $A_1 \ldots A_p$ are n×n coefficient matrices of lagged endogenous variables.

The estimated residuals $\hat{u}_t$ are historical shocks to the corresponding endogenous variable. If, for example, the residual of price level equation in Q1:97 is .01, we claim that one percentage point of the change in price level was unexpected, at least as far as our specification contains all relevant information market participants possessed in Q4:96. However, the source of that disturbance is not yet identified.

We are usually not interested in estimating price level or output innovations, but rather economically meaningful, i.e. supply, demand, etc. shocks, and particularly their dynamic effect on some variables. If, in our example, the output grew unexpectedly in the same period, i.e. it has a positive residual in Q1:97, we can suspect the presence of demand side pressure.

The main task after having estimated the VAR model is to decompose residuals into these structural shocks. This corresponds to finding the contemporaneous relationship between structural and reduced form innovations, or finding matrix C in the equation

$$u_t = Ce_t$$

where u denotes the vector of the reduced form residuals (output, price level, etc.) and e the vector of structural shocks (technology, demand, etc.). It is assumed that structural shocks are orthogonal to each other, while the same is not necessarily true for VAR residuals. Matrix C contains the contemporaneous impact of structural disturbances on endogenous variables. The element in the i-th row and j-th column is the magnitude by which the j-th structural shock affects i-th variable simultaneously. With this formulation the residuals of the reduced form are derived as linear combinations of structural shocks.

[1] For a more detailed introduction, but another classification scheme, see CEE (1998).

Unfortunately, this matrix is not unique, which means that there is more than one structural model that has the same reduced form. We have to add some additional information in order to obtain the results we are searching for. Providing this information is the identification of structural shocks. It can be shown that in order to achieve full or exact identification one needs to impose $n(n-1)/2$ restrictions on C – in addition to n normalisation. When working with fewer restrictions (underidentified system) the point estimates of the parameters we are interested in (e.g. the response of output to one standard deviation monetary policy shock in periods 1, …, 8) broaden to intervals. In the overidentification case we have more assumptions than required for exact identification. The logic of estimation is then somewhat different: one weights the deviations from the restrictions and optimises.

Identification is the most sensitive part of the estimation procedure. We have to assume something about the structure we are investigating. Results from identified VARs usually take the form of a conditional statement. In particular, monetary transmission SVARs usually produce findings that sound like this: 'assuming that the monetary policy shocks' effect on $x, y,\ldots$ has the property …, the effect of monetary policy on $z, w,\ldots$ can be characterised as follows:…'.

Accordingly, *identifying assumptions optimally represent our least disputable prior knowledge about that particular mechanism.* This is important in order to obtain credible results. There are, however, two difficulties in finding the appropriate set of restrictions: (1) we have to impose enough restrictions in order to obtain a clear result and to avoid 'informal identification'; (2) we have to impose few enough restrictions in order to have a convincing identification strategy. While (2) is in accordance with the above-mentioned logic, the former criterion may require further explanation.

Let us consider the example of identifying monetary policy shocks – the purpose of this paper. Monetary policy shocks share some common features with other shocks. Autonomous monetary tightening, for instance, may be similar to a positive demand shock in its contemporaneous effect on the interest rate: in both cases one expects a higher policy rate in the period the shock hits the economy. The reasons are, however, different. Whereas in the first case this is an unexpected deviation of monetary policy from its rule, in the second case the higher interest rate is a consequence of systematic monetary policy that reacts immediately to inflationary pressure. In order to distinguish between the two disturbances further assumptions are needed. Assuming that an autonomous monetary contraction appreciates the exchange rate may, for example, disentangle it from demand shock.

Another reason for having a rich restriction set arises from realising that sometimes implicit assumptions are applied during the model selection procedure. The econometrician usually has a high degree of freedom. Within the SVAR framework, selecting the number of variables and the variables themselves (e.g. GDP vs industrial production as a measure of real output) included in VAR, the choice of sample, lag length, etc. are subject to decision, even if one relies on some model selection criteria. Typically, the researcher estimates several models and compares their outputs. He is inclined to keep the specification that meets some expectations not made explicit prior to estimation. Put in another way, specifications producing more appealing impulse responses are preferred to other set-ups, even if they all meet formal identifying restrictions to the same extent.

This model selection mechanism uses informal or implicit identifying restrictions. Distaste for 'price puzzle' is a good example. We call price puzzle the observed perverse behaviour of the price level following a monetary policy shock, that is rising prices after unanticipated monetary contraction. Suppose we have two sets of impulse responses triggered by one standard deviation monetary policy shock, both obtained from a VAR imposing the same identifying restrictions. One of them exhibits price puzzle, the other does not. It is difficult then to resist the temptation of keeping the well-behaving specification while rejecting the other, which means imposing ex post additional restrictions.

A transparent identification strategy should avoid such steps by making those assumptions explicit. Nonetheless, even a priori exclusion of price puzzle is hard to justify as long as our aim is to estimate the effect of monetary policy shocks on prices, since we have then no chance to answer the question: 'Is the price puzzle a reality or just an identification failure?[2]

Point (zero) restrictions

The most popular identification approach is to restrict some elements of matrix C to be zero. This strategy has the advantage that a structure of contemporaneous impacts like that can be translated to delayed reaction. Identification of monetary policy shocks is usually based partly on assuming no immediate effect on output and prices.

As a special case, so-called recursive identification involves an ordering of the variables. In this specification structural innovations affecting some variable do not appear contemporaneously in the residuals of variables ordered before. The matrix C becomes lower triangular and can be obtained by a Cholesky decomposition of the VAR's covariance matrix.

If we believe that the source of all nominal shocks is the monetary policy, and that monetary policy shocks do not affect output and prices contemporaneously, a 3-variable VAR, including output, prices and interest rate together with a Cholesky decomposition with the innovations in the interest rate ordered last is a good minimal workhorse, which is especially appropriate for international comparison – see, for example, Gerlach and Smets (1995). Most authors use larger models in order to include as much information as possible supposed to be available to monetary policy makers when making decisions, while maintaining the recursiveness assumption – for example CEE (1998), Peersman and Smets (2001).

Faust et al. (2003) estimate first on high frequency data the contemporaneous impact of monetary policy shock and then use the coefficients in their monthly VAR. Although their identification is more sophisticated and fits better the theme of the next subsection, this is an example of using non-zero point restriction. Similarly, Smets (1997) estimates the contemporaneous impact of monetary policy and exchange rate shocks on interest rate and exchange rate outside the VAR and uses those estimates in his transmission VAR identification. In both cases the two step approach is necessary because of the supposed simultaneity between financial variables, thus the invalidity of recursiveness assumption.

[2] What kind of relevance might be attributed to statements such as the following: 'assuming that a contractionary monetary policy shock causes lower prices for one year, we get the result that the response of price level to one standard deviation monetary contraction is...'? In this conditional statement the condition and the statement is mixed up. This problem, however, refers to the aspect of identification credibility.

This point is crucial regarding estimation with Hungarian data. As I argue later, in addition to monetary policy, the risk assessment of forint denominated assets must have been the main force influencing the nominal interest rate and exchange rate during the past decade. Due to the quick reaction of monetary policy to exchange rate movements and the exchange rate to monetary policy surprises, the simultaneity problem seems to be highly relevant, ruling out a priori the adoption of recursive identification.

Another strategy is based on the assumed long-run neutrality of monetary policy. In practice, this means that monetary policy has only a temporary effect on real variables, such as output. Such restriction was applied by Clarida and Gali (1994), Gerlach and Smets (1995), and with Hungarian data Csermely and Vonnák (2002), among others. Note that imposing zero long-run effect is also a point (zero) restriction. For the shortcomings of such restrictions see Faust and Leeper (1994). Perhaps their most important criticism is that in finite samples the long-run effect of shocks is imprecisely estimated and the inferences regarding impulse responses are biased.

Interval (sign) restrictions

The risk of imposing too disputable restrictions can be reduced by being less ambitious and letting parameters (response in certain periods, cross-correlations, etc.) lie in an interval instead of requiring them to take a certain value. This approach can be considered as a robustness check of identification trying to answer the implicit question: how stable are our results if we perturb the parameters of our assumption set? This was the original idea behind Faust's (1998) approach.

Some authors impose their restrictions on impulse responses. Faust (1998) considers only the immediate effect. Uhlig (2005) requires the restrictions to hold throughout a longer period of time. He also does a robustness check with respect to the length of that period.

Canova and De Nicolo (2002) adopt another approach. They first calculate dynamic cross-correlations of variables following a monetary policy shock with the help of a theoretical model. They then identify monetary policy shocks by demanding it reproduce the sign of those cross-correlations as much as possible.

Finally, the other strategy applied in earlier versions of Uhlig's 2005 paper is also worth mentioning. He gave room for his sign preference by minimising a loss function that penalises the deviation of impulse response from the restrictions continuously. In this way he ended up with an exactly identified system, but at the cost of constructing a penalty function that inevitably contains some arbitrariness.

Restrictions on implied structural shock series

As mentioned in the previous subsection, identification can be based not only on responses of individual variables but also on, for example, cross-correlation functions, as Canova and De Nicolo (2002) did. Another plausible strategy is to focus on the history of shocks. One can make use of an additional information set in identifying the historical development of shocks. Using these estimates in the VAR, it is easy to plot impulse responses or to calculate other statistics related to those monetary policy shocks.

Romer and Romer (1989) apply a so-called narrative approach. They created a dummy variable that took the value of 1 in periods when the Fed was deemed to be excessively contractionary. The assessment was based on historical evidence, or more precisely, on their reading of Federal Reserve documents. They used the dummy in a univariate regression. The response to change in that variable was regarded as the effect of monetary policy shocks.

Rudebusch (1998) as well as Bagliano and Favero (1997, 1999) estimate historical monetary policy shocks from financial market data. They do this by comparing expectations reflected in futures or implied forward rates with the actual short-term interest rate one period later. They plug the difference into their VAR as an exogenous variable.

The Romers' dummy variable is subject to the criticism that it is not orthogonal to other important shocks and thus involves a mixture of monetary policy and other disturbances when interpreted as structural innovations, as Leeper (1996) points out. In CEE (1998) this problem is remedied by using VAR and giving room for other types of shock to appear implicitly in the residuals but orthogonally to the exogenous monetary policy shocks, similarly as in Bagliano and Favero (1997, 1999) or in Rudebusch (1998).

Sims (1996) criticised Rudebusch's approach by pointing out that identification based on shock series may be much less reliable than other strategies. His argument is that identification schemes producing similar impulse responses can produce quite different shock series due to omitting some variables from the policy rule part of the specification.

The approach of this paper

Based on historical evidence of the nineties, there is a strong prior belief that risk premium (exchange rate) shocks played a predominant role in shaping Hungarian interest rate and exchange rate development. Thus it is necessary to have a model that can distinguish between two types of nominal shocks, which involves the inclusion of at least two financial variables. On the other hand, short time series constrain our possibilities to construct a model with many variables. To balance these requirements I chose a 4-variable VAR, adding nominal exchange rate to the minimal variable set of output, price level and short interest rate.

The 4-variable set-up and the supposed importance of both monetary policy and risk premium shocks make the identification difficult. The Magyar Nemzeti Bank (MNB) has always paid special attention to the exchange rate, due to its prominent role in monetary transmission mechanism. In the crawling narrow band regime it was the legal duty of MNB to keep the exchange rate within a ±2.25 per cent neighbourhood of the continuously devaluated central parity. Even later, after widening the fluctuation band, the exchange rate remained an important device in coordinating expectations or, at least, in indicating the commitment of monetary policy to disinflation. Sometimes this was manifested in a very quick reaction of interest rate policy to considerable exchange rate movements, mostly due to sudden shifts in risk assessment of forint investments, i.e. risk premium shocks.

On the other hand, being an asset price with a relatively efficient market, the nominal exchange rate of the forint reacts immediately to unexpected shifts of monetary policy. Therefore, the recursive identification approach is not appropriate for isolating monetary policy shocks using recent Hungarian data. The simultaneity of these variables with respect to both financial shocks calls for some alternative identification scheme. The only exception when I applied contemporaneous zero restriction is the case of industrial production in the monthly dataset.

In Csermely and Vonnák (2002) we tried to separate monetary policy shocks from risk premium shocks by assuming that among all possible nominal shocks these two induce the largest immediate appreciation and depreciation of the exchange rate. We admitted that although the impulse responses to risk premium shock met our expectations, in the case of monetary policy the results were not convincing.

As a refinement of that paper's strategy, I assumed here that a contractionary monetary policy shock results in appreciation of nominal exchange rate, that is, I imposed a sign restriction on impulse response function. The same strategy was applied in Jarociński (2006). If I had also pursued identifying risk premium shocks, I would have imposed a similar restriction but with the opposite sign on exchange rate.

In order to obtain credible results and to reduce the risk of identifying a mixture of several shocks instead of pure monetary policy shock, I also applied a completely different approach. Partly in the spirit of the 'narrative approach' and of the Rudebusch-Bagliano-Favero type 'identification based on financial market data' strategy, I identified monetary policy shocks by fixing the dates of the biggest unexpected monetary contraction and easing. Both episodes can be associated with an important, and at least in our sample, unique shift in monetary policy stance. I expect my strategy to gain special credibility from the fact that among economists familiar with the past decade of Hungarian economic policy there is not much debate about the two extreme points of monetary policy shocks. Note that in contrast with Romer and Romer (1989), Rudebusch (1998) and Bagliano and Favero (1997, 1999), my second identification is also an example of interval (or inequality) restrictions.

An important feature of this approach is worth mentioning. I identify only monetary policy shocks as Bernanke and Mihov (1996), Uhlig (2005), and Jarociński (2006) did. In this way I am relieved of the duty of specifying all relevant shocks and searching for further credible identification assumptions. On the other hand, some monetary policy shock vectors may be inconsistent with an implicit structure of the unexplained part of the covariances. When a shock vector is accepted as a monetary policy shock, there is no check whether a reasonable and complete decomposition of VAR residuals could be achieved including that particular shock vector. I assess the costs of my approach to be much lower compared to the benefits from not identifying a full structure.

Later in this paper the near equivalence of both identification approaches is demonstrated[3]. A natural consequence would then be to combine these strategies and impose all restrictions simultaneously. However, I do not present results from a combined identification, since it would not alter the main conclusions.

[3] At least on this dataset.

7.3 Baseline estimation on Hungarian data

In this section I present the results from quarterly VAR estimated on the longest available data series. Although this specification is a natural starting point of the research, later I argue that we can obtain more appealing results from alternative specifications.

Data and VAR specification

For the baseline estimate I used quarterly series of Hungarian data: logarithm of real GDP, CPI, nominal effective exchange rate and logarithm of 1+(3-month treasury bill yields)[4]. The frequency of the latter three was converted by taking the period average. An increase in exchange rate corresponds to depreciation. Since quarterly GDP data prior to 1995 is not provided by the Central Statistical Office, estimates of Várpalotai (2003) were used for that period. The series cover the period Q2:1992-Q4:2003. GDP and CPI are seasonally adjusted.

Following several authors – e.g. Uhlig (2005), Peersman and Smets (2001) – I estimated the VAR in levels. The reader interested in the debate surrounding the question how to make inference and how to interpret results when the data is likely to contain some unit roots should refer to Sims (1988), Sims and Uhlig (1991), Phillips (1991) and Uhlig (1994), among others. Following Uhlig (2005), I make inference in a Bayesian manner and interpret results using Bayesian terminology; thus the difficulties which arise when attempting to construct classical confidence bands in the presence of near unit root regressors can be avoided.

Three lags were enough to produce unautocorrelated residuals, based on the evidence of the multivariate LM-test. The Akaike information criterion also suggested 3-lags specification. An intercept was also included in the VAR.

Estimation and inference

The estimation procedure applied here and the presentation of the results is almost the same as in Uhlig (2005) with the exception of the case when monetary policy shocks were identified by imposing restrictions on shock series.

First, the coefficients and the covariance matrix of the residuals were estimated by OLS. I then used Normal-Wishart prior distribution parameterised by the VAR's coefficient and covariance matrices. As shown in Uhlig (1994), the posterior distribution will then also be Normal-Wishart. My approach differs from Uhlig (2005) in that I excluded the possibility of explosive dynamics by truncating the posterior.[5]

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[4] If, for example, the annual yield is 8 per cent, the corresponding data point is ln(1.08).

[5] Technically it was carried out by calculating the largest eigenvalue for each random draw from the VAR posterior. If the modulus was not greater than one I proceeded with that draw, otherwise I dropped it. As far as the number of draws is concerned, this truncation seemed to be effective in the sense that the procedure was often repeated because of too large eigenvalues. Interestingly, this did not influence the shape of median impulse responses much, with the only exception of price level: excluding explosive roots decreased the relative frequency of 'price puzzle' type responses in the set of all possible responses. Not surprisingly, the posterior distributions became more focused on the median value, allowing for 'more significant' results.

For each draw from the VAR posterior I randomly chose a candidate monetary policy shock, which is in the form of a 4x1 vector comprising the immediate effect on the variables. Depending on where to impose identifying restrictions, I calculated the relevant impulse responses or the shock series implied by the particular shock vector. If the impulse responses or shock series met the expectations, the draw was kept, otherwise dropped. This procedure corresponds to having an implicit flat prior on the part of the 4-dimensional unit sphere that contains 'credible' monetary policy shocks and represents our identification scheme.

As a consequence, if we interpret this procedure as a Bayesian estimation, our prior is formulated on the parameter space consisting of the subspaces of VAR coefficients, covariances and monetary policy shock vectors. As Uhlig (2005) points out, our procedure is a re-estimation of the VAR model, since, depending on how many draws from the 'monetary policy shock space' satisfy the identifying conditions, some parts of VAR coefficient prior will be overrepresented while others underrepresented.

The quantiles of posterior distributions for impulse responses and other outputs reported in the Appendix are calculated from the set of successful draws that in each case contained more than 2000 elements[6].

Impulse responses from sign restriction approach

In the first experiment I identified monetary policy shocks by imposing restrictions on the sign of impulse responses. In particular, it was assumed that an unanticipated monetary policy tightening results in more appreciated exchange rate (negative response) and higher interest rate (positive response). I chose the length of the restriction to be 4 periods, but all the results are robust to changes in the length of restriction. This identification scheme is similar to that of Jarociński (2006) with the exception that I did not restrict the immediate output response to be zero.[7]

Whereas a monetary policy shock should behave as we prescribed, it is not clear how we can exclude other sources of disturbances which produce the same initial responses. The answer is that we can never be sure. The same applies, however, to other identification strategies irrespective of whether our prior belief is formulated as point or interval restrictions. Researchers using the SVAR approach usually assume that the number of endogenous variables equals the number of relevant shocks. In addition, the looseness of interval restrictions (in other words, the underidentification) can make this problem more serious and the resulting picture more blurred – relative to an exactly (or over-) identified system with point restrictions. Nevertheless, this is the price we have to pay for greater credibility of our identification. In this way we end up with less significant results, but all those results that are significant will have more convincing power.

Figure 7.2 shows the resulting impulse responses with the error bands created as quantiles of the posterior distributions for each period. The shape of the consumer price level response suggests

[6] As Sims and Zha (1998) demonstrate, this reporting technique is not optimal, since it may convey a misleading picture about the shape uncertainty of impulse response. In order to understand their intuition, it may be enough here to note that the median impulse response plotted as thick line is the interlacement of points of different impulse responses, and usually is not a plausible impulse response itself. As Figure 7.1 suggests, a presentation of shape uncertainty in the spirit of the above-mentioned paper might be useful here.

[7] This is true only in the quarterly series case. When using monthly data I used that restriction – see the next subsection.

that we probably mixed too many types of shocks under the label 'monetary policy'. The quite significant[8] increase after the shock is the well-documented price puzzle. The usual interpretation is that another shock is identified as monetary policy shock, namely a shock to future inflation – see, for example, Sims (1992). This is anticipated by the monetary policy-maker, who therefore tightens monetary conditions. The usual remedy to this problem is to include some variables in the VAR that play the role of leading indicators of inflation, typically commodity prices – see Sims (1992) and CEE (1998). Uhlig (2005) excludes this puzzle by using the condition of negative price response to contractionary monetary policy shock as an identifying restriction. His estimation focuses on the response of output, therefore his approach could be justified[9]. In our case, however, it is the response of prices, among others, we are interested in, and thus it would not be appropriate to impose restrictions on price level impulse response.

The responses of the interest rate and the exchange rate help us to imagine the size of the shock. The 3-month TB-yield increases by 60 basis points immediately, while the nominal exchange rate appreciates by almost 0.7 per cent. Note that since we restricted the sign of both impulse responses for the first four quarters, the entire posterior distribution is above and below zero for nominal interest and exchange rate, respectively.

The output responds moderately to unanticipated monetary tightening. The immediate effect is virtually zero. This observation suggests that we indeed identified a nominal shock. The level of output declines gradually and reaches its minimum in the third year after the shock. The size of the decrease at its bottom is not particularly huge, 0.2 per cent, but it is worth noting that roughly 95 per cent of the posterior distribution is below zero during the third year; thus we can consider this effect as significant.

An interesting feature of our results is the relative sharpness of the real exchange rate impulse response. The width of the middle two-thirds of the posterior distribution is only 0.3-0.4 of a percentage point in the fifth year after the shock, which is three times wider in the case of nominal exchange rate. This is due to the fact that identification uncertainty is highly correlated between prices and nominal exchange rate. If, for example, some plausible (i.e. meeting identifying criteria) monetary policy shock vector generates rising prices after a contractionary shock (price puzzle), it is likely to generate a more depreciated nominal exchange rate for the same period.[10] Put differently, our data and identifying assumptions have very stable consequences regarding the response of the real exchange rate to monetary policy shocks, but not regarding the price level and nominal exchange rate.[11]

[8] The word 'significant' may be a bit misleading here. Since we apply Bayesian inference philosophy, the probability coverage terminology is more appropriate. The right interpretation is that 'with probability x the response is above (or below) zero'. In our case we can claim that with probability more than 84% the response of the price level is positive 3–6 years after the shock, conditioned on the data.

[9] Nevertheless, see footnote 2 regarding this issue.

[10] This fact has the consequence that we could have mitigated the undesired price puzzle by lengthening the restriction period of nominal exchange rate. However, my identification philosophy was to impose *explicitly* all features about which we have firm prior belief. Following this logic the only legitimate way to fight against price puzzle would have been to require a negative price level response to monetary tightening.

[11] The same will be true for all the other estimation strategies to be introduced later in this paper with the exception of shorter sample experiences.

In the next subsection we compare these results to those obtained from an alternative identification strategy.

Impulse responses from restrictions on shock history

As advocated in section 7.2, identifying restrictions imposed on implied shock history may sometimes have a communication advantage over restrictions on impulse responses. In Hungary during the past 10 years one of the largest monetary loosening was the austerity package of financial minister Bokros, which contained a surprise depreciation of the forint in order to balance the government budget and the current account in March 1995. On the other hand, the widening of the narrow exchange rate band in May 2001 and the following appreciation surprised the market into the opposite direction. In both episodes monetary policy deviated to a considerable extent from its earlier behaviour, and I base my identification strategy on that fact.[12]

I assumed therefore that between 1995 and 2003 the largest unexpected monetary loosening occurred in Q1:95, while during the same period the band widening in 2001 was the largest contractionary monetary policy shock.[13] While specifying the date of the latter step is straightforward, it is not clear in which quarter it was effective. Although the change of the exchange rate regime took place in May, the appreciation continued in the third quarter as well. It is therefore more reasonable to formulate the restriction as 'the bigger shock of the two relevant quarters should be at the same time the biggest between 1995 and 2003'. One can argue that the tightening shock itself was the widening of the fluctuation band of the Forint. It is important, however, to emphasise that we are trying to locate monetary policy shocks using exchange rate and interest rate data, and the figures show even more substantial appreciation from Q2:2001 to Q3:2001 than between the first two quarters, with the central bank not trying to dampen it by lowering short-term interest rates.

The method of estimation is quite similar to that of the previous strategy. For each joint random draw from VAR-posterior and the unit sphere of possible shock vectors I calculated the historical shock series, and the draws not meeting the restrictions described above were rejected. The posterior distributions were constructed from the successful draws. The main results are summarised in Figure 7.3.

The most striking feature of these charts is their similarity to previous ones. This observation indicates that the two sets of identification restrictions, namely those imposed on impulse responses and those imposed on shock history, are nearly equivalent. In other words, the implied history of monetary shocks identified by impulse responses of interest rate and exchange rate typically correspond to our prior belief about when the biggest contractionary and expansionary monetary policy surprises took place during the past nine years. On the other hand, fixing the extreme points of implied history produces impulse responses that are typically in accordance with our intuition regarding the behaviour of the nominal interest and exchange rate in the aftermath of a monetary policy shock.

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[12] One can argue that during those episodes the policy rule changed itself. Since my model does not deal with structural breaks that affect the reduced form or the identification scheme, it seems to be a good approximation to look at those policy actions as extreme shocks.

[13] Note that those shocks are not expected to be the largest on the full sample, i.e. from 1992.

There are, however, differences as well. While the response of output is almost the same in both cases, identification based on historical evidence seems to dampen the price puzzle. The response of the price level to monetary contraction has an appealing sign during the first seven quarters, although later it rises above zero. This may be related to the bigger appreciation of nominal exchange rate after the monetary shock.

Considering the intuition behind identification through shock history, it is not surprising that we have more chance of eliminating such shocks as 'future inflation shocks' suspected to be responsible for the price puzzle. Using historical evidence we force impulse responses (or other statistics we are interested in) to be close to the effect of disturbances in certain periods. In particular, we located the two extreme points of implied monetary policy shock history (the biggest tightening and easing), thus our impulse responses will be similar to the effect of the Bokros-depreciation and (with opposite sign) of the band widening. Since we identify on time domain rather than on the space of impulse responses, we can avoid mixing up shocks that have similar effects. If we are really convinced that these two periods were dominated by monetary policy shocks and we can rule out that at the same time a pair of another type of shocks occurred in both periods with both signs, we can get rid of all pseudo monetary policy disturbances that trigger plausible responses but which do not originate in monetary policy.

On the other hand, the impulse response of nominal interest rate is a bit annoying in the second identification approach. The quick correction after the shock and then the second increase are difficult to interpret. This is due to a special type of impulse response that occurred quite often during random search for plausible monetary policy shock vectors. According to this 'alternative' rate scenario, the initial response is a decline in the short interest rate followed by a gradual increase above zero. The high probability of generating such response from random draws influences the posterior distribution, especially in the first two years.

In Figure 7.4 only the median impulse responses are plotted, allowing for a more convenient way of comparison of different identification approaches. However, it should be noted that all the differences can be considered as insignificant in the following sense: in each case the middle two-thirds of impulse response posterior distribution (dashed lines on Figures 7.2-7.3) contains the median impulse response obtained from the alternative strategy.

7.4 Robustness check: alternative estimates

As a check of robustness I also estimated a 4-variable VAR model on monthly data. Since on our sample the model is likely to contain structural breaks, I re-estimated the monthly model on a shorter sample beginning in 1995. As is demonstrated below, switching to the monthly model does not change the picture significantly. On the other hand, impulse responses estimated on the shorter sample are quite different from full sample results, and resemble those obtained for developed countries in the literature.

Estimation on monthly data

The observations of the monthly model range from M1:1992 to M3:2004. CPI, nominal interest rate and exchange rate series are from the same sources as in the quarterly model. Real GDP was replaced by constant price industrial production, which is available at monthly frequency. I used the seasonally adjusted series corrected for calendar effects produced in MNB.

Lag length of 2 was suggested by most information criteria. Two lags eliminated the bulk of autocorrelation of residuals. The LM-test still detected significant autocorrelation at lag 5, but inclusion of more lags did not help with this problem. I therefore used 2 lags.

Because of the higher frequency, I assumed in both identification strategies that monetary policy influences the output only with lags. While sign restrictions could be imposed on impulse responses in an analogous way to the quarterly case (I chose the length of constrained period to be 12 months, which corresponds to the 4 quarters of our previous exercise), locating the most contractionary and most easing monetary policy shocks in time may require some justification. The Bokros loosening in 1995 is likely to have had its maximum magnitude in March, reflected in a roughly 6% depreciation of the Forint. The contractionary effect of exchange rate band widening in 2001 appeared most sharply during May and June based on exchange rate data. The monthly appreciation rates were roughly 3% and 4% respectively. This seems to contradict the quarterly identification strategy, since we expected the maximum tightening to appear in either the 2nd or the 3rd quarter. This contradiction, however, is of purely technical nature; it is a consequence of taking period averages.

The results are quite similar to those of the quarterly model, as Figure 7.6 demonstrates (results from restricted impulse response approach are not reported). The most important differences are the faster (but still moderate) response of output and the smoother path of interest rate in the monthly model, but all differences are small compared to the sampling and identification uncertainty.

Estimation on subsample

Finally, I estimated the monthly model on a shorter sample. The 12 years of previous estimation are supposed to be full of regime changes. These structural breaks may have blurred the picture we obtained from full sample estimation. Shortening the period under investigation may produce sharper results.

Among the most important changes were the announcements of two systematic monetary policy regimes. In the beginning of 1995 a crawling narrow band exchange rate system was introduced. The central bank announced the changing devaluation rate of the exchange rate band in advance. In 2001 the fluctuation band was widened and an inflation targeting framework replaced the previous regime. Both dates can be considered as significant turning points in preferences of monetary policy and in its behaviour.

The results seem to confirm that there was indeed an important structural break during the first half of the nineties, and it might have been the regime change of monetary policy. Despite the smaller sample, the posterior distribution became more concentrated around the median (compare Figure 7.7 with Figure 7.5), especially in the case of price level, nominal (and real) interest rate and nominal exchange rate. As mentioned earlier, the uncertainties in price level and nominal exchange rate behaviour were correlated, and could be attributed to identification uncertainty. If we restrict our dataset to contain only observations from 1995 on, identification of monetary policy shock became much easier in the sense that only a small set of possible shock vectors met the identifying restrictions. This finding is reinforced by the rather technical experience that random search produced more rarely plausible 'monetary policy vectors' than in the full sample case.

Moreover, there are spectacular differences regarding the point estimates, too.[14] From the point of view of monetary transmission mechanism, the most important change is perhaps the reaction of price level. The immediate response to monetary tightening of typical magnitude is virtually zero, and it starts to decline at the end of the first year. The pace of the decrease is very slow, the greatest effect (0.1-0.15%, depending on identification strategy) can be observed during the fourth-fifth years after the shock. This is in sharp contrast with full sample estimates, where an initial drop in prices was followed by a rise above zero, even if 'history restrictions' were imposed. Due to the fact that the latter phenomenon occurred irrespective of identification scheme and data frequency, we can attribute the bulk of price puzzle to the data prior to 1995.

The behaviour of the nominal interest rate and exchange rate is of great importance, too. While on full sample one standard deviation monetary policy contraction resulted in a permanently (for 2-3 years) 30-40 basis points higher short rate, since 1995 a typical monetary tightening appears in the form of 20-30 basis points higher short interest rate that quickly declines. One year after the shock the distance from baseline path is only less than 10 basis points. On the other hand, this more moderate interest rate policy has virtually the same immediate effect on the nominal exchange rate: a 1% appreciation within a few months, just like in the full sample case. In contrast to the full sample case, the return to the baseline is more gradual and the nominal exchange rate never becomes weaker than in the baseline. We can interpret this result as monetary policy became more effective after 1995 in influencing the nominal exchange rate. This is probably due to the nature of the monetary regimes after 1995. In the crawling peg regime, the pre-announced devaluation rate of the narrow fluctuation band was generally credible. In the inflation targeting regime the inflation forecast was conditioned on the nominal exchange rate as a policy variable, therefore market participants had a quite clear picture about the 'desired' future development of the HUF/EUR. The improvement in efficiency, therefore, can be attributed to the more efficient orientation of exchange rate expectations.

The response of the output seems to be the most robust result across identification and sample choices. Although the short sample with history restriction produced the less smooth decline (it drops immediately to the minimum value of -0.25%), the size of the recession and the beginning of the recovery is roughly the same in all cases: the level of output decreases by roughly 0.3% within the first two years after the shock and starts to increase at the end of the third year.

Together with the price level response, this behaviour exhibits the main characteristics of sticky-price models. Because of the slow adjustment of prices, it is the output that reacts first to the contraction. The price adjustment is coupled with the gradual return of output to its natural level. This pattern is in accordance with survey results, too. Based on a survey among Hungarian companies conducted in 2001, Tóth (2004) concludes that before changing their prices, Hungarian firms typically try to meet shifts in demand by first changing their output.

It is worth noting that the difference between estimates on different time span is much bigger than the difference caused by switching to the alternative identification strategy. On data starting in 1995, both restriction sets produced almost the same picture that fits the typical findings in the

[14] For a convenient comparison see Figure 7.8.

literature. We can conclude, therefore, that our identification strategies are good characterisation of monetary policy shocks, and this becomes obvious when they are applied on a relatively homogenous sample.

7.5 Conclusions

The purpose of this paper was to estimate the dynamic effect of monetary policy on several variables, in particular on output and consumer prices using Hungarian data. Due to possible data problems and the supposed existence of structural changes, two variable sets were used, one of them on two different, but nested samples. Due to doubts regarding the applicability of widely used identification approaches, in particular zero restrictions, sign restrictions were imposed on impulse responses. In order to obtain more credibility, an alternative identification scheme was also proposed. The latter tried to capture the main features of a monetary policy shock by using historical evidence of some periods when monetary policy is known to have surprised market participants.

Although the results are weak in the sense that even the middle two-thirds of the distributions of possible impulse responses contain zero in most cases, the robustness of the point estimates to the identification strategy on the one hand, and the coincidence of the shorter sample estimates with the results of the literature on the other, allow a few firm conclusions to be drawn.

All of our estimates produced the result that one standard deviation unanticipated monetary contraction results in 1% quick nominal appreciation and 0.3% reduction in output. The latter starts to recover after three years. Although the real exchange rate appreciates quite significantly in the first 1-2 years, it returns to its equilibrium after 3-4 years.

Comparing results across different estimates, we can conclude that it is more feasible to estimate the effect of Hungarian monetary policy on data starting in 1995, as long as we do not believe that monetary contraction can cause rising prices one year later.[15] Excluding observations prior to 1995 also has the advantage of obtaining sharper results. The shape of the impulse responses obtained on short sample are quite similar to those which can be found in the literature. They can also be reconciled with the predictions of sticky-price models. Based on these estimates, a typical unanticipated monetary policy contraction amounted to a roughly 25 basis points rate hike and resulted in a quick 1 per cent appreciation of nominal exchange rate during the past 9-10 years. This was followed by 0.3% lower output and 0.1-0.15% lower consumer prices. The impact on prices was slower than on output, it typically reached its minimum only 4-6 years after the shock.

As far as our identification strategies are concerned, the difference between the two was minor. Imposing restrictions on history may help to exclude some puzzles stemming from a too loose identification of other strategies, but in our case the sampling error suppressed possible improvements. In my view, however, it may add to the credibility of the other identification scheme and to the reliability of the results.

As far as possible improvement of the estimates is concerned, the sampling uncertainty seems to be a binding constraint. The data is given, the sample cannot be extended backwards. Short sample estimates revealed that even the observations prior to 1995 provide very noisy information

[15] Nonetheless, this way of choosing the best specification is still subject to the criticism outlined in subsection 'Major aspects of identification'.

about the underlying relationships. Including more variables in the VAR would lessen the degrees of freedom considerably.

On the other hand, reducing the uncertainty stemming from my cautious approach to identification is possible, at least in theory. Identifying more periods when something is known about the direction of monetary policy surprises may produce narrower error bands. In practice, however, after having identified the biggest historical surprises, there remained not much dispersion in implied monetary shock history; therefore exclusion of substantial amount of shock vectors based on history may not be carried out with high credibility.

In the case of restrictions on impulse responses, much improvement could not be achieved, unless we are willing to sacrifice some part of the convincing power of our assumptions. Lengthening the number of periods throughout which sign restrictions are imposed would inevitably arouse the suspicion of arbitrariness. Imposing additional restrictions on variables' reaction we are particularly interested in (price, output) would make the interpretation of the results difficult. In the case of the nominal exchange rate and short interest rate this problem is not so serious, since their reactions are at the very beginning of the monetary transmission's causality chain. Therefore we can have firmer prior belief about their behaviour, especially regarding the first few periods.

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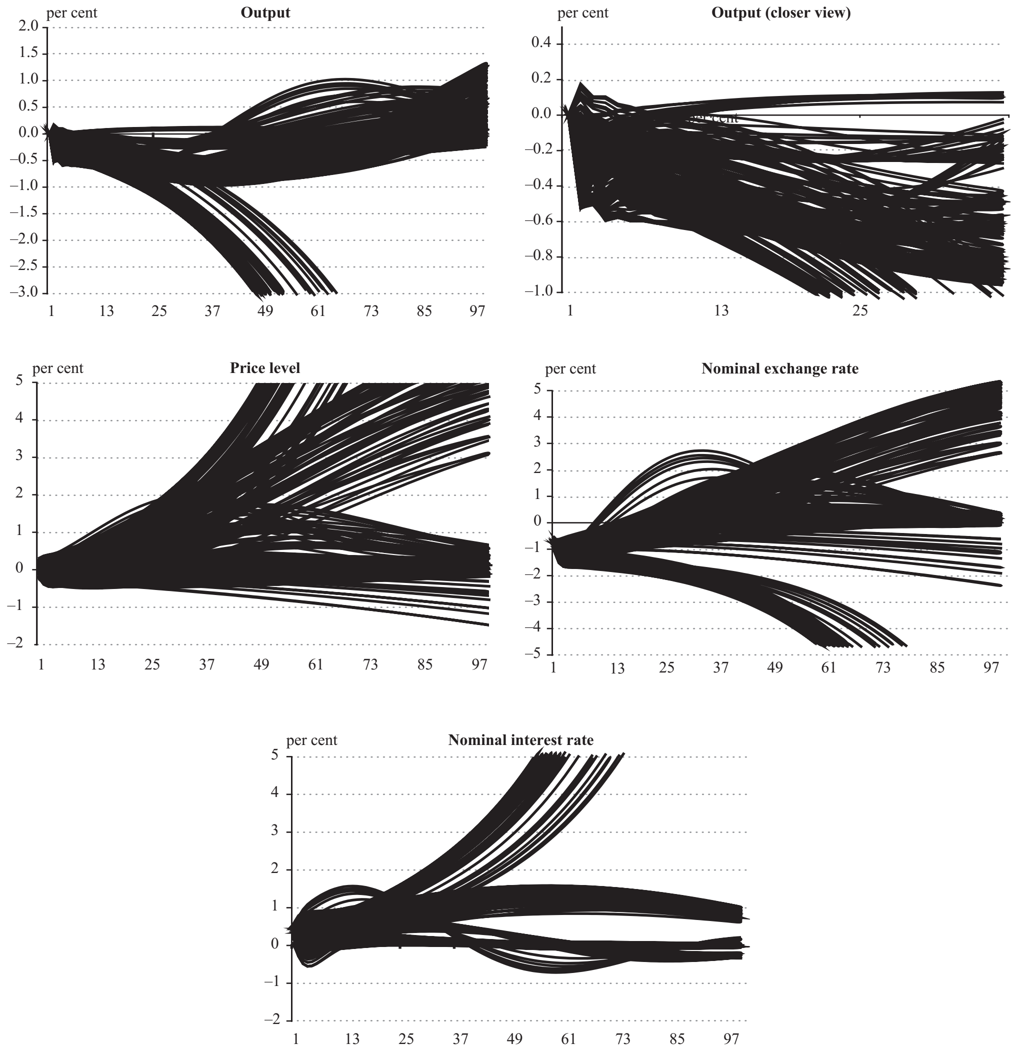
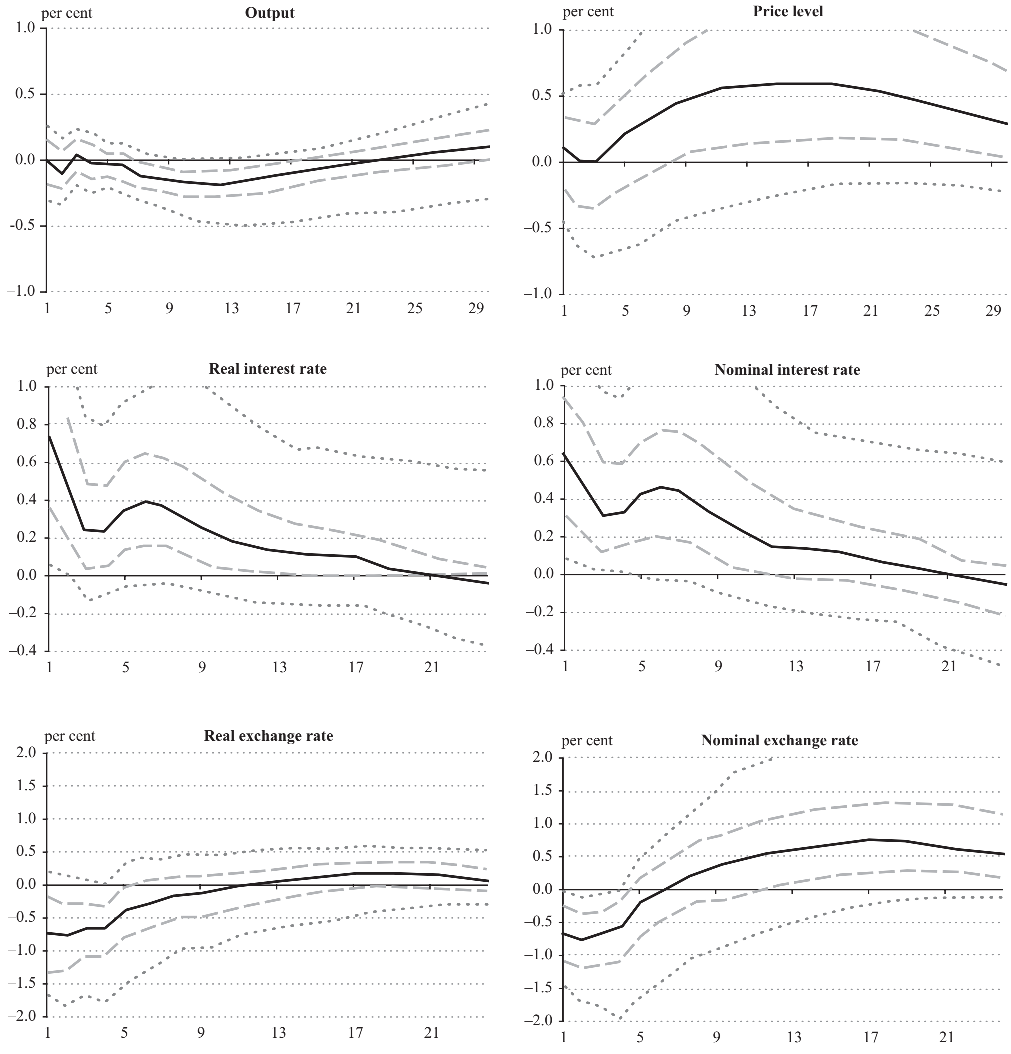
Appendix: Figures

FIGURE 7.1 **Examples of the effect of sampling and identification uncertainty: impulse responses to plausible monetary policy shocks** (estimates on monthly data from 1992 allowing for explosive roots)



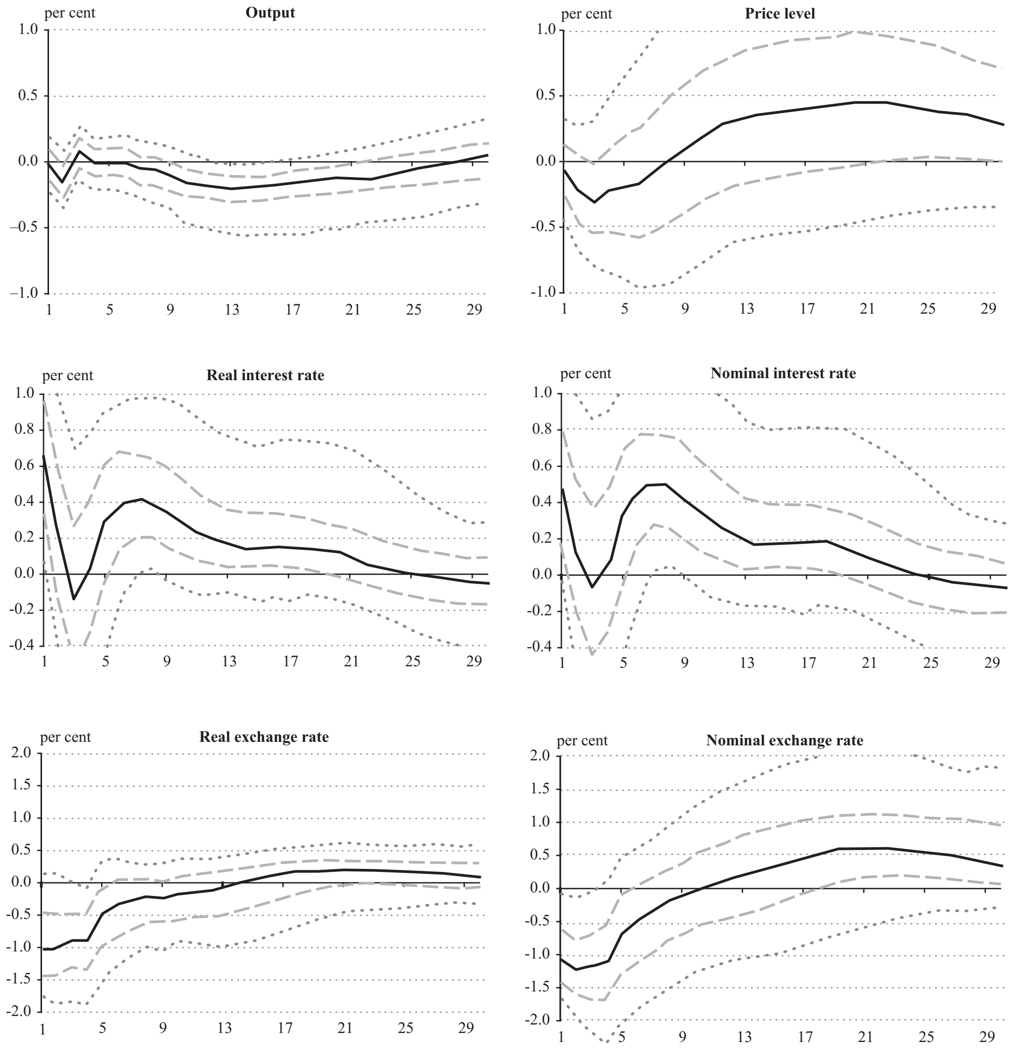
Time scale in months.

FIGURE 7.2 Impulse responses to a one standard deviation monetary policy shock; posterior distributions from the sign restriction approach (full sample)



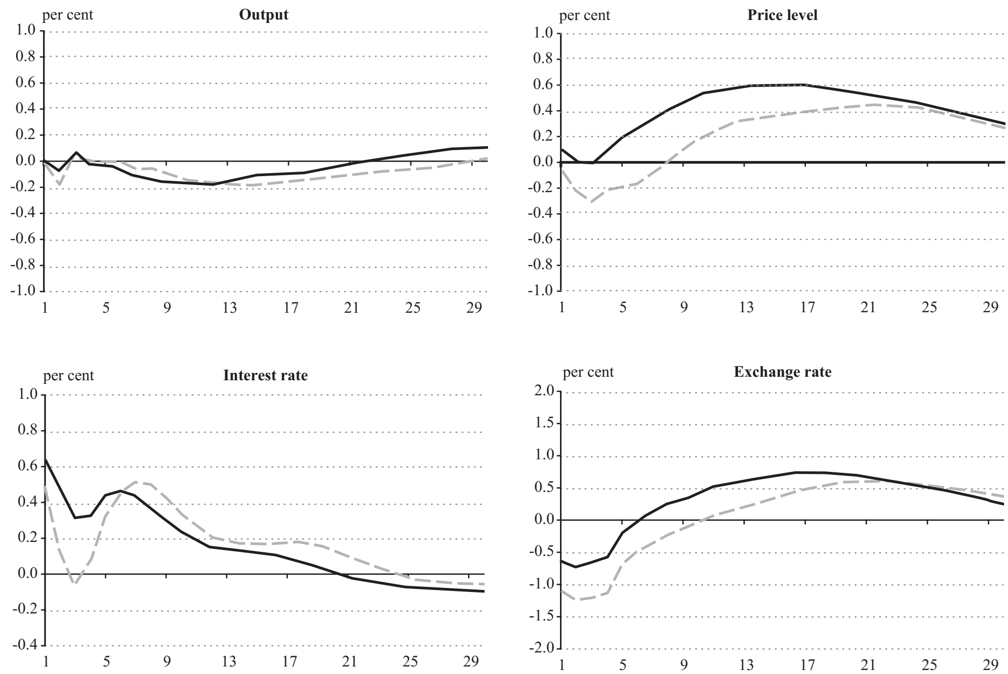
Time scale in quarters. The middle 95.4% (± 2 st. dev. for normal distribution) of the distribution ranges between the dotted lines, the 68% (± 1 st. dev. for normal distribution) between dashed lines. The thick line connects median values for each period.

FIGURE 7.3 **Impulse responses to a one standard deviation monetary policy shock; posterior distributions from the 'history restriction' approach** (full sample)



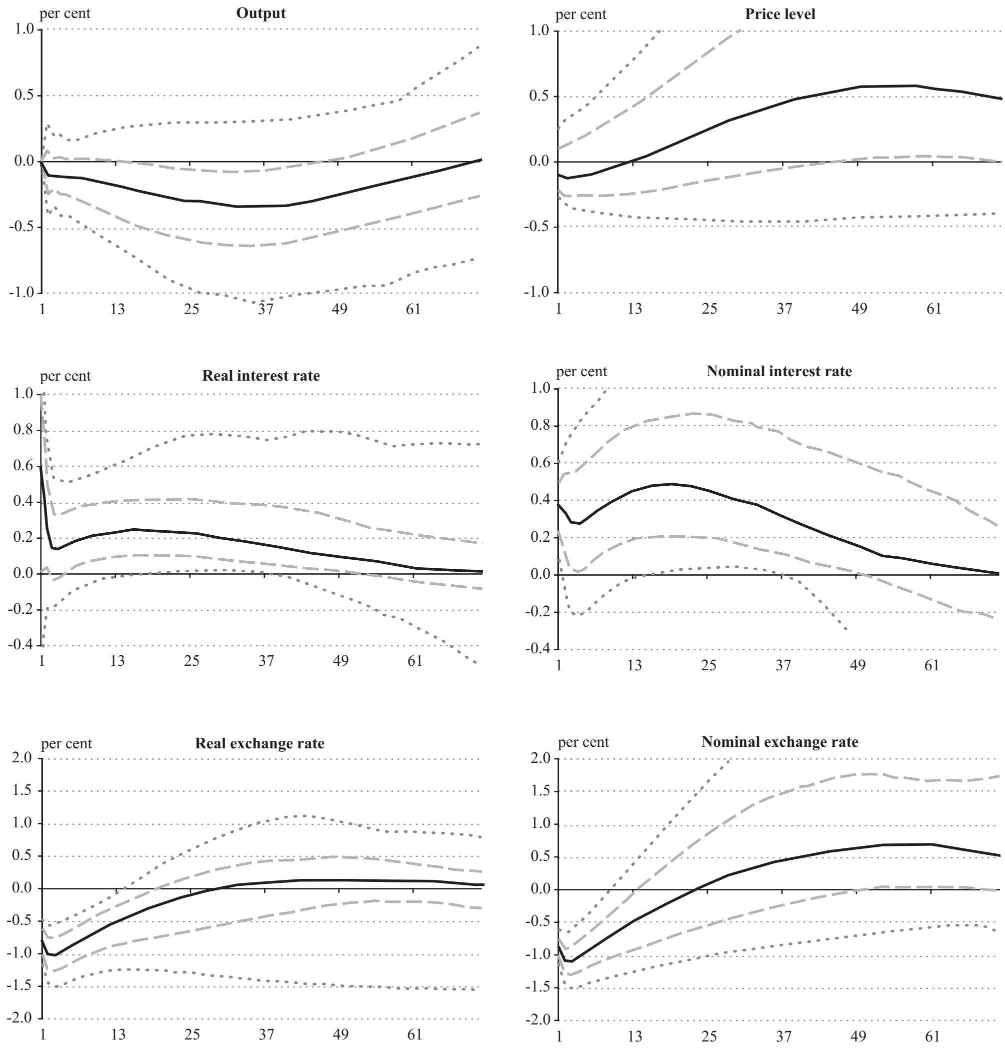
Time scale in quarters. The middle 95.4% (± 2 st. dev. for normal distribution) of the distribution ranges between the dotted lines, the 68% (± 1 st. dev. for normal distribution) between dashed lines. The thick line connects median values for each period.

FIGURE 7.4 Comparison of impulse responses from competing identification approaches (estimates on quarterly data, full sample)



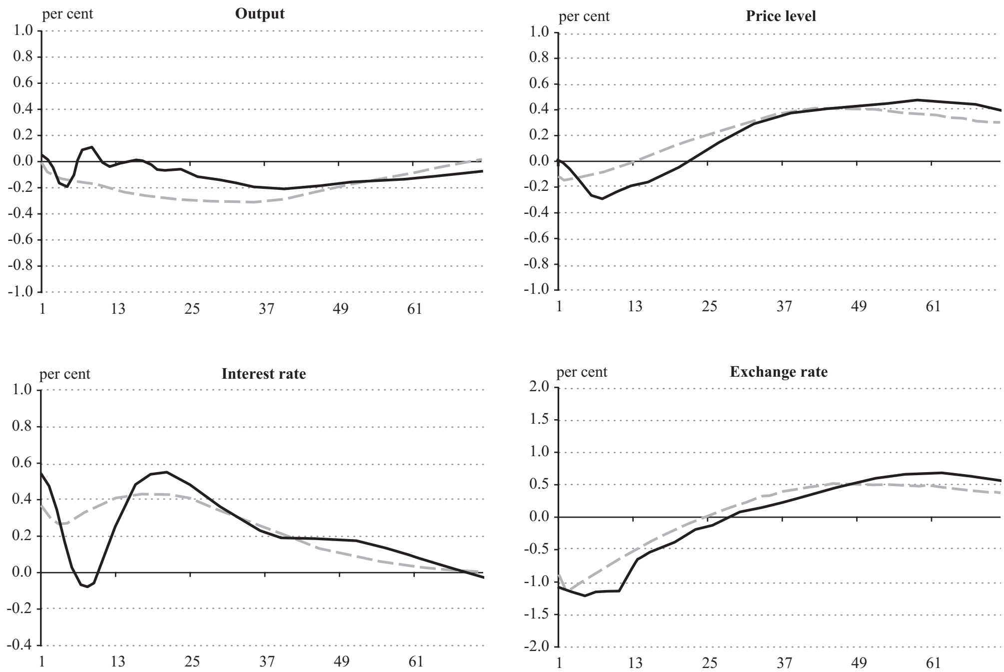
Time scale in quarters. Thick line: restrictions imposed on impulse response functions. Dashed line: restrictions imposed on implied shock series.

FIGURE 7.5 **Impulse responses estimated on monthly data; posterior distributions from the 'history restriction' approach** (full sample)



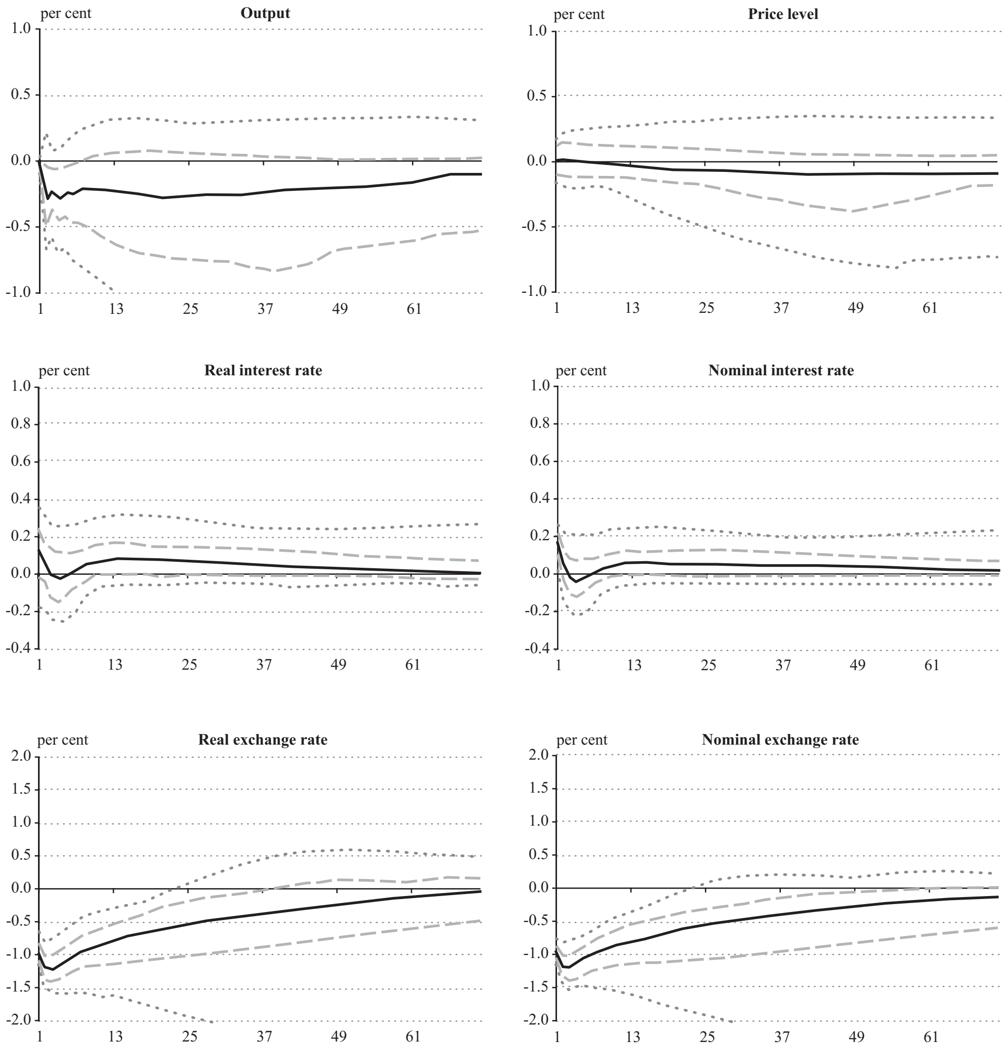
Time scale in months. The middle 95.4% (± 2 st. dev. for normal distribution) of the distribution ranges between the dotted lines, the 68% (± 1 st. dev. for normal distribution) between dashed lines. The thick line connects median values for each period.

FIGURE 7.6 Comparison of impulse responses from quarterly and monthly models; identifying restrictions on shock history (full sample)



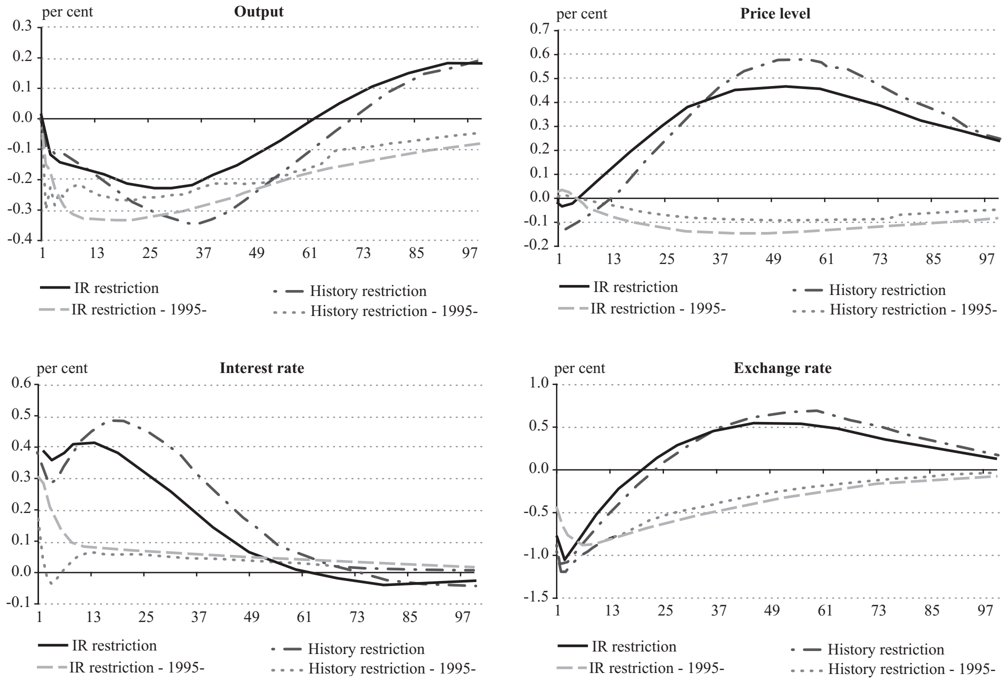
Time scale in months. Thick line: quarterly model. Dashed line: monthly model. Impulse responses of the quarterly model were converted to monthly frequency by interpolation preserving quarterly averages and achieving maximum smoothness.

FIGURE 7.7 Impulse responses estimated on shorter sample using monthly data; posterior distributions from the 'history restriction' approach



Time scale in months. The middle 95.4% (± 2 st. dev. for normal distribution) of the distribution ranges between the dotted lines, the 68% (± 1 st. dev. for normal distribution) between dashed lines. The thick line connects median values for each period.

FIGURE 7.8 Comparison of impulse responses from different samples; monthly data, identifying restrictions on impulse responses (IR) and on shock history



Time scale in months.

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

Zoltán M. Jakab, Viktor Várpalotai

and Balázs Vonnák

8.1 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 in the US. They conclude that following an unexpected monetary tightening, output components contribute to the economic slowdown different extents. Whereas the drop in private consumption dominates in the US, the effect on investments seems to be more important in the euro area.

Van Els et al. (2001) run 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 these economies.

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

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 Magyar Nemzeti Bank (the central bank of Hungary). All remaining errors are our own.

[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.

(2005) give empirical characterisation of the exchange rate pass-through and the effects 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 assess 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 clear-cut conclusions only if there is substantial similarity among the impulse responses of the three models.

The paper is organised as follows. In the following part the three models are described briefly. In the third part we present our estimation strategy and the results. Finally, we conclude in the fourth part.

8.2 Models used in this paper

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 on a sample generally starting from 1995. The specifications usually follow an error correction approach, describing both the effect of long-run relationship and the short-run dynamics.

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

Monetary transmission in the NEM model works through 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 maximization. We employed a production function with constant elasticity of substitution (CES) using capital and labour as inputs. The labour-augmenting technological progress is exogenous. Production function determines potential output - the one prevailing under trend (full-capacity) employment.

The key parameter (the elasticity of substitution between capital and labour) of the production function is calibrated according to microeconometric estimations of Kátay (2003) yielding similar result obtained with 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 the NEM model, a one percentage change in the user cost of capital leads 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, the dynamic response is less than half of the total (long-term) response during the first 6 years.

The long and short-run demand for (private) capital in the NEM has 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.

The real user cost 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 more than the long-term interest rate does. In the short run, this yields a drop in investments after a monetary tightening.

Employment is derived from 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 agree on nominal (and real) wages, and then employees decide on labour demand which determines employment. Elasticity of employment to wage costs equals to the coefficient of capital/labour substitution in the production function in the long run.

Labour demand of the private sector is modelled as follows:

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

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 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 has an effect on consumption by changing the real income. The real interest rate effect on consumption is neglected, because it was found to be insignificant.

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

The exchange rate channel of monetary transmission mostly affects the 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 com-

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

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

pared to that of the core inflation, any change in the exchange rate alters relative import prices. Moreover, imports depend on aggregate demand as well; hence, any effect of monetary policy which affects demand dampens the GDP response. Lower demand leads to lower imports and thus the original drop in GDP will also be somewhat lower.

Aggregate demand changes spill over into prices, wages and employment, which again alters demand and the new equilibrium emerges 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. However, the mark up is not constant but 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 output gap term of the price equation. However, the coefficient of the output gap is calibrated, and its value lies within the range of the other two 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 are:

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

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

A change in prices is, however, driven not only through aggregate demand (output gap); but nominal wages are also affected. Private wages depend on prices (with a long-term elasticity of one), productivity, labour-augmenting technology and unemployment. These equations describe 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 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 lower by 2 per cent approximately.[4]

Wages are relatively persistent to a nominal (price) shock. The half life of the wage response 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 increase. This effect is quite strong. As a result of a monetary tightening, the consumption temporary increases. In international comparison, the effect of unemployment on wages is not extreme.

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

Nominal wages in the NEM are modelled as follows:

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

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

The 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 calculated as a weighted average of import and domestic prices (GDP deflator). Consumer prices are a weighted average of core inflation, regulated, energy and food prices.[5] Consequently, the monetary tightening leads to lower consumer prices. As wages are more persistent than prices, the real income of households increases, which counteracts 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) can be summarized as follows.

The exchange rate channel is quite strong, as it has a direct impact on consumer prices leading to an increase in real income. Consequently, consumption increases in the very short run. The direct effect of a hike in interest rates is neglected. Exports respond rapidly, though only very modestly. 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) yielding 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 found to be insignificant in the past, but they could be more important in the future. For example, housing wealth effects may modify households' behaviour.[6] Through these valuation effects, an initial consumption increase (due to higher real income) might be mitigated, and thus GDP response is underestimated. Moreover, the corporate sector's behaviour is captured by the real user cost (and the accelerator in investment), no balance sheet or credit channels are present in the model.

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

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

An other drawback of the simulations is that the model is mainly backward-looking. Only 'partial forward-lookingness' (through nominal exchange rate and long-term yields) is present. Agents' forward-looking behaviour may 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 may also change. In other words, Phillips curves (the price and the wage equations) 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.

A further 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.

The 5GAP model

The 5GAP model describes the evolution of inflation, components of excess demand, exchange rate and interest rate using a small open economy framework and a floating exchange rate regime assumption 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 inflation targeting monetary regime in 2001 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 consumer price inflation (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 the uncovered interest rate parity rule:

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

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

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

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

The real side of the 5GAP model decomposes aggregate excess demand (alias output gap) (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:

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

It has been assumed that the evolution of these disaggregated gaps[8] are determined by some of the following variables: output gap, foreign demand (y_t^*), real exchange rate and 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:

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

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

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

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

where $f_i(.)$ are linear function of the listed variables and $B_i(L)$ are lag polinoms. As it is apparent from (11)-(14), we assumed that the excess consumption depends on lagged consumption gap and on distributed lags of excess aggregate output gap. Similarly, excess investment depends on its lagged value, 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 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 (λ=1600) series of correspondent seasonally adjusted variable, 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 detected a delayed reaction to a change in explanatory variables (see Figure 8.5).[9]

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

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

The structural VAR (SVAR)

The third approach is based on the structural VAR models similar to those of 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 which 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.

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. Following 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.

8.3 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.

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]

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 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 after a typical monetary policy shock 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 plugged 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 into the NEM model.

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 disappears 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]

We also calculated how many quarters does it take the exchange rate to reach its maximum deviation from its initial level. If UIP holds, it is the first quarter after the shock. The posterior distribution of the peak response also suggests an almost UIP-type dynamics, and weak evidence of delayed overshooting (Figure 8.1 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 assumptions on the interest rate and exchange rate paths. 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, i.e. the variables of major interest, were not affected remarkably 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 8.1, 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 in 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.

[13] Figure 8.1 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.

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 8.2). 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 obvious. 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, although the timing of the reactions differs. 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 the euro area the output response is mainly driven by investments. Contrary, in the US the drop in consumption drives the decline in output. 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.

[16] See Móré and Nagy (2004).

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 8.5, 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 of their results with ours is limited.

In the NEM model investment behaviour works mostly through the change in the user cost of capital. As shown in Figure 8.6, 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 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 manner. 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 8.6). In the backward-looking user cost specification, the drop in investment prices in the past raises the user cost above the long-term rates. Deflation in the investment goods price index pushes the real cost of capital accumulation higher

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

than the nominal interest rate. Intuitively, a monetary tightening makes investment costly not only because of high interest rates, but the opportunity cost is also high due to the decline in prices.[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 8.8.[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 move 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 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 at the components of net exports, the main difference among 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 smaller than in the other two models. There is, howev-

[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, a marked difference in the behaviour of imports. The NEM simulation shows increasing, 5GAP and SVARs point to decreasing imports.[20]

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.

8.4 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 response 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, a mixed 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' consump-

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

tion 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.

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Figures

Main features of the models

Figure 8.1 Elasticity of export and import prices to a 1 per cent permanent depreciation of nominal exchange rate in the NEM

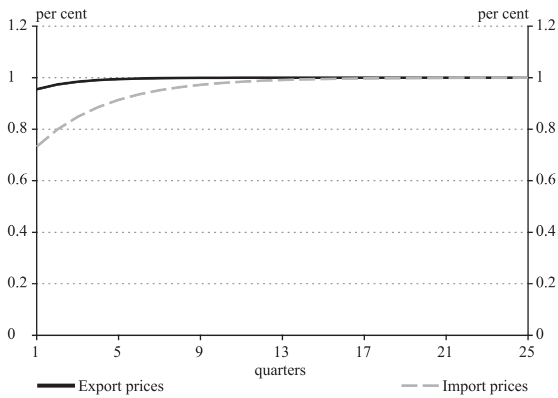


Figure 8.2 Elasticity of imports to a 1 per cent permanent increase in relative import prices in the NEM

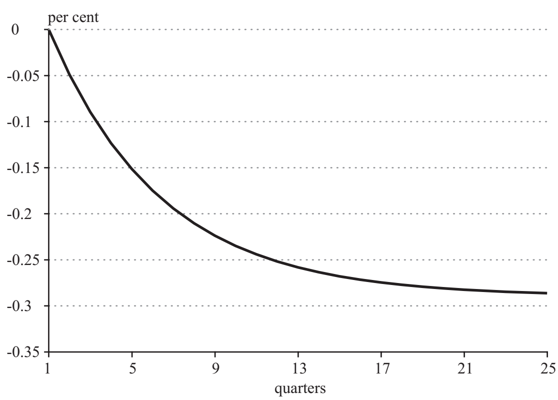


Figure 8.3 Response of GDP deflator to an output gap shock in the NEM model

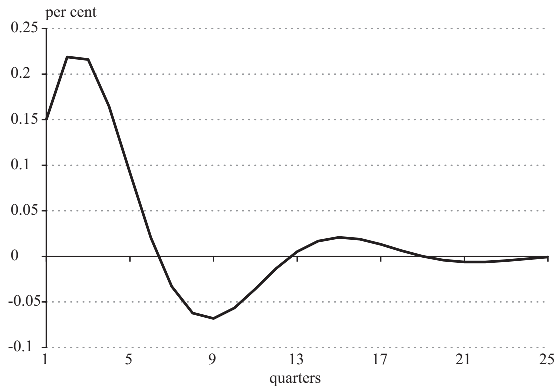


Figure 8.4 Private nominal wage responses in the NEM model

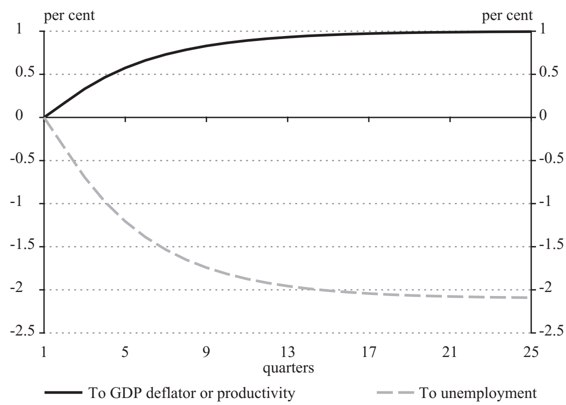


FIGURE 8.5 Single equation impulse responses of gaps to one per cent one-off shocks in the 5GAP model

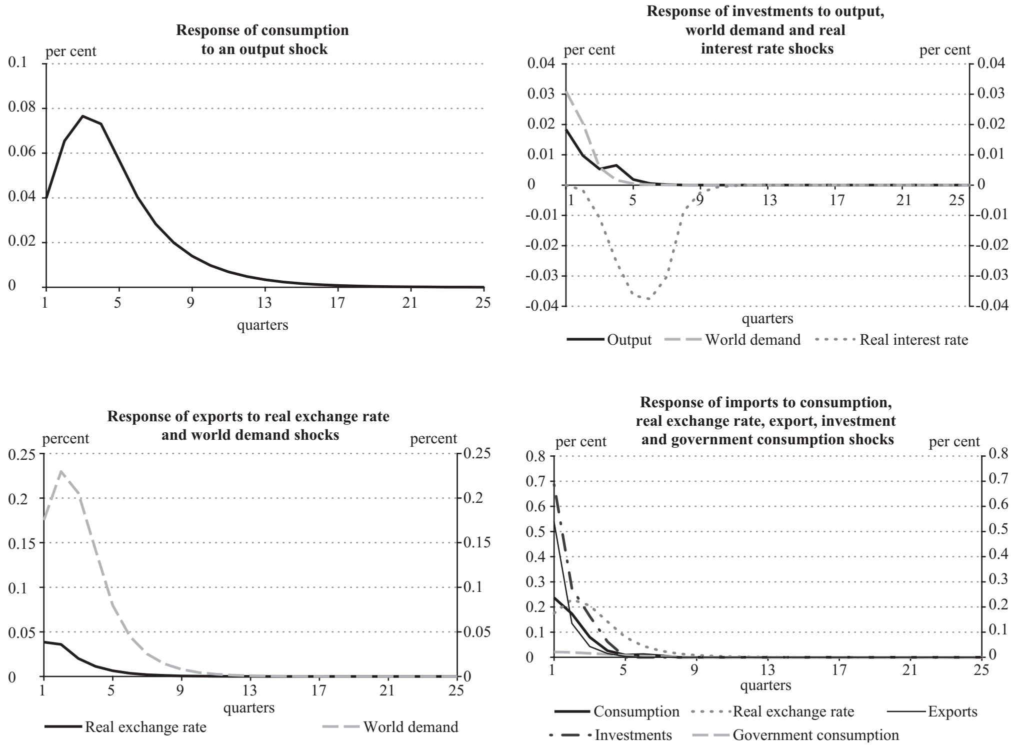
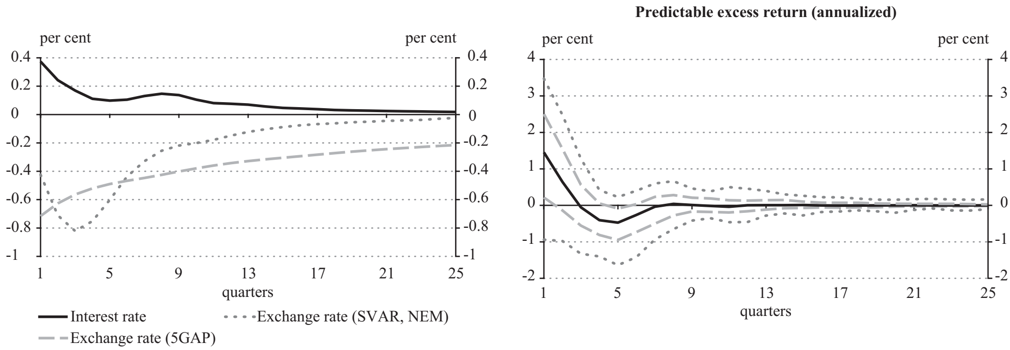


Table 8.1 List of VARs and identification strategies used for calculating impulse responses

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 exchangee 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

Impulse responses to a monetary policy shock

Figure 8.6 Characterisation of a typical unexpected monetary policy tightening: response of short-term nominal interest rate and nominal exchange rate (SVAR estimates)



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

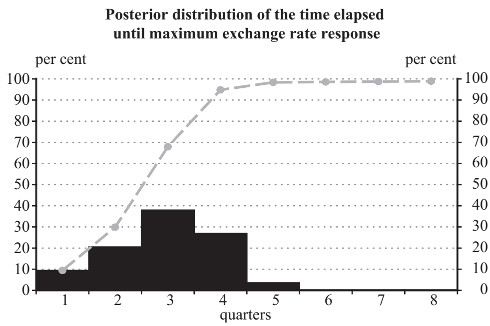
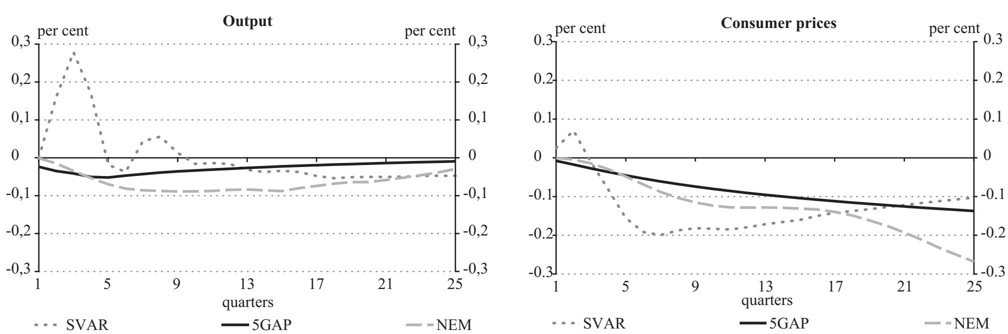


Figure 8.7 Responses of output and consumer price level to a tightening monetary policy shock (results from three models)



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

FIGURE 8.8 Responses of major GDP components to a tightening monetary policy shock (results from three models)

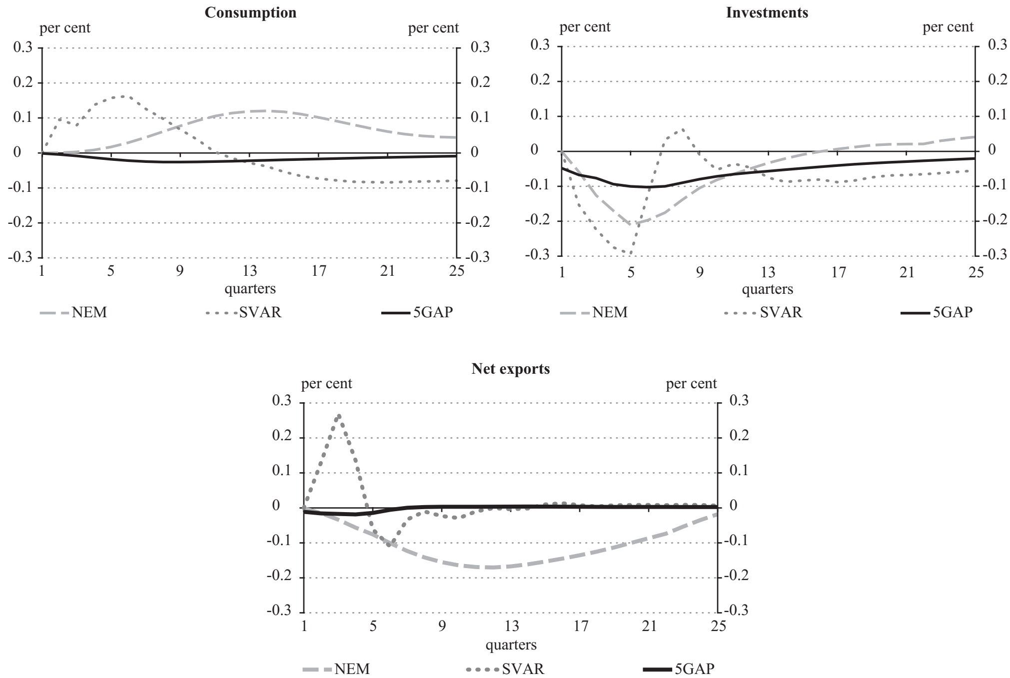
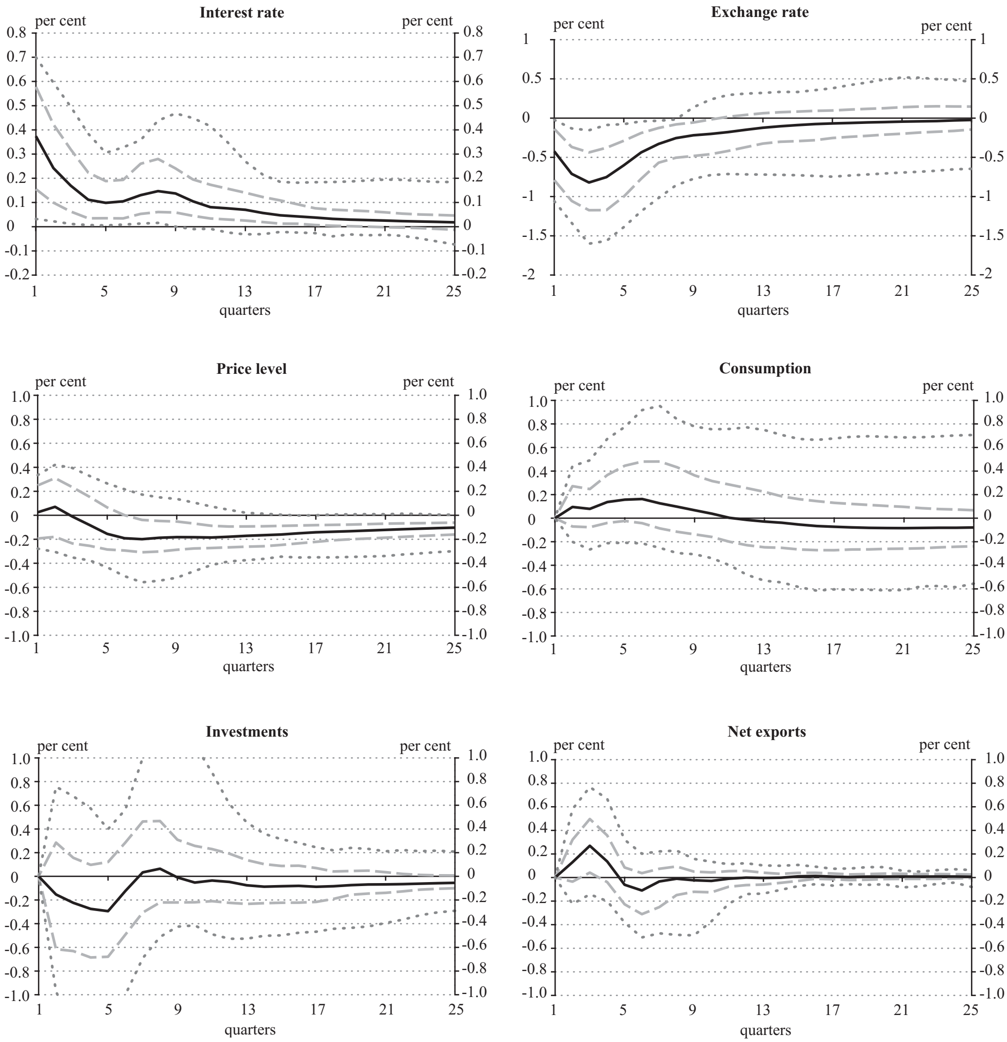
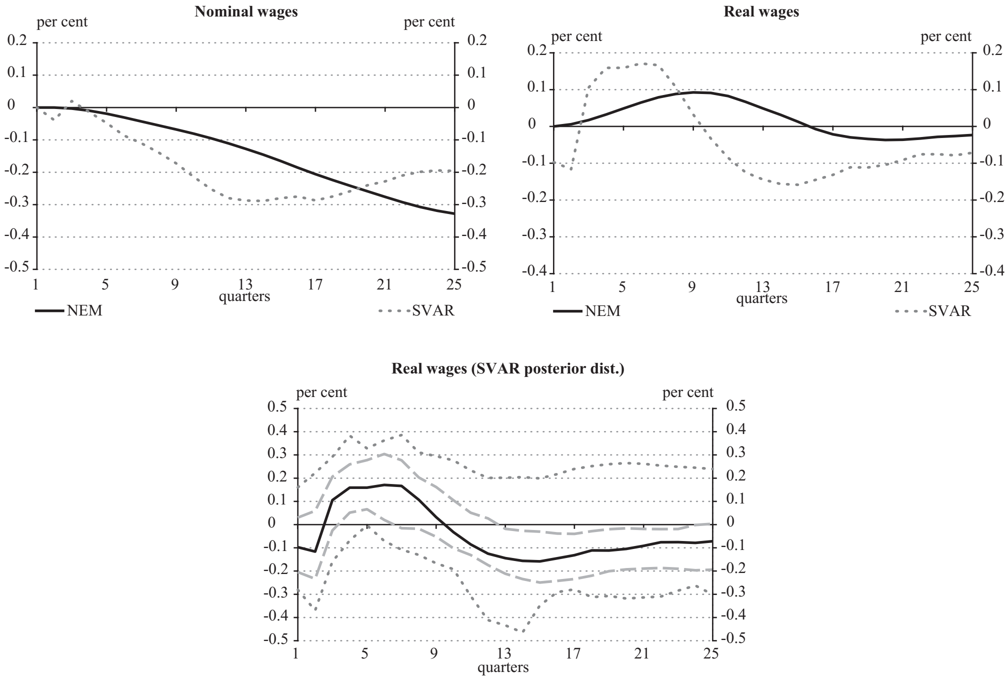


FIGURE 8.9 Responses to a one standard deviation tightening monetary policy shock (SVAR estimates; 6-variable model)



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

FIGURE 8.10 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 8.11 Decomposition of the user cost response in the NEM model

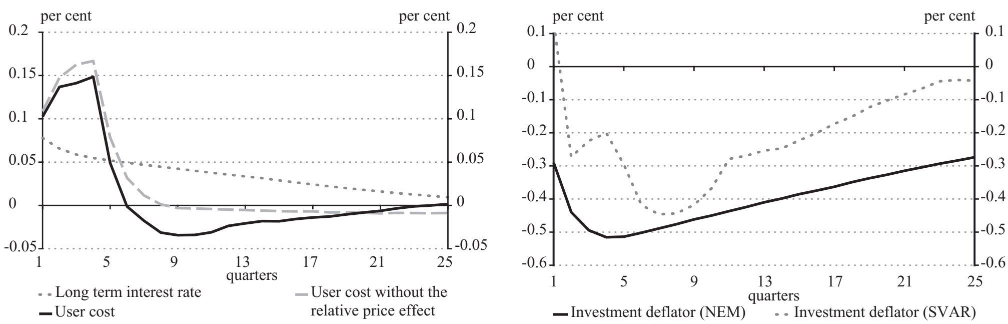


FIGURE 8.12 Responses of traded and non-traded goods prices to a one standard deviation tightening monetary policy shock (SVAR estimates)

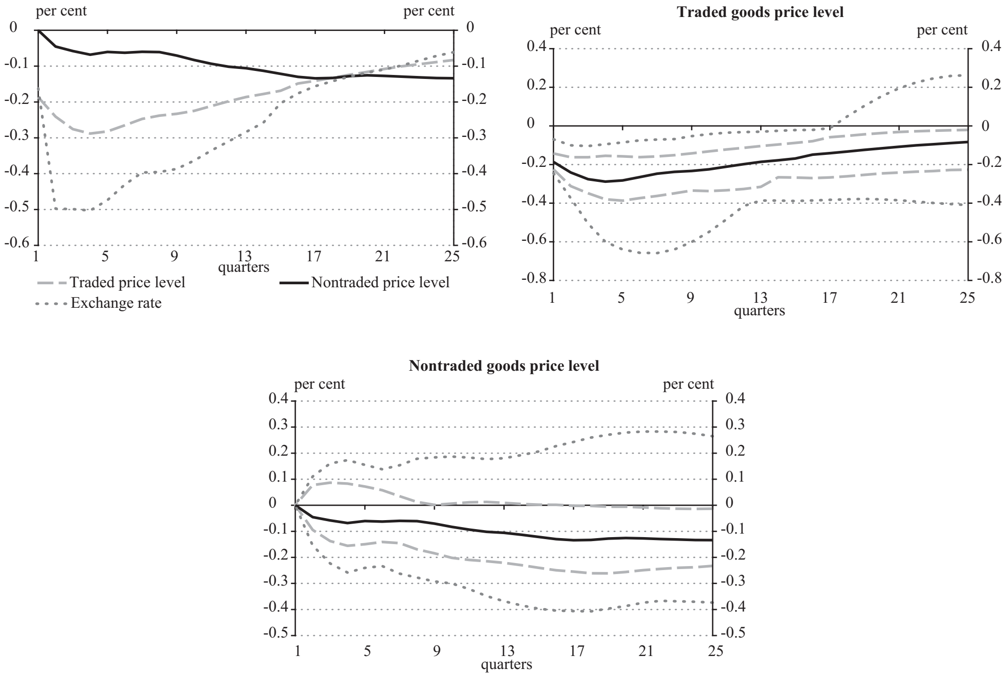
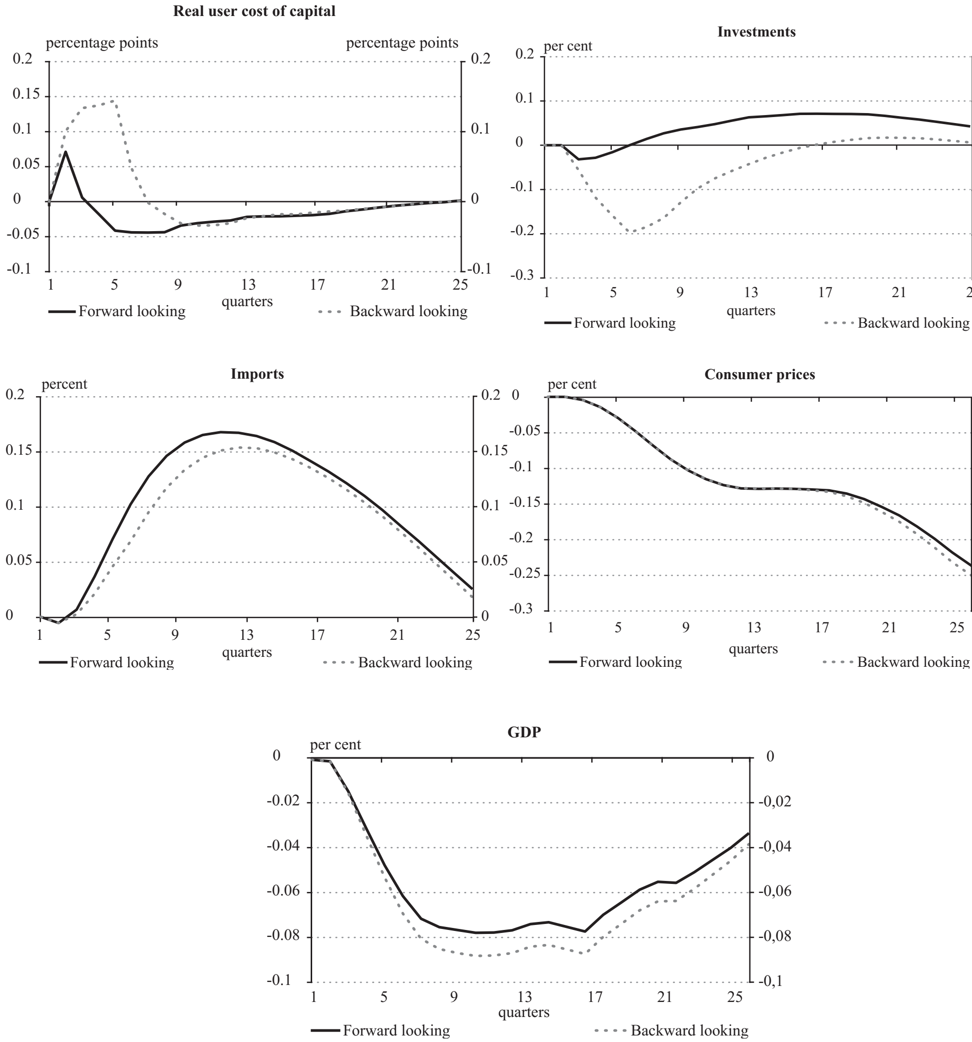


FIGURE 8.13 Different impulse responses for different user cost specifications in the NEM model



9. Investment behavior, user cost and monetary policy transmission – the case of Hungary

Gábor Kátay and Zoltán Wolf

9.1 Introduction

Understanding investment behavior has been an important topic on the economic agenda for some time. Empirical and theoretical models of business investment has been developing rapidly since the 1960's. The interest and need for understanding investment behavior emanated from various reasons. First, it is widely accepted that investment volatility is a prime contributor to aggregate output fluctuations. Also, anemic investment expenditures might signal various economic problems that might need solutions from economic policy makers. While having a clear picture of business investment characteristics is interesting on its own right, this paper seeks to empirically investigate corporate investment behavior in order to shed some light on how monetary impulses are transmitted to the Hungarian nonfinancial corporate sector, namely, to what extent and how business investment reacts to monetary policy decisions.

However, the implication of our approach is that it is not the existence of the traditional interest rate channel that is in focus of the paper. The traditional interest rate channel portrays the transmission of a money supply shock to investment and output (Mishkin, 1996). Rather, what we intend to gauge is to what extent changes in the user cost of capital – of which the interest rate is only a determinant – affect corporate investment behavior. It is of high relevance because being a small open economy, Hungary is widely viewed as a country where the main channel of transmission is the exchange rate and the role of mechanisms operating via the interest rate level is often downplayed.

Several previous studies have tried to capture the relationship between interest rates and investment but those using aggregate data have been rather unsuccessful in this respect. The ambiguity of results and the failure to detect significant linkages between variables can be attributed to a number of reasons. First, aggregation itself obscures effects that could otherwise be important at the firm level and, as a result, significant parameter estimates are rarely obtained on aggregate data. Second, the endogeneity of aggregate investment and the user cost of capital cause simple OLS parameter estimates to be inconsistent and good instruments are difficult to find at the aggregate level. Third, financial market imperfections are not taken into account explicitly in aggregate models of investment, yet their role is widely accepted in the literature.

The authors would like to acknowledge the critical and extensive comments from Gábor Kézdi of Central European University, and colleagues at the Economics Department of the Magyar Nemzeti Bank. All remaining errors and omissions are ours.

Our approach is micro-founded both in the sense of model development and estimation. Applying a micro-approach provides at least partial solutions to the problems mentioned above. Heterogeneity across firms provides for large variance of the observations, which can be exploited in the identification and estimation procedures. Also, endogeneity can be tackled since good instruments are easier to obtain at the firm level. Financial market imperfections are also incorporated and its effects are estimated.

This investigation has been carried out as part of a broader project within the Magyar Nemzeti Bank aimed at mapping various transmission mechanisms of monetary policy. In the current stage, we followed the line of research carried out recently within the Eurosystem Monetary Transmission Network for two reasons. First, results are derived in a simple but rigorous framework. Second, they are comparable to outcomes of previous European studies. Despite its deficiencies, we consider the simple neoclassical model applied in the paper as a good starting point in understanding corporate investment behavior in Hungary.

The paper is organized as follows. The next Section bestows our analysis in the investment literature and addresses some shortcomings to the neoclassical framework. We also touch on certain other issues that cannot directly be tackled within the framework though proved to be important. In Section 9.3 stylized facts are presented along with previous studies of capital formation in Hungary. The theoretical model is discussed and the optimization problem of a representative firm is solved in Section 9.4. Estimable specifications are derived in Section 9.5. Characteristics of our data and the way we constructed key variables are presented in Section 9.6. Our estimation strategy and results are exhibited in Section 9.7 and Section 9.8 concludes. Further data details are provided in the Appendix.

9.2 A brief overview of the investment literature

The goal of this selective overview is to bestow our analysis in the field and present the problems and findings of previous studies that led to the extant empirical frameworks in applied investment studies. We start with discussing the key assumptions and findings of the neoclassical framework because prior to Jorgenson's model (Jorgenson, 1963), capital demand was simply considered as a response to fluctuations of sales or output[1] and no rigorous framework existed for understanding investment behavior. The second part of the section deals with several additional issues which could not be addressed within the neoclassical framework.

The explicitly dynamic decision problem of the firm was introduced by (Jorgenson, 1963). Jorgenson showed that investment was driven by a 'shadow price' or implicit rent of one unit of capital service per period of time. He called this rent the *user cost of capital*. He derived the optimal capital stock under constant returns to scale and exogenously given output. To make the rate of investment determinate, the model was completed by a distributed lag function.

While there have been many different approaches within the neoclassical framework in understanding investment spending, several issues have repeatedly been encountered by researchers. We do not intend to present a complete list of questions related to the Jorgensonian model but concentrate on the main issues overviewing previous results.[2]

[1] This approach refers to the sales accelerator investment demand models.

[2] A comprehensive survey of investment studies up to the beginning of the nineties can be found in, for example, Chirinko 1993.

First, the assumption of continuous substitutability of the two input factors implies that the firm is able to adjust its capital stock, be it either investment or disinvestment. Thus, it can freely increase or decrease its capital stock until its marginal product is equal to its marginal cost. Rapid changes in the capital stock are not punished meaning that adjustment is costless in the model. As a consequence, the firm can achieve the optimal capital stock instantaneously and the decision problem becomes static.[3] The absence of adjustment costs has been challenged many times ever since the introduction of convex adjustment costs in the firm's optimization problem by (Gould, 1968). However, taking adjustment costs into account does not invalidate the Jorgenson condition, it only increases the marginal cost of capital and introduces dynamics in the optimization problem.

Second, the inharmonious treatment of delivery lags of investment and the immediate adjustment of optimal capital was another source of criticisms of the neoclassical framework. Empirical models usually assume that optimal capital is achieved according to an ADL process. Hence, dynamic adjustment is introduced in the model, but the particular form of this adjustment process does not follow from any of the key assumptions. Also, if optimal capital adjustment is instantaneous, the investment path generated by a delivery lag distribution may not be optimal. Therefore, the interpretation of lagged parameter estimates is ambiguous: it is not clear to what extent they describe adjustment or the effects of past expectations on current investment.

Finally, the treatment of expectations resulted in further criticism of the neoclassical model. A vast amount of effort has been made to develop and estimate models which explicitly tackle the problem highlighted by Robert Lucas in his seminal article (see, for example, Lucas-Prescott,1971; Muth, 1961 for early models). Nevertheless, its practical success and policy applicability have not been unambiguous. There are various arguments why the role of explicit models has had so little direct impact on current policy evaluations. First, as stated by Chirinko (1993), pp. 1900, in its original form the Lucas critique 'was user unfriendly' and 'cast in an unfamiliar technical language'. Also, explicit models performed rather poorly when confronted with data.

An alternative theory suggested by Tobin (1969) stated that the rate of investment is a function of the marginal *q-value*. Marginal q was defined as the ratio of market value of new additional investment goods to their replacement costs. If the firm can freely change its capital stock, adjustment takes place until the marginal q is equal to 1. In the estimated *q-model,* the effects of all lagged variables and the expectations of all relevant future variables are captured by q. Thus, the effects of delivery lags can be interpreted as the influence of lagged expectations of q on investment. While the neoclassical theory and the q theory had been considered as concurrent models for a considerable period of time, Hayashi (1982) demonstrated that, under certain assumptions, the two are equivalent. He also showed that if a firm is a price-taker and assuming constant returns to scale in both production and installation, then the (unobservable) marginal q is equal to the average q, which is the ratio of the market value of the firm to the replacement cost of its capital stock.

The investment literature of the last three decades has focused on two other important aspects of investment decisions. The first issue concerns the question as to what extent investment deci-

[3] This is why Hayashi (2000) has called the optimal policy as 'entirely myopic'. In other words, since capital is a variable factor input, the optimal policy is only to maximize the current return every moment in time without regard to the future.

sions are reversible. The second is related to the timing aspects of investment decisions, namely, how the realistic possibility of postponing current investment affects traditional investment decision rules. These issues could not been addressed within the neoclassical framework and gave rise to the 'orthodox theory of investment', also called as 'real option approach to investment'.

Costs of capital adjustment are augmented when capital can be sold only at a price considerably lower than its purchase price or cannot be sold at all. This phenomenon is referred to as the irreversibility of investment. Pindyck (1991) sets out two main arguments. First, capital is firm or at least industry specific in most cases and it is not likely that there is a liquid secondary market at hand. Apart from limited demand, the resale price of capital is also negatively affected by the fact that the potential buyer is not likely to use the acquired asset in the same market conditions. If the firm wants to sell its capital goods, the buyer is likely to face the same market conditions in output markets and hence, it might not be worth to buy the asset at all. The difference between the resale price and the purchase price of capital can also be significantly negative if capital is not firm or industry specific. This difference is generated by asymmetric information between the seller and the buyer and is referred to as 'lemon price'-effect after Akerlof (1970).[4] Because of all these, investment costs are sunk for the firm and do matter in the optimization problem.

The above problems associated with the irreversibility of investment rise only in the presence of uncertainty. In the standard neoclassical framework it is assumed that firms are able to accurately estimate future output prices, investment prices, costs and interest rates.[5] In an uncertain environment, the possibility to postpone investment becomes valuable. The additional value is generated by the possibility to wait for new information to arrive. Postponing investment and waiting provides the firm with a call option of which the price it takes into account when deciding about investment. If the firm invests today, it loses the option of investing tomorrow and the opportunity cost of investing today increases the cost of investment. Pindyck (1991) pointed out that irreversibility, uncertainty and the possibility to wait together call for an amendment of the 'naive net present value' rule. That is, in optimum, the marginal product of capital has to be greater than its marginal cost. Uncertainty increases the value of waiting (call option) and decreases the propensity to invest now. Hence, stability and predictability might be as – or even more – important investment incentives as taxes or interest rates.

Abel et al. (1996) relaxes the total irreversibility assumption. In their simple model the firm can resell its capital later but at a price that is not known at time of the resale decision (expandability). This provides for another possibility called the put option. The option to sell later, which is associated with the partial irreversibility case, increases the propensity to invest today. In the end, the optimal decision to invest is determined by these two options.

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[4] A difference between the purchase and resale price of capital goods might arise even if these problems are not serious in factor markets. If the transaction costs of selling capital goods are significant or comparable to the purchase price, it might not be worth selling capital goods at all.

[5] Uncertainty in a broader sense does appear in some early neoclassical models. Yet, uncertainty is associated with the explicit modeling of expectations in these or, to be more accurate, with the inability to properly model these expectations. In the context of our overview, we refer to the uncertainty emerging from the probabilistic nature of future outcomes of variables which are relevant for the optimizing firm. It is also important in this context that this is losely associated with the irreversibility of the investment.

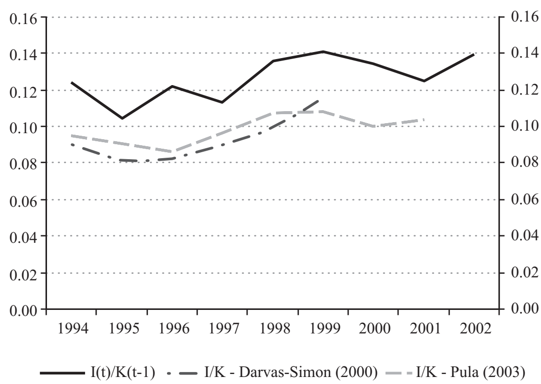
Adjustment costs, uncertainty, irreversibility and expandability are not explicit in our model. One might argue that this makes our analysis very simplified and unrealistic but the neoclassical framework is a clear and rigorous starting point in understanding corporate investment behavior. Also, it is relatively easy to derive empirically testable hypotheses in this framework. Moreover, the recent research in the European Monetary Transmission Network used similar framework so comparing our conclusions to previous results is straightforward.

9.3 Business cycle and investment in Hungary – Stylized facts

Previous studies of investment and capital

To our knowledge, two former investigations carried out capital stock estimation on Hungarian data. Both studies of capital formation produced similar conclusions both in qualitative and quantitative terms (Figure 9.1). Pula (2003) estimated aggregate investment (corporate plus public) series using Central Statistics Office (CSO) survey data. He used CSO data only on investments put into operation[6] in his calculations. Our calculation approach is similar to that of Pula (2003) in the sense that we derive investment using changes in balance sheet capital data, that is, we accounted for only activated investment.

Figure 9.1 Investment rate series of previous studies



However, there are two differences that may account for the gap between our series and that of Pula (2003). First, his dataset consisted of firms employing more than 5 persons on average while our dataset is somewhat broader as will be seen in the dataset description. Second, CSO surveys fixed capital formation which covers the purchase and production of new tangible assets. On the contrary, we used balance sheet data on intangibles as well. These differences might explain why our investment rate is higher. Yet, despite differences, the two imply similar conclusions regarding both the level and the dynamics of investment.

[6] In CSO terminology, investments put into operation are investments brought into proper use, as well as their part independently put into use.

The other study by Darvas-Simon (2000) produced aggregate investment broadly similar to that of Pula. However, they used investment[7] data instead of investments put into operation. Further discussion of previous results can be found in Pula (2003).

Determinants of Hungarian investment

As regards macroeconomic conditions, the first few years of the 1990's was characterized with volatile inflation, real interest rates and an appreciating real exchange rate. The macroeconomic environment was rather unstable. This instability emanated largely from the structural changes which were induced by the transition process. To avoid loss of competitiveness stemming from adjustments in market prices, policy makers recurrently decided to realign the nominal exchange rate, which, in turn fuelled inflation expectations. Without these exchange rate adjustments, however, the huge current account deficit inherited from the 1980's would have caused the already heavy debt burden to increase further. Also, economic policy faced pressing reforms on the fiscal side. Against this backdrop came the comprehensive economic reform package in 1995, which eliminated economic imbalances and promoted macroeconomic consolidation afterwards. As an immediate result of the measures, both the budget and the current account deficit halved, which obviously was a favorable consequence. However, economic growth and investment dampened at the same time.

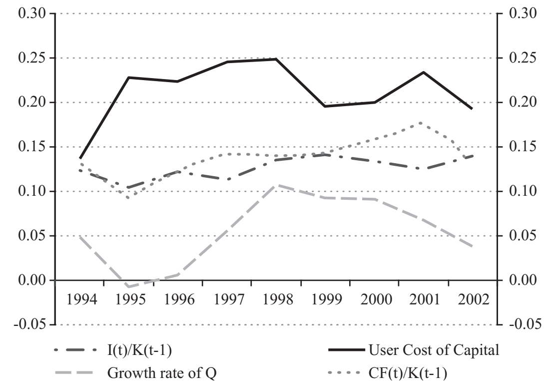
In light of these events it is not surprising that investment activity was more intense in the second half of the period under investigation. The onset of the 1990's was the very time of the transition to market economy when firms were driven to remarkably revaluate their capital stock as existing capital goods inherited from the planned economy had become obsolete.

This is reflected in the fact that the investment rate peaked after the middle 1990's. In these years (1997-1998), foreign direct investment culminated, pumping heavy inflows of fresh capital to the Hungarian corporate sector and fuelling buoyant investment activity.

From 1999 onwards, the slightly decreasing but still stable investment rate suggests companies might begin to foresee their deteriorating profit opportunities with the nearing recession and they gradually began to refrain from actively investing in new capital goods and, accordingly, rather accumulated cash-flow. This can be seen from the increasing cash-flow-to-capital ratio. However, the increase in the investment rate in 2002 supports the view that – although some slack in economic activity could still be felt that year – Hungarian firms engaged in heavy investment at the end of 2002. These developments in the business cycle can be also tracked down looking at the growth rate of output: the decrease in average output in 1995 was followed by rapid recovery in the next three years; then, after another two years of high growth (1998-1999), output grew at a lower pace in 2001-2002.

[7] Investment comprises new acquisition, establishment, production of new tangible assets, the expansion, change of the function, conversion, reconstruction of existing tangible assets, the substitution of which were used up, with the exclusion of cultivation, maintenance and renewal of the natural forests. The continuous maintenance and repair of the tangible are not part of investment.

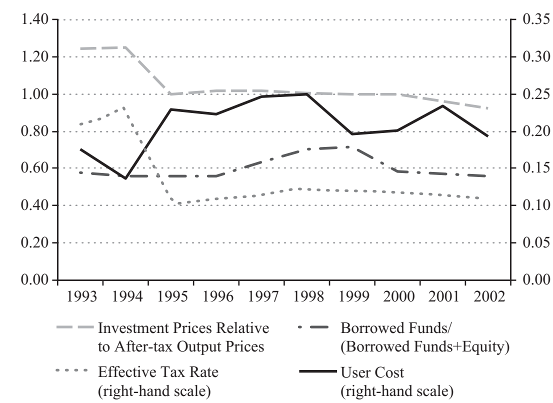
Figure 9.2 Investment, User Cost, Cash Flow and Growth of Sales*



** To replicate macro data, we used K(t-1) as weights to calculate averages of I(t)/K(t-1) and CF(t)/K(t-1). For the growth rate of Q, weights are Q(t-1) values. Since it is not evident what variable one should use calculating a weighted average of the user cost, we present hereafter the unweighted averages of the user cost of capital and its components.*

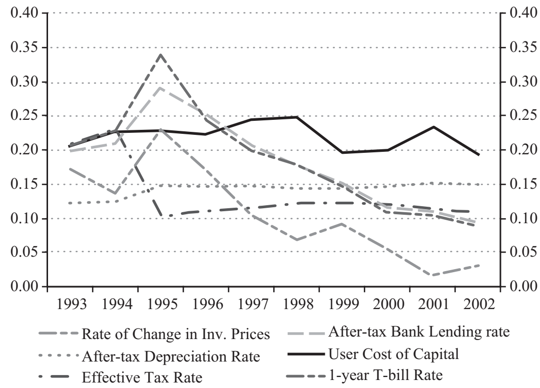
As we will see in Section 9.4, theoretical results enforce the intuition that user cost developments are primary determinants of investment behavior. Therefore, we found it instructive to analyze how each of its components evolved in our sample period. Several findings emerge when breaking down the user cost of capital. First, the average cost of capital exhibited moderate volatility throughout the period. In 1993-94, it fell slightly below 15%. However, already in the first year of the macroeconomic stabilization (1995), when fiscal reforms and a new monetary regime[8] were introduced, the user cost increased to over 20% and went down under 20% only at the end of the nineties and in 2002. Driving forces behind these movements are analyzed below (see Figure 9.3 and Figure 9.4).

Figure 9.3 Average User Cost of Capital and its after-tax components I



[8] Crawling peg exchange rate regime with a one-off initial devaluation of the national currency (9%).

Figure 9.4 Average User Cost of Capital and its after-tax components II



The most obvious effect on the cost of capital was put out by changes in the interest rate level.[9] 1994 saw a rise in the interest rate level but this rise was not reflected in the cost of capital because other factors, e.g. investment price movements, counterbalanced the elevating effect of interest rates. However, interest rate effects were prevalent in 1995 when a sharp rise in the interest rate level increased the cost of capital. From 1996 on, the continuously declining interest rates permanently pushed the user cost of capital downwards. The only exception was 2001 when rates remained stable.

Another important factor determining the costs of capital holders is investment price inflation. Investment prices affect capital owners via two terms. The first is the rate of change in investment prices, the other is the investment price level relative to the output price level. As investment prices increase, capital owners realize these price gains. As prices decrease, they suffer a loss on their assets. Investment price inflation showed a rather smooth path during the period under investigation. Investment price growth accelerated in the first two years of our sample period and have been decreasing ever since with the exception of 1999. The continuous decline might be explained by the general downward inflation trend in the economy. The deceleration in investment price inflation had an elevating effect on the cost of capital, that is, the slower upward investment price movements from the middle 1990's ever reduced the price-gains capital goods holders realized throughout the period. In 1999, however, a temporary price hike took place reinforcing the downward pressure falling interest rates already put on the user cost. These two effects seem to have been strong enough to be apparent in the diminishing average cost of capital in 1999.

The price of investment relative to output also plays a role. It shows how dear investment goods are compared to final goods. This relative price term exhibited a slowly abating pattern in the period under review except that it fell sharply in 1995. This slightly downward trend exerted a diminishing effect on the user cost throughout the whole period.

Changes in corporate tax rates also play a role in user cost developments. Tax changes may influence the user cost via various mechanisms. First, a tax cut increases the after-tax output price, which in turn makes investment cheaper relative to the (after-tax) value of output. This

[9] Interest rates are generally deemed as the opportunity cost of investing in physical capital goods.

implies that a tax cut in itself makes investment more attractive. Second, a tax cut reduces the tax savings on paid interest leading to higher after-tax interest rates and, therefore, higher opportunity cost of investment. Third, as depreciation is also tax-deductible, a cut in corporate taxes reduces tax advantages of the depreciation write-off bringing about a higher after-tax depreciation rate. Since losses in the value of capital assets is borne by capital owners, a rise in the depreciation rate directly augments the cost of capital. Hungarian corporate tax rates were cut two times in the 1990's. The first, four percentage point, cut took place 1994 (40% to 36%). This change was not reflected in the average effective tax rate because of the effects of various tax credits and because the rate of companies unaffected by the tax cut – that is, enjoying total tax exemption – was quite high throughout the decade (more than 30%). However, the more drastic shift in 1995 halving the rate to 18% had a measurable effect. The effective tax rate remained stable in the rest of the decade.

9.4 Theoretical framework

The neoclassical model of investment

The decision problem we exhibit is fairly standard in the literature[10]. The representative firm chooses capital, labor, and financing structure over an infinite horizon. We assume a CES production function where the two inputs, capital and labor can be continuously substituted. A general form of this technology can be written as

$$Q_{it} = F\left(K_{it}, L_{it}\right) = A_{it}\left[\alpha K_{it}^{\frac{\sigma-1}{\sigma}} + \left(1-\alpha\right) L_{it}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}\upsilon}, \tag{1}$$

where Q_{it} is output (value added), K_{it} is capital stock, L_{it} is employment, A_{it} is the Solow residual, α and $(1-\alpha)$ are shares of the two inputs, σ is the elasticity of substitution between capital and labor υ is the degree of homogeneity or the volumen elasticity. In the case of homogenous technology this latter parameter is equal to unity but we do not restrict υ to be unity. The production function is twicely continuously differentiable with

$$F_K(t) > 0, F_L(t) > 0, F_{KK}(t) < 0 \text{ and } F_{LL}(t) < 0 \quad .$$

That is, the function is strictly monotonous in both capital and labor with decreasing returns to scale in both factors.

Firm i chooses the two inputs and financing structure in time t so as to maximize the present value of future profits:

[10] Apparently, there are differences across studies in terms of the objective function and the budget constraint. The two most standard objective functions are the market value of the firm, that is, the value of shares and the firm's profit function. They are essentially lead to the same results as profit determines the value of the firm. Certain studies specify these functions in continuous-time, while others exhibit discrete-time versions of the problem. There are also differences as to what components enter the profit function. Some studies incorporate the effects of dividends or investment tax credit, some others do not. Nevertheless, these studies model investment on a very similar theoretical basis.

$$\max W_{it} = \int_{t=0}^{\infty} e^{\left(\int_{p=0}^{t} r_p dp\right)} \pi_{it} dt \tag{2}$$

where W_{it} is the market value of the firm, B_{it} is the value of external funds, r_t is the market interest rate or discount rate and γ_{it} is profits. The problem has two limiting constraints.

The first constraint is the budget constraint of the firm stating that expenses can exceed revenues by the amount of borrowed funds:

$$\pi_{it} = (1-u_{it})[p_{st}F(K_{it}, L_{it}) - w_{it}L_{it} - i_{it}B_{it}] + u_{it}\delta_{it}p_{st}^{I}K_{it} + \dot{B}_{it} - p_{st}^{I}I_{it} \tag{3}$$

where u_{it} is the effective tax rate, p_{st} is the price of output, w_{it} is the price of unit of labor (i.e. wage cost), i_{it} is the interest paid on outstanding bank credits, p^{I}_{st} is the industry specific investment price index, δ_{it} is the rate of depreciation and I_{it} is the investment volumen. As it can be seen from the above formula, depreciation and paid interest is tax deductible in the model.

We note here that the interest rate is assumed to be positively correlated to the amount of funds borrowed. This is because higher amount of funds borrowed increases the risk of default and banks expect higher compensation for this increased risk in the form of higher interest rates. However, it is negatively correlated to the amount of capital since a firm with relatively high proportion of valuable assets is less likely to be non performing on its liabilities. In what follows, we assume that the spread charged by banks (risk premium) for the increased default risk is simply a function of the firms' leverage:

$$i_{it} = i_{it}\left(\frac{B_{it}}{p_{st}^{I}K_{it}}\right), \text{ where } i_{it}' > 0. \tag{4}$$

For the optimal debt/capital ratio to be unique, a sufficient condition is $2i_{it}' + \frac{B_{it}}{p_{st}^{I}K} i_{it}'' > 0$.

The second constraint is the capital accumulation equation[11]:

$$\dot{K}_{it} = I_{it} - \delta_{it}K_{it} \tag{5}$$

We note here that assumptions about the rate of depreciation have important consequences with respect to the final specifications of the model. In the literature it is common to assume that the rate of depreciation is constant over time and across firms. However, many critiques called this hypothesis into question (e.g. Chirinko, 1993). The constant depreciation hypothesis is likely to be erroneous also in the case of Hungary. The modernization of the production technologies and the incursion of ICT in the production made existing capital assets less and less valuable and implied continuously increasing depreciation rate during the catching up process. These considerations call for a depreciation rate which varies over time. By the same token, it can be argued that it is unlikely that capital assets in different industries are subject to the same rate of depreciation. It is more reasonable to assume that this rate is heterogenous across industries or firms. Drawing

[11] We assume that the accounting rate of depreciation is equal to the economic rate of depreciation.

on these, we assume that the rate of depreciation is both time and firm specific as shown in equations (3) and (5).[12]

Optimality conditions

Substituting eq. (3) and eq. (5) into eq. (2) and differentiating with respect to the decision variables we arrive at the first order necessary conditions (FONC). The FONC for the external funds gives the following equation:

$$r_t - (1-u_{it})i_{it} = (1-u_{it})\frac{B_{it}}{p_{si}^I K_{it}} i_{it}' \tag{6}$$

This condition states that the optimal leverage is a result of counterweighting tax advantages of taking on more credit against the increasing interest burden caused by higher leverage. Since the right hand side of the equation is *per definitionem* positive, the after tax effective interest rate is smaller than the discount rate in optimum. As we will see later, the cost of capital is determined by the weighted average of these two latter interest rates. Hence, the access to bank credit and the related tax advantages (tax-deductibility of interest paid) reduce the effective cost of investment and thereby increase the demand for capital. The FONC for the capital stock gives

$$(1-u_{it})p_{st}F_K(K_{it},L_{it}) = p_{st}^I r_t + p_{st}^I \delta_{it}(1-u_{it}) - \dot{p}_{st}^I + (1-u_{it})\frac{\partial i_{it}}{\partial K_{it}} B_{it} \tag{7}$$

After rearranging and plugging eq. (6) into eq. (7), the Jorgenson condition is obtained, which states that, in optimum, the marginal product of capital is equal to its marginal cost, that is, the user cost:

$$F_K(K_{it},L_{it}) = UC_{it} \tag{8}$$

where

$$UC_{it} = \frac{p_{st}^I}{p_{st}(1-u_{it})}\left[\left(1-\frac{B_{it}}{p_{st}^I K_{it}}\right)r_t + \left(\frac{B_{it}}{p_{st}^I K_{it}}\right)(1-u_{it})i_{it} - \frac{\dot{p}_{st}^I}{p_{st}^I} + (1-u_{it})\delta_{it}\right] \tag{9}$$

If we abstract from borrowing possibilities and taxes $(B_{it} = 0,\ u_{it} = 0)$, the formula for the user cost becomes the one published by Hall-Jorgenson (1967). Taking borrowing possibilities and tax aspects of the optimization into account, one arrives at the definition of Hayashi (2000).

[12] Nevertheless, our derivations are invariant to this assumption. It only plays a role when deriving empirically estimable equations.

Effects of monetary policy on investment

In this model, economic policy exerts its influence on corporate investment behavior via the user cost of capital. Tax policies are captured by the firm specific effective tax rate, which directly influences the cost of capital. Monetary policy, however, does not have a direct effect on the user cost. To highlight the role of monetary policy in this model, we can think of the mechanism as a three step process. In this process, each step is embodied by a partial elasticity parameter. We have to stress here that this decomposition is valid only if we stipulate in each step the 'all-else-equal' condition. That is, if we consider the *ceteris paribus* effects of changes in variables. Minding this, we can write the decomposition as

$$\varepsilon_m^K = \varepsilon_{UC}^K \times \varepsilon_r^{UC} \times \varepsilon_m^r ,$$

where ε_m^K is the elasticity of the capital stock with respect to the monetary policy interest rate. This is what concerns monetary policy makers at the end of the day. ε_{UC}^K is the elasticity of the capital stock with respect to the user cost of capital, ε_r^{UC} is the elasticity of the user cost with respect to the market interest rate and ε_m^r is the elasticity of the market interest rate with respect to the policy interest rate.

The mechanism via which monetary policy affects the capital stock is then straightforward. First, a change in the policy rate causes market rates to change, which in turn feeds into the user cost of capital. However, a few considerations are in order here.

First, it is not short but long term rates that determine the cost of capital since investment-related credits are typically of long maturity. Hence, long interest rates are taken into account in the user cost of capital. Second, it is not necessarily true that short term policy rate changes are spread across all market interest rates and maturities. According to the expectation hypothesis of the yield curve, long term interest rates are averages of expected values of future short term rates. If monetary policy and economic policy in general is credible then short rate changes are not necessarily reflected in long term interest rates. A preemptive monetary tightening intended to prevent the economy from overheating might leave long rates unchanged just because it makes future tightening unnecessary. This is reflected in unchanged expectations of future interest rates and, as a consequence, investment might not react to a tightening just because the relevant interest rates have not changed. In this setup, one would wrongly conclude that monetary policy cannot curb investment activity. Third, if firms finance investment directly from capital markets via, e.g., bond issuance, then monetary impulses might be transmitted to market interest rates more efficiently compared to a situation when the primary source of financing investment is provided by banks. In the latter case, if banks are not competing heavily to finance firms, they are less motivated to reduce the price of credit in the case of a loosening. This is the case also, when the key determinant of credit supply is not the central bank.[13]

In the next step, long term interest rates influence the user cost of capital. Since interest rates are part of the user cost, the *direct effect* of interest rates on the user cost can be derived analytically from the user cost definition. We emphasize that this effect corresponds to the elasticity ε_r^{UC}

[13] One may think of, for example, to capital inflow from foreign investors here.

presented above if and only if changes in interest rates do not affect other variables in the user cost definition. Assuming that banks adjust permanently their lending interest rates by the same percentage as market rates change, the direct effect on firm's user cost of one percent change in long term interest rate ($\breve{\varepsilon}_r^{UC}$) is nothing else than the weight of interest rates in the user cost definition, that is:

$$\breve{\varepsilon}_r^{UC} = \frac{\frac{p^I}{p(1-u)}\left[\left(1-\frac{B}{p^I K}\right)r+\left(\frac{B}{p^I K}\right)(1-u)i\right]}{UC} \tag{10}$$

This is how the total effect of changes in interest rates on the user cost is generally simplified in the empirical investment literature (see for example Chatelain et al., 2001 or Butzen-Fuss-Vermeulen, 2001). However, the elasticity of user cost w.r.t. market rates depends on other components of the user cost as well. These are not present in the numerator above. Namely, it is the sign and the magnitude of $\frac{p^I}{(1-u)p}\left[(1-u)\delta-\frac{\dot{p}^I}{p^I}\right]$ that matters. This suggest that, holding all other variables constant, higher expected investment price inflation implies higher user cost response to market rate change. Hence, if expected investment price inflation exceeds the after-tax depreciation rate, the fraction at stake is on average higher than 1, which should be the case in most countries with high inflation.

The user cost elasticity w.r.t. market rates can be simplified to the expression (10) only if other variables in the user cost definition are kept unchanged. While this assumption is reasonable in the short run, it is certainly fictitious and unrealistic in the long run. First of all, changes in interest rates may change the relative costs of financing new acquisitions by debt or equity. According to eq. (4), the firm's leverage is a function of the difference between the market interest rate and the after tax interest rate. If this latter expression changes, the firm might readjust its debt/equity ratio in the long run so as to regain to optimum. Thus, market rates affect firms' leverage, which in turn affect apparent borrowing rates and hence firms' user cost. The elasticity of user cost with respect to the market rate is thus lower than it would be without the possibility of choosing the financing structure of new investment. In other words, the ability to adjust its leverage gives the firm the ability to attenuate interest rate shocks. Secondly, interest rate changes may influence investment price inflation and also the relative price of investment to output prices. These effects are much more difficult to quantify and are far beyond the focus of this paper.

In the last step, firms facing different user cost outcomes react and adjust their capital stock accordingly. The aim of the empirical models presented below is to gauge this phase. Estimating ε_{UC}^{K} answers the question how responsive is the stock of capital to changes in the user cost of capital.

The specifications presented hereafter can be used to capture effects of financial market imperfections, which give rise to an additional monetary transmission channel. Before presenting what these effects stem from and how they are measured, we describe how we derived empirically feasible equations from theoretical ones.

9.5 Empirical models

With the optimality conditions at hand, one needs empirically feasible equations. One way to obtain estimable specifications is to substitute the partial derivative of the CES function in eq. (1)

with respect to capital into eq. (8) and take logs (small letters represent logs). After rearranging, the following long-run demand for capital is obtained:

$$k_{it} = \left(\sigma + \frac{1-\sigma}{\upsilon}\right) q_{it} - \sigma uc_{it} + \sigma \log(\upsilon\alpha) + \frac{\sigma - 1}{\upsilon} \log(A_{it}) + \varepsilon_{it} \tag{11}$$

To be able to perform econometric tests on our model we assumed that the Solow residual can be decomposed into a firm specific and a time specific term: $A_{it} = A_i^{\kappa 1} A_t^{\kappa 2}$. In the case of equation (11) this decomposition means that the last two terms of the right hand side *(σlog ($\upsilon\alpha$) + log(A_{it}) (σ–1) / υ)* can be broken down to an idiosyncratic fixed effect η_i and a time specific effect η_t.

Obviously, the long-run optimum stock of capital k_{it} is unobservable, hence we have to characterize the adjustment process of capital. We assume, following others (e.g. Angeloni et al., 2002; Chatelain and Tiomo, 2001; Valderrama, 2001), that capital adjustment can be described using its own previous values and the lags of the user cost and the output. The autoregressive distributed lag equation derived in this manner serves as the basis of our econometric analysis in which *(p,q)* are the parameters of the ADL specification:

$$k_{it} = \sum_{p=1}^{p} \omega_p k_{i,t-p} + \sum_{q=1}^{q} \phi_q q_{i,t-q} + \sum_{q=1}^{q} \sigma_q uc_{i,t-q} + \eta_i + \eta_t + \varepsilon_{it} \tag{12}$$

Using this equation, one can derive the long run parameters of the user cost and output[14]:

$$\sigma_{LT} = \frac{\sum_{q=1}^{q} \sigma_q}{1 - \sum_{p=1}^{p} \omega_p} \text{ and } \phi_{LT} = \frac{\sum_{q=1}^{q} \phi_q}{1 - \sum_{p=1}^{p} \omega_p} \tag{13}$$

Introducing long run parameters disentangles the apparent inconsistency between the optimal capital demand and ADL specifications. Neoclassical theory assumed instantaneous adjustment of the optimal capital stock. This obviously contradicts to specifying an ADL adjustment process in empirical equations. Assuming that capital adjustment can be characterized by its own previous values and lags of other variables points to the presumption that frictions in factor markets are at work. While immediate capital adjustment is clearly an unrealistic assumption, supposing frictionless markets over the long run, or rather, assuming firms are able to adjust their capital to the new optimum level after several years, may be more plausible. This implies, in turn, that long run parameter estimates can be paralleled with long run frictionlessness in factor markets

[14] We note here that eq. (12) is a reduced form of some underlying model of the capital stock. Hence, in this specification partial elasticities and, also, long-run parameters embody the effects of both expectations and technology parameters that are not explicitly specified in the model. Therefore, one should exercise caution when interpreting parameter estimates as pure adjustment characteristics. Despite the problem has long been known, it is not yet a wide-spread practice in applied investment research to tackle these issues explicitly (see, for example, Abel and Blanchard, 1986; Chirinko, 1993 or Angeloni et al., 2002). Since we intend to produce parameter estimates that are derived in a comparable framework in order to evaluate our results with respect to previous European studies of investment, we did not address these issues in this paper. We refer the interested reader to the Lucas crtitique mentioned in the model overview and the survey of Chirinko (1993).

because these parameters embody effects after adjustment in volumes and prices have taken place. Hence, long run parameter estimates can be closely related to those of the capital demand equation (11).

In this framework, an additional channel of monetary policy transmission can be captured. This channel is generated by financial market frictions and is called the credit channel in the investment literature (see e.g. Mishkin, 1996).

Studies of the credit channel and, as part of it, the balance sheet channel, are based on the observation that the classic hypothesis of Modigliani and Miller is not valid. That is, external and internal sources of funds are not perfect substitutes for the firm. In this view a wedge arises between the cost of these funds in capital markets because of market imperfections such as asymmetric information, agency problems, moral hazard and adverse selection. These imperfections bring about a transmission channel which traditional models could not capture. At the centre of these arguments is the statement that a firm with a smaller net worth is more exposed to the effects of adverse selection and moral hazard and the supply of external funds is inelastic. This is because the only information available for creditors to judge whether a firm is a timely and reliably solvent borrower is its net worth. A firm with a smaller net worth is less able to cover its liabilities in the event of a default and, as a consequence, creditors are less willing to provide financing. Thus, asymmetric information in financial markets make certain firms financially constrained. The moral hazard aspect of asymmetric information, in turn, is highlighted by the owners willingness to take on risks. When their share in the firm is smaller the potential loss they face is smaller and hence, their propensity to launch riskier investment projects is greater. Riskier projects are obviously more likely to fail and therefore, if the financial leverage of a firm increases it causes creditors propensity to finance to dampen. Thus, asymmetric information drives a wedge between the firm specific interest rate and the market rate. In other words, firms find it cheaper to invest out of retained earnings than out of borrowed funds. This implies, in turn, that those investment projects yielding the market rate will not be executed because the cost of financing in these cases is greater than the internal rate of return of the project. This is an important implication since, absent information asymmetries, these models would be economically justified to execute. Put it another way, the understanding the effects of these phenomena is important because they have serious economic consequences: their existence may lead to the misallocation of resources.

In this framework, monetary policy can influence firms' balance sheets in several ways. A monetary loosening, for example, causes share prices to rise which directly diminishes the effects of the above mentioned information problems. The approach of measuring the effect monetary policy exerts on firms' balance sheet directly is called the financial accelerator approach. This investigates whether weak balance sheets of firms amplify monetary policy shocks on firm spending (see Vermeulen, 2000 for an empirical investigation).

Mishkin (1996) puts forward an argument also for indirect monetary policy effects in this context. He argues that monetary policy exerts its influence on investment via the price level and inflation. Since credit agreements are contracted in nominals, a shock in inflation diminishes the real burden borne by borrowers. However, the real value of assets of the borrower does not diminish because it is determined by supply side factors. Moreover, changes in the nominal interest rate modifies firms' cash-flow having direct effects on investment for the financially constrained firms.

Since the publication of the seminal paper of Fazzari et al. (1988) it is usual to control for these financial constrains by entering cash-flow in the regressions. (Fazzari et al., 1988) originally applied cash-flow as a proxy for the firms' own funds to control for its effects on investment. However, using cash flow as a proxy for own funds in equations similar to might give rise to multicollinearity, since cash-flow is correlated to future profits and future profitability (Chatelain et al., 2001; Vermeulen, 2000). Yet, extant firm-level databases' cross-section dimension provides for a huge amount of observations which mitigates the multicollinearity problem.

The cash-flow augmented equation is:

$$k_{it} = \sum_{p=1}^{p} \omega_p k_{i,t-p} + \sum_{q=1}^{q} \phi_q q_{i,t-q} + \sum_{q=1}^{q} \sigma_q uc_{i,t-q} + \sum_{q=1}^{q} \frac{CF_{i,t-q}}{p^I_{s,t-q} K_{i,t-q-1}} + \eta_i + \eta_t + \varepsilon_{it} \qquad (14)$$

One might argue that this specification is not a proper one because it is not the control variable – investment or the investment ratio –, but the optimal capital stock that enters eq. (14). To have the control variable $(I_{it} / K_{i,t-1})$ in the empirical model (14) we use $\Delta k_{it} = ln (I_{it} / K_{i,t-1} - \delta_{i,t} + 1)$, which can be calculated from the discrete version of the capital accumulation equation (5). Approximating the right hand side of this latter equation with its first order Taylor series, we arrive at

$$\Delta k_{it} = \frac{I_{it}}{K_{i,t-1}} - \delta_{it}$$

This equation says that capital stock changes are an overall result of investment and depreciation. When investment is equal to the loss of value in the capital stock the real capital stock does not change and there is no net effect of investment. This is usually called replacement investment. If investment is greater (lower) than the depreciation value, the real capital stock increases (decreases) and investment has a positive (negative) net effect on the capital stock. Let $\tilde{I}_{it}$ denote replacement investment and $\hat{I}_{it}$ net investment. Then, the overall investment is $I_{it} = \tilde{I}_{it} + \hat{I}_{it}$.

This distinction between replacement investment and net investment is quite common in the literature (Chirinko, 1993; Letterie and Pfann, 2003). However it is not so common to address this distinction explicitly in estimated equations. To be more accurate, equation (14) specifies net changes in the real capital stock, while equations explaining the ratio of investment with respect to capital typically try to explain overall investment. This can be done using the simplifying assumption of constant rate of depreciation. However, if this latter condition does not seem to hold, which is likely in our case (see considerations after the capital accumulation equation in Section), the investment rate specification should be modified.

To see this, suppose that capital adjusts according to an ADL(2,1) structure. Subtracting $k_{i,t-1}$ from both sides of equation (14) and using the previous relationships $\Delta k_{it} = \frac{I_{it}}{K_{i,t-1}} - \delta_{it}$ and and knowing that $\frac{\tilde{I}_{it}}{K_{i,t-1}} = \delta_{it}$, we have that

$$\frac{\hat{I}_{it}}{K_{i,t-1}} = (\omega_1 - 1)\frac{\hat{I}_{it-1}}{K_{i,t-2}} + (\omega_1 + \omega_2 - 1)k_{i,t-2} + \sum_{q=1}^{q}\phi_q q_{i,t-q} + \sum_{q=1}^{q}\sigma_q uc_{i,t-q} + \sum_{q=1}^{q}\frac{CF_{i,t-q}}{p^I_{s,t-q}K_{i,t-q-1}} + \eta_i + \eta_t + \varepsilon_{it} \tag{15}$$

As we have already mentioned, most of the studies assume that the rate of depreciation, that is, the rate of replacement investment, is constant. In this case, net investment rate could be replaced by overall investment rate in eq. (15) and standard estimation methods can be applied using $\frac{I_{it}}{K_{i,t-1}}$ only, as the constant depreciation rate cancels out due to differencing. This is done by, for example, Chatelain-Tiomo (2001). If the constant depreciation assumption does not seem to hold, that is, the depreciation rate depends on both i and t, the two are not equivalent.

Another specification we estimated is a modified version of eq. (15). This equation is obtained by first differencing eq. (14), using the Taylor-approximation described above and plugging the level of cash flow to this differenced equation. Consequently, net investment is explained by its lagged value(s), the difference of output and user cost and the level of cash-flow. As a result, firm-specific fixed effects cancel out and the equation is:

$$\frac{\hat{I}_{it}}{K_{i,t-1}} = \sum_{p=1}^{p}\omega_p \frac{\hat{I}_{i,t-p}}{K_{i,t-p-1}} + \sum_{q=1}^{q}\phi_q \Delta q_{i,t-q} + \sum_{q=1}^{q}\sigma_q \Delta uc_{i,t-q} + \sum_{q=1}^{q}\frac{CF_{i,t-q}}{p^I_{s,t-q}K_{i,t-q-1}} + \Delta\eta_t + \Delta\varepsilon_{it} \tag{16}$$

Equations similar to eq. (16) were estimated by Kalckreuth (2001). However, there is an important difference between eq. (16) and the one in Kalckreuth (2001). In his estimations a fixed effect is added to the differenced equation. He argues in favour of this specification that not only the productivity level but also its growth rate might be firm specific. This would mean that firms were able to achieve significantly different productivity growth at the individual level even during a short estimation period. This assumption is not quite common in the literature and it seems especially strong in our case in light of the short timespan of our panel. Also, if fixed effects were present in the differenced equation (16), using standard difference-based estimators, such as Anderson-Hsiao's or Arrelano-Bond GMM, would lead to differencing twice and hence would result in further loss of observations.

9.6 The data

Our database consists of the corporate tax returns of double entry book keeping firms between 1992 and 2002. However, the investment ratio is stable and credible only from 1993 so we did not use data in 1992 for the analysis.[15]

[15] This suggests that capital revaluations during and after the transition period had still been in process in 1992.

We excluded several groups from the analysis: financial intermediaries, firms in public administration, compulsory social security and education, firms in health and social work and private households with employed persons.

We also filtered out missing observations for employees, capital and depreciation for the whole database. Where enough information was available, we corrected false data. Using the last two variables we constructed real capital stock for estimation purposes. The steps of this calculation are presented in the next subsection.

We reduced the database further because we thought very small firms' investment behavior is significantly different from other firms. We found that very small firms' tax return data are imperfect and unreliable in many cases. Hence, we excluded firms where the number of employees was lower than two. We also excluded observations where the number of employees was lower than five in three consecutive years. As a result, firms in the final sample with number of employees greater than two and smaller than five in a specific year employ more than five in the previous two or the next two years. Thereby we excluded the smallest firms while best preserved the panel structure of our data.

TABLE 9.1 **Number of observations**

Year	Number of firms in the population	Number of firms in the analysis	Number of omitted firms per cent of the population
1993	66,409	18,729	72%
1994	79,794	22,660	72%
1995	90,726	24,447	73%
1996	105,728	26,495	75%
1997	120,480	29,214	76%
1998	130,835	32,835	75%
1999	139,141	35,563	74%
2000	151,913	37,478	75%
2001	184,703	39,406	79%
2002	199,798	42,023	79%
Total number of observations	1,269,527	308,850	76%

We cleaned the other variables on the reduced sample. We corrected for false data using the following rules:

- If the calculated real capital stock is negative,
- If sales revenue is negative,
- If the calculated user cost is negative,
- If the depreciation rate is greater than 1,
- If the debt to assets ratio is greater than 1.

We also checked for outliers. For the cash-flow ($CF_{it} / p^1_{st} K_{i,t-1}$), depreciation rate ($\delta_{it}$), logarithm of user cost ($logUC_{it}$) we defined threshold values each year as the 1st and 99th percentiles of the distribution. For the investment rate $(I_{it} / K_{i,t-1})$ these values were the 1st and 95th percentiles. For the change in the capital stock $(\Delta \log K_{it})$, change in sales $(\Delta \log Q_{it})$, the change in the user cost $(\Delta \log UC_{it})$ and the change in employment $(\Delta \log L_{it})$ we used the Chebyshev method: an observation was considered to be outlier if the absolute deviation of a variable from its mean in a specific year was greater than five times its standard deviation: $|\bar{y}_{it} - y_t| > 4 \times sd_t\,(y_{it})$.

As a result of all this, our unbalanced panel consists of 73,649 firms' data between 1993 and 2002 with 308,850 observations. After industry- and size-based filtering the size of the database collapsed to 31% of the initial data set. The final number of observations is 78% of this smaller database, which is 24% of the whole population.[16]

Table 9.2 Descriptive statistics of variables used, 1993-2002

Variable	Mean	Sd.	Minimum	25%	Median	75%	Maximum
I/K	0.437	0.704	-0.603	0.037	0.175	0.541	5.724
logK	8.911	1.999	0.989	7.572	8.783	10.137	19.857
logQ	10.477	1.545	-0.144	9.427	10.393	11.399	19.829
logUC	-1.750	0.918	-11.764	-2.038	-1.665	-1.313	-0.301
CF/K	0.734	2.686	-14.990	-0.002	0.224	0.846	58.329

The descriptives of variables used in the analysis are summarized in Table 9.2, definitions and further details are provided in the appendix. Out of these, we give a detailed presentation of our capital stock and user cost data in the next subsection.

Capital stock

We encountered several problems measuring the capital stock. We deemed capital stock as the sum of tangibles and intangibles. Ideally, components of the capital stock should be registered on market prices. However, according to Hungarian accounting rules, the capital stock enters the balance sheet on book value and the amount of depreciation also should be accounted against book value. If the market value of the capital asset on the firm's balance sheet differs from its book value, the firm can decide whether it adjusts the value of the capital assets registered on its books. Furthermore, we have no information on the composition and age structure of the firm specific capital stock. Putting all this together, we are given a capital stock which is an amalgam of capital assets with different age and valued at different prices. Hence, raw capital stock data cannot be considered to be valued either at current or constant prices.

We therefore compiled capital stock data using the idea of the perpetual inventory method (PIM). The idea behind the PIM is that having an initial condition, the capital accumulation equation can be used to construct the stock of capital.

[16] Obviously, the final number of observations used in the estimations varied because different number of lags of variables were needed at different specifications.

$$K_{it} = \sum_{j=0}^{t} g(t,i) \times I_{i,t-j} \tag{17}$$

where K_{it} is the after-depreciation real capital stock at the end of each year, I_{it} is real investment in year t and $g(t,i)$ is a function that specifies the depreciation of the extant capital stock and new investment. The above equation says that the capital stock can be calculated if we know the initial stock and the net effect of investment and depreciation. If K_{it} is net investment cumulated up to period $(t–1)$, that is, the before-depreciation capital stock in time t, then the capital stock in time t is

$$K_{it} = (1 - \delta_{it})K_{i,t-1} + I_{it} \tag{18}$$

This is nothing but the discrete version of the continuous capital accumulation equation (5) defined in the dynamic optimization problem of the firm. We defined the initial condition of the capital stock as the value in the year the firm entered the database and expressed it in 1992 prices.

To calculate the real capital stock we needed firm-level investment data. We used capital stock data registered according to accounting rules because the database did not contain data on investment directly. We refer to this capital stock data as accounting capital. Investment is calculated based on eq. (18): it is equal to the after-depreciation difference between the accounting capital stock in year t and $(t–1)$:

$$p_{st}^{I} I_{it} = \overline{K}_{it} - \overline{K}_{i,t-1} + \delta_{it}\overline{K}_{i,t-1} = \overline{K}_{it} - \overline{K}_{i,t-1} + DEP_{it} \tag{19}$$

where $(p_{st}^{I} I_{it})$ is nominal investment, $\overline{K}_{it}$ is accounting capital at the end of year t and DEP_{it} is the value of depreciation write-off in year t. Then, deflating investment with the industry specific investment price index (p_{st}^{I}), we arrive at investment volume (I_{it}).

With the knowledge of the initial condition we can construct firm level real capital stock using real investment and the depreciation rate. Our database only contains year-end data, which causes another measurement problem. If we define the effective rate of depreciation as the ratio of accounted depreciation in year t and the accounting capital stock of the previous year-end $(\delta_{it} = DEP_{it} / \overline{K}_{i,t-1})$, we apparently overestimate the realistic depreciation rate for actively investing firms. This is due to the fact that investment as well as disinvestment occurs throughout the whole year seriously affecting accounted depreciation. If a firm invests, it can account an amount of depreciation already in the year of investment and, correspondingly, in the case of disinvestment it can benefit from registering the value of depreciation up to the point of disinvestment. To avoid unrealistically high depreciation rates we assume that investment occurs at the beginning of each year and disinvestment occurs at the end of each year. The capital accumulation equation and the depreciation rate in the two cases is the following:

1) in case of investment $(I_{it} > 0)$, $\delta_{it} = \frac{DEP_{it}}{DEP_{it} + \overline{K}_{it}}$ and $K_{it} = (1-\delta_{it})(K_{i,t-1} + I_{it})$, because the total capital stock against which the firm writes off depreciation is the stock after investment at the 1st of January, and
2) in case of disinvestment $(I_{it} < 0)$, $\delta_{it} = \frac{DEP_{it}}{\overline{K}_{it}}$ and $K_{it} = (1-\delta_{it}) K_{i,t-1} + I_{it}$.

We might assume, as an alternative, that investment and disinvestment takes place in the middle of the year. In this case the firm writes off half of its depreciation on the new investment and half of its depreciation on the disinvestment kept for six months. Hence, without regard to the sign of I_{it}, the depreciation rate and the capital stock at the end of the year can be calculated as

$$\delta_{it} = \frac{DEP_{it}}{DEP_{it} + \overline{K}_{it} + \overline{K}_{i,t-1}} \text{ and } K_{it} = (1-\delta_{it})K_{i,t-1} + \left(1 - \frac{\delta_{it}}{2}\right)I_{it}.$$

We carried out our estimations using variables calculated in this manner but results were robust to these modification. Therefore, these results are not published in this paper.

User cost

Following equation (9) in the derivation, we defined the user cost as

$$UC_{it} = \frac{p^I_{st}}{p_{st}(1-u_{it})}\left[\left(\frac{E_{it}}{B_{it}+E_{it}}\right)LD_t + \left(\frac{B_{it}}{B_{it}+E_{it}}\right)(1-u_{it})IR_t - \frac{\Delta p^I_{s,t+1}}{p^I_{st}} + (1-u_{it})\delta_{it}\right] \tag{20}$$

where B_{it} is the sum of long and short term liabilities, E_{it} is own funds, IR_t is a weighted average of bank lending rates with maturities over one year, LD_t is the one year benchmark t-bill rate, u_{it} is the effective tax rate, p^I_{st} is the industry specific investment price index, p_{st} is the industry specific price deflator (PPI or GDP deflator, depending on industry) and δ_{it} is the effective depreciation rate as defined in the previous section.

Since the firm finances its investment using both external funds $(B_{it} / (B_{it} + E_{it}))$ and internal funds $(E_{it} / (B_{it} + E_{it}))$, the user cost of capital is determined by the interest rates of borrowed funds, the return on equity and the shares of these sources of capital components in the firm's liabilities. Opposed to the theoretical formula where the denominators contain physical capital, we used the sum of external and internal funds in our calculations. This is justified by the fact that the optimal rate of external funds depending on tax advantages is a function of the accounting leverage.

The return on equity was proxied using benchmark t-bill rates. This obviously underestimates the cost of own funds. Namely, it is standard that the expected rate of return on a risky project is greater than the risk free rate. The difference between the two is the risk premium. However, the risk premium is difficult to measure so for the sake of simplicity we consider the benchmark rate as a proxy for the opportunity cost of equity.[17]

The cost of borrowed funds are generally measured by the interest paid. Calculating an apparent interest rate, which is the ratio of interest paid and total stock of debt, would be evident.

[17] Three year rates are only available since 1996, the five year rates since 1997 and the most compelling ten year rate since 1999. Therefore we used the one year benchmark rate uniformly between 1992 and 2002.

However, there is no separated data for debt in the firms' liability stock prior to 1999. Dividing interest paid by the sum of short and long term liabilities significantly underestimates the real interest burden[18], which demonstrates the huge share of non-interest bearing liabilities (e.g. accounts payable) within overall liabilities. Consequently, we used the weighted average of bank lending rates assuming all the firms can borrow at similar conditions.

9.7 Estimation and results

Estimation method

Our first model based on eq. (14) was the ADL(2,1) in levels of the log of the capital stock:

$$k_{it} = \sum_{p=1}^{2} \omega_p k_{i,t-p} + \sum_{q=1}^{1} \phi_q q_{i,t-q} + \sum_{q=1}^{1} \sigma_q uc_{i,t-q} + \sum_{q=1}^{1} \frac{CF_{i,t-q}}{p^I_{s,t-q} K_{i,t-q-1}} + \eta_i + \eta_t + \varepsilon_{it},$$

where ε_{it} is a white noise term, uncorrelated across firms and in time. Individual effects are stochastic so both the lags of capital and the other variables can be correlated to η_i. Because of the endogeneity problem, some transformation is needed to get rid of these individual effects.

The well-known within estimator handles this with mean-differencing but it will still produce inconsistent parameter estimates in the presence of lagged dependent variables and other endogeneity problems, particularly in panels with short time period. The lag of the mean-differenced dependent variable $\left(\tilde{k}_{i,t-1} = k_{i,t-1} - (T-2)^{-1} \sum_{s=1}^{T-1} k_{is}\right)$ and the mean-differenced error term $\left(\tilde{\varepsilon}_{it} = \varepsilon_{it} - (T-2)^{-1} \sum_{s=2}^{T} \varepsilon_{is}\right)$ are by all means correlated. If $(\omega_1 > 0)$, the term $-(T-2)^{-1}k_{it}$ in the former and the term ε_{it} in the latter are negatively correlated and, also, the term k_{it} and the term $(-(T-2)^{-1}\varepsilon_{i,t-1}$ are negatively correlated. These negative correlations suppress the positive correlation between other terms $(-(T-2)^{-1}k_{i,t-1}$ and $-(T-2)^{-1}\varepsilon_{i,t-1}$ for example). As a result, the overall negative correlation between $\tilde{k}_{i,t-1}$ and $\tilde{\varepsilon}_{it}$ leads to significantly underestimated within parameter estimate of the lagged dependent variable (Nickell, 1981).

From Nickell (1981) we know that the inconsistently estimated parameter of the lagged dependent variable impacts the parameter estimates of the other variables as well. The direction of the bias depends on the sign of correlation between the lagged dependent variable and other explanatory variables. Continuing to assume that $(\omega_1 > 0)$, if this correlation is positive the parameter estimate of the other explanatory variable is biased downwards and vice versa.

The endogeneity of explanatory variables give rise to inconsistency of the estimates, too. A shock to the capital stock affects the firm's output because it is clear from the production technology specification that a positive shock to the capital stock causes output to increase. A capital shock also might modify the cost of capital. A change in the capital stock might alter the leverage of the firm and, according to eq. (4) the bank lending rate and the user cost. Taking these factors into account, the endogeneity of cash-flow cannot be ruled out because a firms's cash-flow is a positive function of sales revenue. However, cash-flow and leverage are negatively correlated. These effects do not necessarily cancel out each other but the direction of the bias cannot be foreseen.

[18] The variable created in this fashion oscillated between 4 and 6% on average.

Individual effects can be eliminated by first differencing as well. As opposed to the within transformation, the error term values for every time period do not appear in the equation in this case and the strict exogeneity of explanatory variables is not required. In the case of dynamic panel data models, however, OLS estimation on first differences of variables still produces inconsistent parameter estimates. This is because the lagged dependent variable (Δk_{it-1}) and the differenced error term $(\Delta \varepsilon_{it})$ are negatively correlated, which comes from the opposite sign of the $(t-1)$ terms. This negative correlation causes the parameter estimate of the lagged dependent variable to be biased downwards with the extent being generally higher than that of the within estimates.

Consistent parameter estimates can be obtained using appropriate instruments for the endogenous variables. Anderson-Hsiao (1981) suggests the first differenced two stage least squares (2SLS) estimator. Maintaining the initial assumption that there is no autocorrelation in the disturbance term and assuming that the capital stock and all the explanatory variables are uncorrelated to future disturbances, lags $(t-2)$ and earlier of the variables – both levels and differences – are all valid instruments. Empirical research showed, however, that using levels of variables as instruments produce generally more efficient estimates than differences. Another advantage of using level instruments is that we do not lose additional observations due to lagged differencing, that is, we have more instruments given the number of observations.

Also, lagged values of the employment level were used as possible excluded instruments. Since labour is one of the main determinants of production, the number of people employed is a suitable candidate. However, the two input factors are evidently interrelated and thus present labour usage may be correlated with the error term, which violates the orthogonality condition. Moreover, some recent empirical research have documented significant dynamic interrelation between the two input factors (Dixit, 1997). This means that the correlation between the demand for capital and the demand for labour is not restricted to one period but adjustment dynamics in one factor affect adjustment in the other factor over a period of more than one year. The fact that labour adjustment may precede investment implies that lagged employment is also correlated with the present error term. Nevertheless, it is reasonable to assume that this correlation does not hold if the time span between investment and labour decisions is large enough. Therefore, we assume that the error term in t is uncorrelated with employment in $(t-2)$ and earlier, which means that present investment decisions do not affect firm's labour policy two years before. Consequently, the level of employment in $(t-3)$ and earlier are possible instruments as well. Evidently, the validity of these instruments was tested using appropriate statistical methods *('difference-in-Hansen test')*, just as the validity of the other instruments used in the regressions.

Econometric results

We summarized our estimation results of the first specification in Table 9.3. The parameter estimates of the Within estimator (first two columns) appear to be significant for all variables. However, as we mentioned earlier, we know that the parameter estimate of the lagged dependent variable is biased downwards because of the incorrect assumption of strict exogeneity. In spite of the downward bias, the magnitude of the parameter estimate (0.609) of the lagged dependent variable points to quite high persistence in capital stock dynamics. The estimates of both sales and user cost parameters are of the expected sign. This is also true for cash-flow. However, the magnitude of cash-flow parameter estimates shows that firms' investment is not highly sensitive to the financial position. The results obtained using First-differenced estimates (second and third columns) are, by and large, in line with the Within estimates. There are two differences, though. First, in line with the theoretical considerations, it is apparent that the parameter estimate of the lagged dependent variable is more downward biased (0.18) than the within estimate. Second, the parameter estimate of lagged sales is of higher magnitude in this estimation.

In the 2SLS estimates, we instrumented endogenous variables by all the available observations for each variable back to time *(t–5)* in order to improve the accuracy of our estimations.[19] However, we found that including lag *(t–2)* of sales resulted in invalid instrument matrices, so we used *(t–3)* to *(t–5)* lags of this variables as instruments. One can argue in favour of omitting lags of this variable that, for example, current output is correlated with future output, that is, current output can be interpreted as a proxy for future demand conditions. Therefore, an investment shock in time *t* is correlated with lagged output. Of course, this implies that earlier lags of sales might also be somewhat correlated with the current capital stock. However, we found that using lags *(t–3)* and earlier as instruments did not result in categorically invalidating the instrument matrix and can be accepted as valid instruments. Also, employment *(t–3)* to *(t–5)* were used as excluded instruments (see consideration above). The use of employment as instrument improves significantly the accuracy of our estimates without violating the orthogonality condition. As a result, the marginal significance level of the Hansen J-statistic in our final specification was 0.062, the absence of correlation between the differenced error term and the instrument matrix could not be rejected at 5% significance level. Based on the AR2 test for second order serial correlation in the residuals, we could not reject the null of zero serial correlation.[20] Moreover, diagnostic tests and parameter estimates seemed to be robust to changes in the lag structure used in the instrument matrix.

The 2SLS parameter estimate of $logK_{i,t-1}$ is 0.71, which is higher than the one obtained in either Within or First-difference estimation. This relatively high persistence in the capital stock is in line with our expectations. However, the parameter of the second lag of capital was not significantly different from zero. This suggest that only the lag *(t–1)* plays a role in the adjustment process of capital. 2SLS results show that the sensitivity of capital stock with respect to contemporaneous sales is higher (0.5) than previous biased estimates. The parameter of lagged sales did not appear to be statistically different from zero.

The estimate of the contemporaneous user cost parameter is statistically significant. The order of magnitude (-0.223) suggests that user cost changes are important determinants of corporate investment. This provides evidence against simple sales-accelerator models that include only sales and exclude user costs. The lagged parameter estimate (-0.016) is lower in absolute value than that of time *t* and almost significant at usual significance levels. As is generally the case in the empiri-

[19] Since cash-flow contains lagged capital in the denominator, we fixed the maximal number of lags used as instrument to four in order to save observations. Therefore, we 'only' lose two years in the estimation comparing to the simple FD estimator.

[20] If the AR(2) test showed nonzero correlation, the consistency of the Anderson-Hsiao estimates would be called into question. This is because the second order serial correlation of differenced error terms means that *(t–2)* shocks are reflected in the capital level at time *t* and hence second lags of the endogenous variables would not be orthogonal to the differenced error term.

cal literature, the cash-flow capital ratio enters the equations with a significantly positive sign. Contemporaneous cash-flow has a greater effect on current investment, while the significance level of past values of cash-flow is much higher than that of current cash flow.

These parameter estimates imply long run coefficients that provide some interesting empirical findings.[21] The long run coefficient of sales is practically unity which provides evidence for constant returns to scale in the production function.[22] This surprising result was robust across specifications, as will be seen later. However, one has to exercise care in interpreting this as straightforward evidence because we are using sales as a proxy for output. The long run user cost parameter[23] estimate appears to be quite high (-0.828) compared to other estimates. At a glance, it seems to be a high elasticity compared to certain former estimates: estimating a comparable model on French manufacturing data, Chatelain and Tiomo (2001) have found this coefficient to be (-0.16)-(-0.311). Nevertheless, it is not completely out of line with previous results because Chatelain and Teurlai (2004) estimated this elasticity to be even higher for small service sector firms. The finding that our estimated user cost elasticity is below unity implies that the assumption of Cobb-Douglas technology would not have been appropriate in our case.

In the second specification, the ratio of net investment with respect to capital is regressed on a set of variables (see equation (15) for a detailed presentation). We present only the consistent parameter estimates hereafter. Diagnostics indicated that this specification was more sensitive to the choice of the instrument matrix than the previous specification (Table 9.4). This instability was also reflected in point estimates. We proceeded choosing the instrument matrix in the same manner as we have done in the previous specification and chose all available lags back to $(t-5)$ as instruments. However, instead of lags of the investment ratio, we used the lagged levels of capital *(logK)* as instruments in the final model because the specification performed better in terms of diagnostics. The Hansen-J statistic's marginal significance level was 0.084. The AR(2) structure of the residuals can easily be rejected based on the test.

Regarding persistence, we note that it is not the parameter of the lagged investment ratio but that of the $logK_{t-2}$ that determines the true capital persistence in this specification (see equation (15)). Although the apparent auto-regressive parameter is $(\omega_1 - 1)$, the underlying auto-regressive component remains $(\omega_1 + \omega_2)$. Therefore, the persistence parameter can be obtained by adding 1 to the estimated parameter of $logK_{t-2}$. With a value of 0.47, this specification implies lower persistence for the capital stock than the one obtained in the level estimation (0.71).

The contemporaneous sales parameter is estimated to be over unity (1.38) in this specification while the lagged is negative (-0.83), both being significantly different from zero and greater in absolute terms than in the previous specification. However, the long run elasticity is still practically unity. This corroborates the finding of constant returns to scale, which emerged from the level estimation. Yet, the relatively high and opposite sign short run elasticities can hardly be interpreted as a plausible adjustment process.

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[21] Nevertheless, it has to be stressed again that some caution is needed when interpreting these coefficients. We noted earlier when we defined long run coefficients that ADL parameters may include effects of changes in expectations and technology and they do not necessarily embody only the adjustment characteristics of variables.

[22] See the coefficient of output in equation describing the long run demand for capital. It can be seen that if the coefficient of output is unity then this implies the returns-to-scale parameter to be unity as well.

[23] Which is, in the context of our model, also the estimate of the elasticity of substitution between production factors.

The user cost elasticities (-0.38 and -0.03) are significant and greater in absolute terms compared to the level estimation results. However, due to lower persistence, the long run coefficient (-0.83) is comparable in magnitude to the previous result. For cash-flow, both parameters are significantly different from zero and greater than previously obtained elasticities. As a result, the long run coefficient of cash-flow is also greater (0.43) than it was in the level estimation (0.23). The greater sensitivity is not necessarily implausible because cash-flow might take up the effects of profitability expectations and future sales since output and cash-flow are correlated.

In sum, this specification was less stable and these results are slightly less plausible than those obtained using the level equation.

The third specification regresses the investment ratio on differences and lagged differences of sales, user cost and the level of cash-flow. This specification proved to be much more robust to different instrument matrices: the orthogonality of instruments could be accepted in all cases (Table 9.4). The marginal significance level of the Hansen-J statistic of our final instrument set is 0.21, this same value for the AR(2) test is 0.59.

TABLE 9.3 Estimation results – Specification 1

dependent variable: log capital (logKt)	**Within**		**First-differenced**		**Anderson-Hsiao 2SLS**	
	coef.	**Z stats.**	**coef.**	**Z stats.**	**coef.**	**Z stats.**
$\log K_{t-1}$	0.609	*238.65*	0.181	*69.02*	0.710	*12.85*
$\log K_{t-2}$	0.056	*23.31*	0.105	*42.55*	0.001	*0.10*
$\log Q_t$	0.157	*72.98*	0.161	*72.68*	0.500	*2.76*
$\log Q_{t-1}$	0.035	*15.58*	0.100	*43.24*	-0.207	*-1.54*
$\log UC_t$	-0.492	*-191.63*	-0.375	*-154.22*	-0.223	*-2.95*
$\log UC_{t-1}$	-0.003	*-3.10*	-0.030	*-27.57*	-0.016	*-1.56*
CFt/K_{t-1}	0.035	*76.60*	0.029	*65.54*	0.053	*1.82*
$CFt\text{-}1/K_{t-2}$	0.015	*32.94*	0.017	*40.22*	0.013	*2.61*
Long-run coef. of sales	0.574	*91.82*	0.366	*81.38*	1.013	*6.09*
Long-run coef. of user cost	-1.480	*-130.63*	-0.567	*-115.85*	-0.828	*-3.36*
Long-run coef. of cash-flow	0.152	*57.27*	0.065	*54.66*	0.229	*1.58*
Hansen J statistic					16.26	P=0.062
AR2 test					1.00	P=0.317
Wald test for year dummies	5684.16	*P=0.000*	4927.81	*P=0.000*	54.25	*P=0.000*

Source: Apeh 1993-2002.

Notes: Capital, sales and cash-flow measured in thousands of HUF. Cash-flow deflated by sectoral investment price index (own estimation), sales deflated by sectoral PPI for industry and GDP deflator for agriculture and services. Year dummies included. Heteroscedasticityrobust standard errors estimates. Long-run standard errors were computed using 'delta method' (see e.g. Wooldridge, 2001, pp. 44).

Instruments for 2SLS estimation: second to fifth lags of capital and user cost, second to fourth lags of cash-flow, third to fifth lags of sales and employment.

TABLE 9.4 **Estimation results – Specification 2 and 3**

dependent variable: net investment rate ($\hat{I}_t / K_{t-1}$)				
	coef.	**Z stats.**	**coef.**	**Z stats.**
$\hat{I}_{t-1}/K_{t-2}$	-0.352	-3.86	0.595	6.50
$\hat{I}_{t-2}/K_{t-3}$			-0.016	-1.49
$\log K_{t-2}$	-0.531	-3.85		
$\log Q_t$	1.375	2.59		
$\log Q_{t-1}$	-0.826	-2.00		
$\log UC_t$	-0.379	-2.07		
$\log UC_{t-1}$	-0.028	-1.12		
$d\log Q_t$			0.781	2.98
$d\log Q_{t-1}$			-0.352	-1.77
$d\log UC_t$			-0.285	-2.36
$d\log UC_{t-1}$			-0.035	-1.95
CF_t/K_{t-1}	0.190	2.92	-0.005	-0.13
CF_{t-1}/K_{t-2}	0.041	3.93	0.065	3.36
Long-run coef. of sales	1.032	4.76	1.019	5.19
Long-run coef. of user cost	-0.765	-2.51	-0.760	-2.60
Long-run coef. of cash-flow	0.433	2.08	0.142	2.64
Hansen J statistic	13.91	P=0.084	10.97	P=0.204
AR2 test	0.12	P=0.905	0.54	P=0.588
Wald test for year dummies	31.77	P=0.000	50.53	P=0.000

Source: Apeh 1993-2002.
Notes: Capital, sales and cash-flow measured in thousands of HUF. Cash-flow deflated by sectoral investment price index (own estimation), sales deflated by sectoral PPI for industry and GDP deflator for agriculture and services. Year dummies included. Heteroscedasticityrobust standard errors estimates. Long-run standard errors were computed using 'delta method' (see e.g. Wooldridge, 2001, pp. 44).
Instruments for both 2nd and 3rd specification: second to fourth lags of capital and cash-flow, second to fifth lags of user cost, third to fifth lags of sales and employment.

Capital persistence in this specification is determined by the sum of estimated lagged dependent variable parameters. In this case persistence is valued to be 0.58, which is comparable to but lower than that of the level estimation (0.71) being still higher than in the second specification (0.47). Although having the same signs as in the second specification, sales parameter estimates are lower in absolute terms (0.78 and -0.352) than those in the second specification (1.375 and -0.826). This suggests parameters can be more plausibly interpreted as adjustment process characteristics. The long run coefficient of sales is robustly close to unity again. The user cost parameters are slightly higher in absolute value (-0.285 and -0.036) but still close to those produced in the level estimation (-0.223 and -0.016). The long run coefficient in this specification was close to those obtained by the two other specifications (-0.76). Regarding cash-flow, the contemporaneous parameter estimate is not statistically different from zero, but the lagged cash-flow appears to have significant explanatory power. This reinforces what one might have suspect already looking at the significance levels obtained in the previous estimations, mainly in the first specification.

To summarize, we believe that our overall sample estimation results are plausible. The parameter estimates are of the expected sign and magnitude. To put results in an international context, we compare long run coefficients from the third specification to what Angeloni et al. (2002) estimated using data for Germany, France, Italy and Spain. Despite differences, our parameter estimates are not out of line with those of (Angeloni et al., 2002).[24] For the user cost, their long run elasticities ranged between (-0.027)-(-0.521), with the estimate for Germany being the highest and for France being the lowest. For cash-flow, the estimate fell between (0.079 for Germany)-(0.301 for Italy). It is only the long run parameter of sales that is consistently lower in their estimation (0.018 for Spain)-(0.387 for Germany).

We carried out estimations also with the 'difference-GMM' estimator suggested by Arrelano-Bond (1991). However, results based on the entire sample proved to be unstable to the instrument matrix. Heterogeneity across firms might well explain why these latter results are unstable. Also, the homogeneity assumption of parameters of other variables in general might be a question. For example, firm-level heterogeneity might be key from the point of view of cash-flow effects as larger firms are more likely to be less financially constrained than smaller firms. The validity of these hypotheses is to be tested by splitting the sample but presenting sample split results are beyond the scope of this paper.

9.8 Conclusion

We investigated corporate investment behavior in Hungary using non-financial firm level data between 1993 and 2002. Using the standard neoclassical framework we estimated several specifications. Assuming that optimal capital stock adjusts according to an ADL structure, we derived a level equation for the stock of capital and two equations for the investment-to-capital ratio. In each empirical equation we used firm specific user cost of capital data along with sales and cash-flow.

The main findings of the investigation are the following. Estimations based on the whole sample show that in the long run the user cost of capital is a significant determinant of investment and the long run sensitivities are, broadly speaking, in line with previous European estimates. The difference of results might be, at least partly, explained by sample differences and certain specification-related issues.

This result invalidates simple sales accelerator models where the only important determinant of investment is output. We also discuss that there are mechanisms, though not obvious, through which

[24] These differences might account for the disparities of results. First, their database contained mostly manufacturing data. Second, they have benefited from a longer time span (1983-99) of their database letting them use earlier lags both in the ADL structre and as instruments in the estimation. Third, they assert that their sample is biased towards larger firms. This might also be true for our sample but it is hard to assess whether the bias itself causes parameters to be inacceptably out of line with expectations. Last, but not least their specification contains a fixed effect even in the differenced equation. This causes the AR parameters to be smaller because the firm-specific effect takes up the autoregressive characteristics of investment rate dyamics. To understand what this implies and what the considerations are behind including/omitting a fixed effect in the differenced equation, see the discussion of the last equation within the section on empirical models.

long term interest rate changes affect the user cost and, in the end, investment. It has to be stressed, however, that being essentially partial, this model is not able to describe the exact mechanism how monetary impulses are transmitted to the cost of capital and, accordingly, corporate investment.

Another interesting finding of the paper is that the coefficient of output is robustly close unity, which provides strong evidence for constant returns to scale in the production function. To control for financial constrain effects we added cash-flow to the equations. Results show that the financial position of a firm is an important determinant of investment suggesting that credit channel effects might be at work.

Our results provide the first set of microeconomic insights to Hungarian corporate investment behavior. Drawing on these, further investigations, including splitting the sample and applying more recent frameworks, will be aimed at depicting a more refined picture of investment behavior in Hungary.

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9.10 Appendix

The variables were constructed from tax return and balance sheet data of double entry book keeping Hungarian companies between 1992 and 2002. Costs and sales revenues were deflated using industry specific production price deflators for manufacturing, energy and mining. For other industries (agriculture, construction and services) we used industry specific GDP deflators. In calculating firm specific real capital stock we used weighted averages of domestic sales prices of machinery investment, import prices of machinery investment and construction investment prices of the industries where the weights were the domestic, import and construction investment proportions of each industry. Definitions of the variables are listed below.

Number of employed (L): Average number of employed during the year, rounded to the nearest integer.

Capital stock (K): The stock of tangible and intangible assets. There is no data collected for investment in corporate tax returns, hence capital data cannot be constructed by the generally used version of the perpetual inventory method (see Section 9.2).

Output (Q): Output is proxied by sales revenues of the firm.

User cost of capital (UC): User cost is defined as (see Section 9.2):

where:

B_{it} = The sum of short and long term liabilities. It contains: accounts payable, liabilities to owners, sum of short term credits and loans, and other liabilities. Long term liabilities are composed of investment credits and other credits.

E_{it} = Equity is calculated: subscribed capital – subscribed capital unpaid + capital reserve + revaluation reserve + profit or loss for the year + accumulated profit reserve.

IR_t = weighted average of bank lending rates with maturities over one year

LD_t = one year benchmark t-bill rate

U_{it} = effective tax rate

δ_{it} = effective depreciation rate

- if $I_{it} > 0 : \delta_{it} = DEP_{it} / (DEP_{it} + \bar{K}_{it})$
- if $I_{it} < 0 : \delta_{it} = DEP_{it} / \bar{K}_{it})$

where DEP_{it} is value of depreciation accounted in year t and K_{it} is accounting capital at the end of year t.

Where equity was negative, we assumed $(E_{it} / (B_{it} + E_{it})) = 0$ and $(B_{it} / (B_{it} + E_{it})) = 1$. In these cases the user cost is determined entirely by the cost of external funds.

p_{st} = industry specific price deflator (PPI for industry and GDP deflator for agriculture, construction and services)

p^{I}_{st} = industry specific investment price index. As yet, the Hungarian Central Statistics Office has not published industry specific price indices for the period prior to 1999, hence we calculated them as weighted averages of investment prices of domestic machinery, investment prices of import machinery investment and construction investment prices in total economy where the weights were the domestic, import machinery investment and construction investment proportions of each industry.

Cash flow (CH): Firms' cash flow was calculated on the basis of Schedule No. 7 to Act C of 2000 On Accounting. We defined cash-flow as: Income before taxes + Depreciation write-off + Loss in value and backmarking – Change in trade debtors – Change in accrued and deferred assets – Change in inventories + Change in accrued and deferred liabilities + Change in short term liabilities + Change in long term liabilities + Change in subscribed capital (corrected for subscr. cap. unpaid) – Corporate tax paid or payable – Dividends and profit sharing paid or payable.

10. The expected effect of the euro on the Hungarian monetary transmission

Gábor Orbán and Zoltán Szalai

10.1 Introduction

The prime motivation for the research on monetary transmission in the euro area was to find out whether it is possible to detect asymmetries within the monetary union which may make the transmission of the single monetary policy significantly different across participating countries. If such concerns are justified, then the enlargement of EMU by including countries with potentially very different monetary transmission mechanisms (MTM's) could be costly for new entrants on the one hand and disruptive for the functioning of the ECB by provoking disagreement among decision-makers on the other. In this case it may also be questioned that it is the interest of the new Member States to become full participants of EMU sooner rather than later.

At present the most important mechanism through which monetary policy affects the real economy in Hungary is the (euro-forint) exchange rate channel. After the permanent and irreversible fixing of the euro-forint parity, this mechanism will no longer exist and the impact of monetary policy will be transmitted mainly via the interest rate channel, which is presently seen as rather weak. This has raised concerns that the influence of the ECB's interest rate policy on the real economy in Hungary could be very limited after euro adoption. Furthermore, fears have been voiced regarding the responsiveness of social partners to monetary policy signals, i.e. the effectiveness of the expectations channel of monetary policy. An additional key concern, which was particularly strong prior to the launch of the euro, is that a member state may experience markedly different monetary conditions within the monetary union due to differences in the composition of the effective exchange rate as result of a very different trade orientation. Lastly, asymmetries of MTM between the euro area and Hungary could be reinforced by large differences in the strength of the credit channel.

Our ultimate goal in this study is to find out to what extent such concerns regarding the propagation of the single monetary policy to the Hungarian economy are justified. We review the euro area monetary transmission literature and some stylised facts from the euro area and Hungary in order to formulate expectations on the changes in the Hungarian MTM after Hungary has adopted the euro. The following section details the changes we expect in the scope of the interest rate channel in Hungary after euro adoption. The third section discusses the expectations channel in order to explore the responsiveness of negotiated wages to monetary policy signals. The fourth section looks into the issue of extra-euro area trade orientation. In this section we focus on asym-

We thank Zoltán Wolf for valuable assistance with the APEH database and Judit Neményi and the participants of the MNB presentation for their useful comments.

metric *effects* of the same policy, as opposed to asymmetric *shocks* that a single policy has to react to. The fifth section deals with the expected changes in the credit channel of monetary policy. The last section concludes.

10.2 Expected changes in the scope of the interest rate channel

Although the pass-through of bank lending and deposit rates from money market rates is already quite powerful in comparison to the euro area (see Horváth et al., 2004), credit extended by banks to firms and households lags behind the European average and a large share of it is foreign currency denominated. As a consequence, the effect of interest rate changes on macroeconomic performance is considered to be rather weak and the exchange rate is presently seen as the key channel of monetary transmission. For these reasons, concerns have been voiced that the disappearance of the euro-forint exchange rate channel after euro adoption will leave Hungary without a proper mechanism through which monetary policy may affect the real economy.

In this section we deal with the expected changes in the scope of the interest rate channel of monetary policy including the expected progress in financial deepening after Hungary has adopted the euro. By changes in its scope we mean mechanisms that presently do not belong to the interest rate channel, but will be part of the interest rate channel after euro adoption. We argue that the interest rate channel will embrace a broader set of mechanisms after euro adoption than it does today, because the ECB's monetary policy already affects the Hungarian economy in a number of ways, or will do so once Hungary has adopted the euro. In the following we discuss these effects one by one.

Domestic liabilities in foreign currency

Euro adoption is expected to enhance the interest rate channel by turning euro denominated liabilities of domestic agents into a medium of monetary transmission. These liabilities already play a role in the MTM process, but they transmit monetary policy actions from the ECB and not those of the domestic monetary authority.

As seen in Table 10.1 nearly half of the total outstanding domestic credit was denominated in foreign currency by 2004, of which 80% is denominated in euros and the rest is mostly in Swiss francs. The figures also reveal that this has to do with a high stock of corporate FX borrowing, with many firms using foreign currency loans. The increase in FX borrowing was remarkable in this sector in the second half of the 1990's when economic integration with the euro area accelerated. Moreover, we have witnessed a trend of rapidly growing household indebtedness in foreign currencies, albeit from a very low base.

TABLE 10.1 Forint and foreign currency loans in Hungarian private sector credit (% of GDP)

		1997	1998	1999	2000	2001	2002	2003	2004
Forint	Firms	13.4	13.2	13.1	14.0	15.0	14.2	14.01	3.4
	Households	4.0	3.5	4.0	4.9	6.2	9.4	13.1	13.7
FX	Firms	14.8	17.5	19.4	23.7	2.6	16.9	20.5	21.4
	Households	0.0	0.1	0.2	0.4	1.0	1.4	2.9	5.0
Total	FX	14.9	17.6	19.5	24.2	23.6	18.3	23.4	26.4
	Forint	17.4	16.7	17.0	18.9	21.2	23.7	27.1	27.1

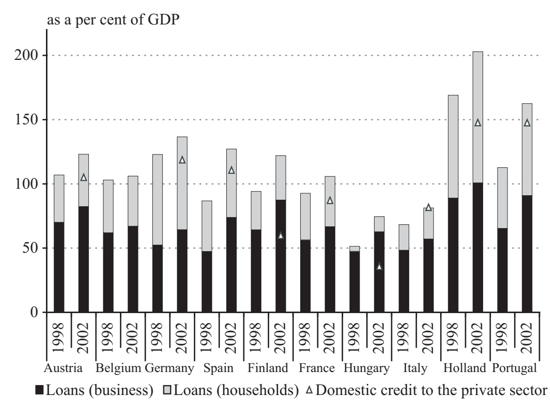
Source: MNB.

Domestic and total private sector credit

In this subsection we present evidence that the private sector is actually more exposed to changes in interest rates due to higher indebtedness than domestic credit figures would suggest. At present this would not matter much for monetary transmission, as an overwhelming share of this stock is denominated in foreign currency, however, with euro adoption, it will substantially extend the scope of the interest rate channel.

Looking at data from Eurostat's financial accounts allows us to get a better picture of the level of corporate and household exposure to monetary policy than the generally used domestic credit figures. As shown by the white triangular markers in Figure 10.1, the distinction between domestic bank credit and the actual loan exposure of the private sector is very important in the case of Hungary (also for Finland). The discrepancy between the figures implies that a large share of total loans of the private sector is extended by non-residents (either banks or firms), which makes debtors sensitive to foreign monetary policy. However, to the extent that the Hungarian private sector borrows in euros, the cost of these loans will be influenced by euro area monetary policy.

Figure 10.1 Loans to the non-financial private sector



Source: EUROSTAT and IFS. Data for Greece, Ireland and Luxemburg are not available.

Nonetheless, even if we increase the credit stock to include loans granted by non-residents (or resident firms), we still find that the indebtedness of the non-financial sectors is lagging behind the euro-zone average and this is mainly attributable to the small scale household lending. However, it is also apparent from the figures that there was a considerable increase in this value between 1998 and 2002. The figures reported in Table 10.1 show that this growing trend has been sustained since then.

Prospects of financial deepening

In the following part of the paper, we discuss expectations of a further deepening of the Hungarian financial sector on the road to the euro based on the experience of present day euro area participating countries. This process is likely to be reinforced by the adoption of the euro.

The financial catching-up process referred to in the previous subsection is further underpinned by the convergence process and the introduction of the euro both directly and indirectly (IMF 2004). On the one hand, the process of convergence of permanent incomes and high rates of return on investment projects will boost the demand for credit in the region. On the other hand, lower nominal interest rates will push down the nominal cost of borrowing and this may in some cases be reinforced by higher equilibrium inflation rates reducing real rates. Fiscal convergence can also promote private credit growth by reducing the financing requirement of the government. The experience of non-core euro area countries suggests that the dramatic expansion of private credit could begin as early as five years before euro adoption and continue thereafter. Some region-specific factors should lessen the risk of a credit boom, such as the more advanced stage of yield convergence and greater competition in the banking sectors, making the drop in bank lending rates less abrupt. Moreover, FDI could continue to substitute for some bank borrowing.

The IMF (2004) estimated an error correction model for the euro area including bank loans to the private sector, the long-run real interest rate and per capita income on PPP. Applying the parameters obtained from this model to Hungary, it is suggested that the credit ratio was 38.4 percent below its equilibrium level in 2002 (this average value for Central European countries is 41%). Dynamic simulations in IMF (2004) reinforce the intuition that adjustment could take place very rapidly in the years to come.

Box 10.1 Empirical evidence of a stronger interest rate channel as a result of euro-driven financial deepening – the Spanish experience

The Banco de España has published some results concerning the relationship between financial deepening and the interest sensitivity of economic agents (de Molina – Restoy, 2004). Significant changes have taken place in the financial accounts of the household and corporate sector in Spain throughout the 1990's, especially in the size and composition of households' financial assets, and households have also become more indebted. The authors present the results of the formal tests carried out on the stability of parameters in the consumption and investment equations of the Spanish Quarterly Projection Model using a rolling window technique. The results suggest that the parameters of the interest rate, financial and housing wealth, user cost and cash flow have been very unstable, and increased significantly in absolute value between 1990 and 2002, which means that the wealth effect and the effect of the user cost increased significantly. Another important finding is that simulating a 200 bps rise in the short and long term interest rates with the model's parameters set for 2002 they obtained considerably larger GDP-responses than with parameters for 1990. This analysis provides some evidence in support of the assertion that increased monetary stability in the convergence period and the subsequent participation in the monetary union implies stronger income and wealth effects of monetary policy also for new member states.

The role of interest-sensitive industries

A large share of the Hungarian manufacturing output is produced in interest-sensitive industries (see Box 10.2), in which foreign presence is the most pronounced.

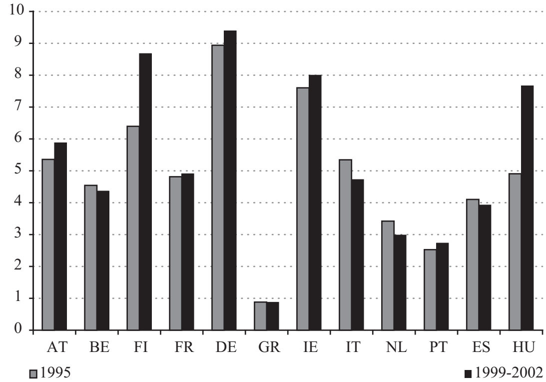
Box 10.2 Empirical evidence on interest-sensitive industries

The empirical work by Dedola and Lippi (2000, 2003) gives an estimate of the impact of an unanticipated monetary policy shock on 21 industrial sectors of 5 OECD countries using a VAR which contains industrial production, commodity prices, the price level, the money stock and the short-term interest rate. Their results confirm the hypothesis that the machinery and equipment and the motor vehicles industries (these together constitute the production of durable goods) are considerably more sensitive to interest rate movements than the average sensitivity of manufacturing to monetary policy. This finding has been confirmed by Peersman and Smets (2002). The data reported in Dedola and Lippi (2000) show that among the larger countries of the euro zone, Germany is relatively more specialized in durable goods and that manufacturing in general has a greater weight in Germany’s and Italy’s output. The update by Dedola and Lippi (2003), however, finds much smaller heterogeneity at the country level than at the level of industrial sectors as regards the impact of the single monetary policy.

Figure 10.2 shows that those industrial branches that are found in the literature to be particularly interest rate sensitive have a fairly high share in Hungarian manufacturing. Nonetheless, Hungary is certainly not an outlier, because Finland, Ireland and Germany have very similar figures.

In Hungary the large share of interest rate sensitive industries is largely attributable to the composition of FDI (see Figure 10.3), implying that these sectors are not actually sensitive to Hungarian monetary policy. In terms of the cost of capital, they may be influenced by monetary policy measures of the home country, as affiliates of foreign enterprises choose between financial markets between the two countries when it comes to raising capital. Furthermore, the goods and

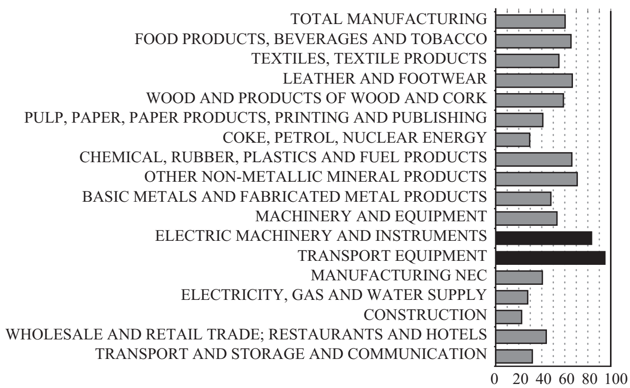
Figure 10.2 The share of interest rate sensitive sectors (machinery and equipment, motor vehicles)



Source: OECD-STAN database.

services produced by the affiliates of non-resident firms are mostly sold in foreign markets, so the demand for these goods is not sensitive to domestic monetary policy, but the monetary policy of the destination country mostly but not exclusively in the euro area. A significant portion of Hungarian exports consists of intermediate goods to be re-exported by final exporters, mostly German ones. From this we conclude that both the demand for the products of these sectors and investment into these sectors are sensitive to ECB monetary policy. This effect will increase the significance of what we will call the Hungarian interest rate channel after euro adoption.

Figure 10.3 The share of FDI as a per cent of total equity, 2001



Source: Hungarian Central Statistical Office.

The effect of macroeconomic performance in the euro area

Finally, the monetary policy of the ECB already has a third indirect, though equally important influence on the Hungarian macroeconomic performance through its impact on the euro area growth and inflation developments. As Hungary is very closely integrated with the euro area in terms of foreign trade, changes in the euro area business cycle have a strong impact on the Hungarian real economy (for recent results see e.g Darvas-Szapáry, 2004 and Benczúr-Rátfai, 2005). After euro adoption this effect may no longer be considered an 'external demand' effect, but rather as an impact of monetary policy on GDP and inflation.

10.3 The expectations channel: nominal wage developments and wage-setting institutions

The importance of the expectations channel in EMU

The development of wages is one of the most important factors determining the price level and inflation. This is because wages are not only part of the aggregate demand, but also constitute input cost of the production of goods and services. In this double role nominal wages affect price developments in the EMU and the competitive position of a participating country within the monetary union as well.[1] Wage bargaining partners tend to take into consideration the future price developments as well as the central bank's expected reactions to price and wage developments.

EMU has brought about an economic environment characterized by credible monetary stability. Thus, wage bargaining parties should be governed by expectations based on lasting price stability and the negotiated nominal wages should be in accordance with it. Negotiated wages are important, because these tend to last variously for one to three years in EMU participating countries and so insert some nominal rigidity into the economy. Negotiated wages are translated into nominal unit labour costs by productivity. The resulting economy-wide unit labour cost (ULC) development directly affects inflation. A simple rule of thumb can be applied: a nominal wage increase equal to the sum of expected inflation and rate of productivity growth is neutral for inflation. In this way nominal unit labour costs remain unchanged.[2] As price stability is defined as small but positive inflation rate (close to but below 2 per cent in EMU), ULC increasing below but close to 2 per cent could be seen as neutral for inflation on average. However, price inflation occasionally exceeds this average or medium term value and productivity also changes – sometimes unexpectedly – with changes in the economic cycle, so it is important to look at actual productivity and inflation figures for the assessment of wage developments.

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[1] Nominal wage developments are so important that some economists see it as the most decisive factor to provide an answer to the puzzle of monetary policy working in an approximately predictable way in a large group of countries despite the limited knowledge about monetary transmission. See for example Bofinger (2001), p. 114.

[2] The above is really a rule of thumb, because it does not take into account many factors that affect cost and demand conditions in an economy. In many cases, actual wage developments diverge from the negotiated wages thanks to various bonuses in case of unexpectedly strong productivity growth or promotions ('wage drift', see ECB (2002), Box 5. on p. 37. Wage contracts in most of the European countries include compensation for higher than expected inflation rates (see European Commission (2004), Table 2. on page 215. In open economies exchange rates and commodity prices are also important. On the demand side saving and investment balance, indebtedness, the government expenditures, while on the supply side taxes and the economy's cyclical position are very important for inflation. Finally, this simple formula does not take into account whether the initial level of wages had been appropriate and deviation from the rule of thumb would be justified to correct past developments.

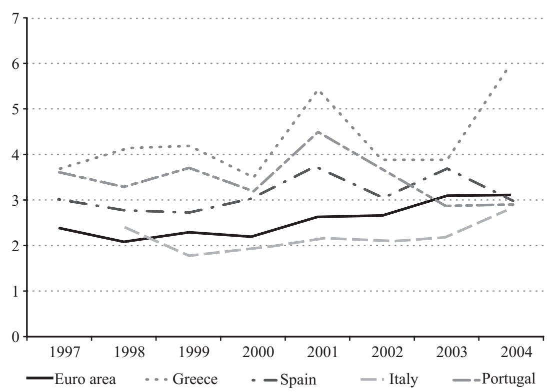
In this section we look at the more recent wage developments of selected euro area member countries to assess two risks from the point of view of Hungary's EMU participation. First, there is a concern that in Hungary's case the frequent calls for wage convergence – based on the still huge wage differential compared to EMU-average – with little regard to developments in productivity, may imply that monetary policy signals, i.e. the expectations channel of the Hungarian monetary transmission mechanism, may be weaker in Hungary than in the euro area.

Second, the wage bargaining institutions in Hungary are in a formal sense quite flexible, because there are no strong centralized wage-bargaining institutions at the aggregate or even the industry level.[3] We would like to understand its implications for expectations channel of MTM after euro adoption. Therefore we investigate the question whether the historical record on wage negotiations of their institutional setup is a strong determinant of the extent to which the wage-bargaining process in a participating country was able to adapt to the new monetary regime.

Negotiated wages and nominal unit labour costs in selected participating countries

It is interesting to look at the negotiated wages in those countries where historically the inflation rate has been higher than price stability as defined by the ECB. The following countries have been picked up on this basis: Greece, Portugal, Spain, and Italy. It is also interesting to look at wage developments in yet other countries, where inflation convergence did not pose great challenge before entering EMU, but inside EMU significant positive inflationary divergence has taken place. These countries are Ireland and the Netherlands. We have also added Finland to the other two as this country had been exposed to significant inflationary pressures.

Figure 10.4 Negotiated wages in the euro area, Greece, Portugal, Spain and Italy (per cent)



Source: European Industrial Relations Observatory (EIRO).

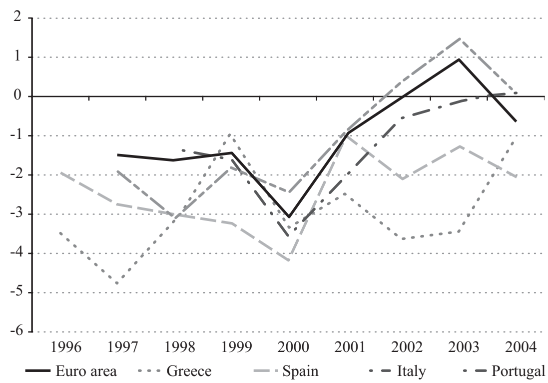
[3] See for example OECD (2004) p. 151.

There are countries formerly characterised by high inflation rates, such as Italy, where wage increases have been moderate recently. Figure 10.5 illustrates that unit labour costs exerting disinflationary effects except in the year 2003, when they became neutral for inflation.

In other countries such as Greece nominal wage increases mostly compensated only for excess inflation over the inflation rate expected at the time of concluding the wage contract (see Figure 10.4) and nominal wage increases did not exceed the sum of increase in productivity and inflation. In Greece's case it cannot be excluded that wage bargaining partners and price setters had agreed on temporary wage and price moderation aiming only to help the country to comply with the convergence criteria, and to return to higher nominal wage and price increases after entering the euro area (Figure 10.5).

In Portugal excessively high negotiated wages resulted in a boom and a sharp correction during the downturn phase and in 2003 unit labour costs were inconsistent with price stability.

Figure 10.5 Use of the scope for distribution* in the euro area, Greece, Spain, Italy and Portugal (per cent)



* *'Scope for distribution' stands for the difference between nominal wages and the sum of the increase in productivity and inflation. The expression refers to the fact that in case of zero difference, there is no change in the distributional shares in the national income between the factor owners. The terminology has been borrowed from Hein et al. (2004).*
Source: AMECO database.

In the past decade wage-setting behaviour in these countries has been consistent with price stability, with Portugal in 2003 being the only exception. This suggests that wage bargaining in previously high inflation countries adapted mostly successfully to the environment of monetary stability.

However, we also have a reverse example: the Netherlands, a country showing nominal and real wage moderation for nearly two decades, experienced excessive wage increases in both nominal and real terms after entering the euro area (see Figure 10.6).

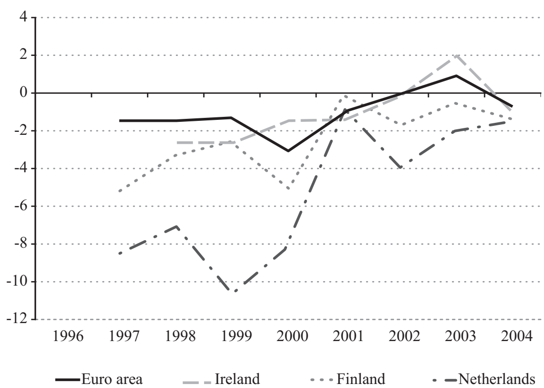
In Finland's case the excessive negotiated wages are the most modest among the three and the quickest to return to wage moderation (i. e. quicker than both in the other two smaller countries and in the euro area as a whole, see Figure 10.6). In our view Ireland's negotiated wages only reacted to external shocks in this period and was the consequence, rather than the cause of the upward pressure on the price level. Both in Ireland and the Netherlands, the wage excesses were

Figure 10.6 Negotiated wages in the euro area, the Netherlands, Finland and Ireland (per cent)

Source: EIRO.

larger than in Finland and the correction takes more time to be effected. Nonetheless, it is expected that wages will return to moderate levels by 2004 or 2005. It is interesting to see that in these three countries wage increases have been fairly moderate, if we compare them to the sum of inflation and productivity increase (see Figure 10.7), with one exception being the Netherlands in 2003.

Figure 10.7 Use of the scope for distribution* in the euro area, Ireland, Finland and The Netherlands (per cent)



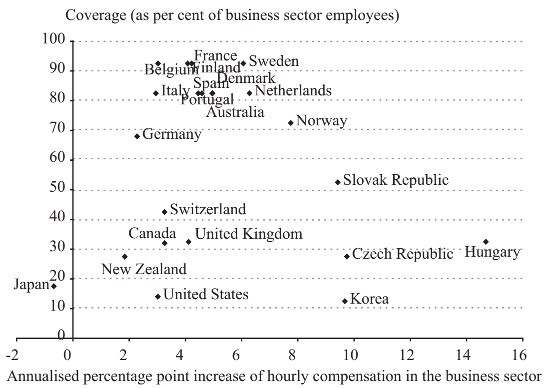
** See note to Figure 10.5.*
Source: AMECO.

Based on the evidence discussed above, there does not appear to exist a strong link between the wage-bargaining track record and the extent to which a particular country was able to adapt to a new environment of monetary stability after the adoption of the euro. This suggests that from this point of view Hungary will not necessarily experience a radically different expectations channel from that in the euro area.

Institutional factors of wage formation

Before the inception of EMU many commentators questioned the suitability of the existing European wage-bargaining institutions and labour market regulations for the monetary union. These wage-setting institutions were expected to aim at excessive wage growth, which could lead to loss of competitiveness and decreased employment because of the little scope for businesses to pass over wage premia on consumer prices in competitive European markets. According to this view, a solution to this 'excessive wage claim bias' would be to move in the direction of either total decentralisation or complete centralisation of wage-bargaining institutions.[4] In most large European countries the dominant type of wage-bargaining institution is the intermediate one. It is held in this view as having the most serious inflation bias, because it is too small to internalise all the gains from macroeconomic benefits of moderate wage developments (as the wholly centralised systems do), but is too big to take into account the consequences for competitiveness (whereas bargainers at the company level do).

Figure 10.8 Bargaining coverage and nominal compensation (2000-2002)



Source: EIRO.

The experience of the present EMU-participating countries demonstrates that the existing wage-bargaining institutions could adapt to the new realities of EMU. As seen from Figure 10.8, there is no strict relationship between the institutional arrangements and wage inflation in the period under review. We can conclude from the above, that as far as lasting price stability is concerned, present wage-setting institutions do not seem to pose a major problem in Europe.

The implications for Hungary of the experience of present participating countries before and after joining EMU are mixed. In standard theory Hungary's institutional set-up would lead to moderate wage developments. However, as we can see from the above evidence, decentralised bargaining institutions are far from being a guarantee for appropriate wage developments.

[4] This advice is based on the famous 'hump-shaped' view of wage-bargaining institutions invented by Calmfors and Driffil (1988). OECD (1997) and later studies – including Calmfors (2001) himself – found limited support for this simple and apparently compelling relationship.

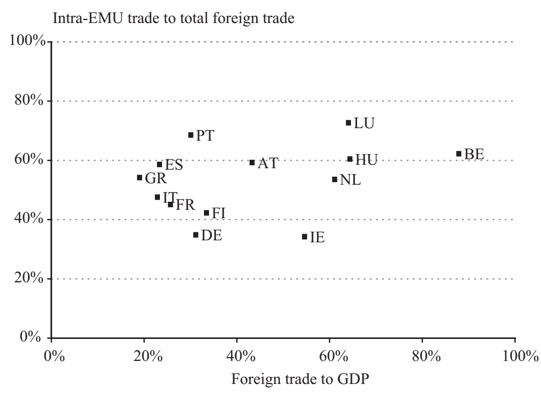
Nonetheless, there does not seem to be anything in the current Hungarian institutional set-up that inherently prevents quick and sustained wage moderation supportive to price stability and sustained long-term growth.

10.4 The exchange rate channel

An additional key concern, which was particularly strong prior to the launch of the euro, is that the loss of the exchange rate channel may not affect every country in the same way. A member state may experience markedly different monetary conditions within the monetary union due to differences in the composition of the effective exchange rate as result of a very different trade orientation. A country participating in the monetary union cannot rely on monetary policy to adapt to asymmetric shocks that might occur due to a higher degree of openness toward non-participating countries than the EMU-average. The problem is particularly important for smaller countries that have little weight in the aggregate EMU economy; hence their conditions have little effect on interest rate decisions by the ECB.

As Figure 10.9 shows, in EMU, most small countries that are characterised by a high degree of openness are fairly well integrated with the euro area as concerns their trade relationships. Two exceptions are Finland and Ireland, both of which are small and quite open economies with most economic ties linking them to outside the euro area. Among the larger countries of the euro area, Germany has a high share of extra-EMU trade in its total foreign trade, which makes it very sensitive to the euro exchange rate despite the large size and lower degree of overall openness of its economy.

Figure 10.9 Openness (the ratio of intra-EMU trade to foreign trade and foreign trade to GDP, 2003)



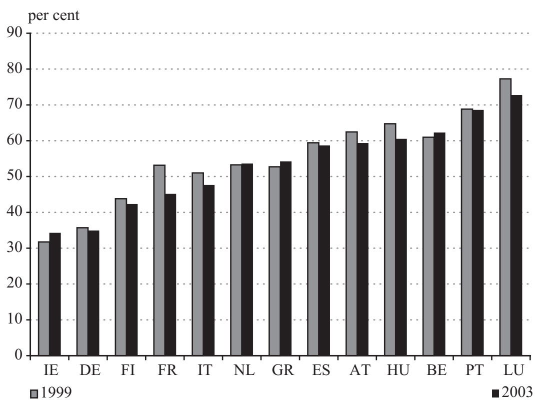
Source: IMF Direction of Trade Statistics, AMECO.

Figure 10.10 suggets that by 2003 many countries of the euro zone, especially the larger ones increased their share of trade with countries outside the currency area in total trade to above the 1999 level. This fact seemingly contradicts the general consensus which holds that the single currency should enhance trade between the countries participating in the monetary union (see e.g.

Rose 2000). This increase in extra euro area trade, however, is minor, and it is probably attributable to a number of temporary factors such as strong US demand, the rise in oil prices, greater economic integration with Central and Eastern Europe and other fast growing economies (like China) and perhaps even the weakening of the euro against the US dollar in part of this period (HM Treasury 2003). Gravity models of trade[5] and other empirical research have shown that the introduction of the euro actually promoted trade integration to a measurable extent. Micco et al. (2003) use a panel of 22 developed countries including the 12 participants of the European monetary union from 1992 to 2002 and find that EMU has not only increased bilateral trade between participating countries but also with the rest of the world.

The picture may change even more after Central and Eastern European countries have introduced the euro. The openness of Austria, Italy and Germany towards the enlarged euro area will increase disproportionately more than that of Hungary or any of the newcomers or old EMU-participants because of their closer linkages to the CEEs. We expect that this development will decrease heterogeneity across countries already in the euro area and those joining later.

Figure 10.10 The share of trade with the euro area in total trade 1999, 2003



Source: IMF Direction of Trade Statistics, AMECO.

Hungary is already one of the countries most integrated into the euro zone, even though it has not adopted the euro yet. Hungary has relatively close ties with those euro area countries that are more exposed to external shocks (e.g. Germany or Italy), but this would be gradually mitigated somewhat as more and more CEE countries adopt the euro, considering that Germany and Italy settle a substantial share of their total foreign trade with these countries. On the other hand, trade integration with the euro area is expected to be further reinforced as a consequence of full EMU-participation (as shown in the study edited by Csajbók-Csermely 2002).

[5] E. g. HM Treasury 2003.

10.5 The credit channel

A separate, so-called credit channel has been added recently to the more traditional channels of the MTM discussed above. Limitations of space and focus prevent us from discussing this channel in greater detail.[6] For our purposes suffice it to remember that it refers to various financial market imperfections (agency costs, moral hazard and adverse selection). As a result, credit markets do not always clear by attaining equilibrium prices (in this case interest rates). In this view financial intermediaries sometimes and/or vis-à-vis some sort of clients apply credit rationing instead of setting market clearing interest rates.

As this view of MTM relies heavily on imperfect financial markets, it has been seen as naturally applicable to Europe. The reason for this is that financial markets in Europe are dominated by banks and bank dominance in itself is seen as a sign of capital market imperfection. The credit channel has been further divided into balance sheet and bank lending channels. First, we start with the bank lending channel then we turn to the so-called balance sheet channel.

The bank lending channel

In the bank lending view of the MTM it is supposed that banks play a unique role in the economy: they provide credit for those clients who are not able to raise external funds from other financial intermediaries or from directly issuing securitised debt. Thus, certain sorts of clients may be rationed by their sole source of external finance, namely banks. Smaller firms and households are affected disproportionately more than the larger ones. As a consequence, the output of these clients will diminish which results in a slowdown of the economy as a whole. A related issue is that not only the size of their clients, but also the size of the bank's themselves may be crucial for credit channel. The logic behind this is similar: smaller banks are more often liquidity constrained and find it difficult to offset the tightening actions of the central bank. Some researchers refined the argument by looking for more direct indicators of potential liquidity constrain than the sheer size of a bank: direct measures like the proportion of liquid assets in total assets have proved to be significant determinants of banks' reactions to monetary tightening.

In principle, a very powerful bank lending channel could make the Hungarian MTM asymmetric compared with the euro area and its presence could be an important source of concern regarding the propagation of ECB's monetary policy measures through the Hungarian economy. However, the relevance and validity of the approach itself has been subject to fierce theoretical criticism. We think it is fair to say that most of the controversies are directed to one basic feature of the theory, namely that banks are directly constrained in their ability to lend by available liquidity on the inter-bank market and this liquidity is fully or nearly so controlled by the central

[6] The literature on the subject is voluminous. A textbook presentation of the subject and a good summary of empirical literature can be found in Walsh (1998) Chapter. 7. For a list of articles see p. 286, footnote 1 of the same book. For representative application on MTM see the conference volume of Boston Fed (Peek et al. [eds] 1995). Stiglitz and Greenwald, who were two of the earliest advocates of financial market imperfections and non-standard MTM channels nicely summarised their views in a new book, Stiglitz et al. (2003). For a more critical survey of capital market imperfections as a basis for new macroeconomic paradigm see for example Delli Gatti et al. (2001).

bank.[7] Thus, proponents of the bank lending channel found themselves in a position where they had to ignore (or deemphasise) the importance of financial innovations in circumventing quantity constraints on financial markets. Also, they had to ignore those important recent developments that have led to the use of models and operation frameworks in which monetary aggregates do not play any significant role. These new approaches are based on the short term interest rate as a key variable both as an instrument and an operating target of the central bank. The justification of a separate bank lending channel in addition to the traditional interest rate channel is equally hard empirically. Available econometric techniques are not suited to identify a separate bank lending channel which is capable to separate the demand and supply of bank loans and isolate this from the broader balance sheet channel.[8] They mostly try to find variables that could be used as instruments for the loan supply effect. However, empirical works using such roundabout ways seem to have little chance to settle the debate between researchers.

The balance sheet channel

Proponents of the balance sheet channel aim to explain the widely shared experience that smaller firms and households periodically face credit constraint when it comes to raising external funds because they cannot offer sufficient amount of collateral for creditors. In a perfect market only the expected earnings should limit the creditworthiness of banks' clients or their projects.[9] In an imperfect real world this does not seem to be the case for many categories of potential borrowers.[10] As financial market imperfections are more prevalent in the case of low net worth clients with little to offer as collateral, adverse financial conditions tend to affect smaller firms and households more heavily. In addition, the collateral value itself is dependent on the state of the economy and subject to change responding to interest rate movements. Thus, credit flows toward these clients tend to be pro-cyclical: a fall in credit supply may result from a monetary tightening also because it devalues firms' collateral base and so the more widespread is the use of collateral, the higher is the influence of interest rates on loan supply.

A corollary of non-price clearing of the market is its pronounced non-linearity. A relatively small interest rate change – e. g. an increase of policy rate by the central bank – can have large effect on real activity, depending on the initial conditions of the balance sheet of non-financial companies and households. This is also called the financial accelerator effect.[11]

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[7] See Goodhart's contribution to the volume edited by Scheffold (2002). For an empirical model and test of credit channel with the central bank targeting interest rates instead of money supply see for example Bofinger et al. (2004).

[8] See for example Walsh (1998).

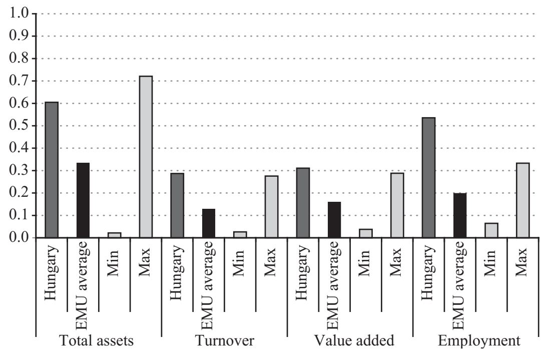
[9] In a traditional general equilibrium framework, there is no difference between internal and external sources of finance. All the relevant information about the riskiness and expected payoff of the projects are available freely to all participants. In this perfect world there is no room for debt contracts and financial intermediaries. Not even for firms, hence the use of 'projects', instead of companies. In a world with imperfect markets, not all the relevant information are readily available to all, thus, financial intermediaries – called 'banks' – emerge to gather and process the necessary information. The information collected in this way is costly, but would lose its economic value if it were available for third parties.

[10] Even if the cash flow plan is realised, the borrower may choose not to (fully) repay the credit if she thinks it is more profitable to her.

[11] See the concept in a business cycle context in Bernanke et al. (1995).

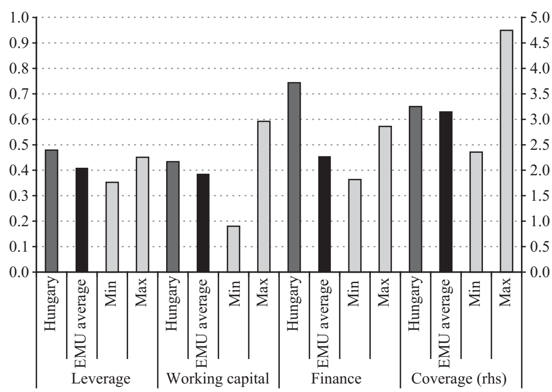
The balance sheet channel seems to be partly relevant to Hungary's case. A rough comparison of potential importance of credit rationing can be obtained by using available data on enterprise balance sheets in EMU countries and Hungary.[12] The following graph shows that in Hungary the enterprise sector consist of smaller entities than the EMU average measured by either in terms of total assets, turnover, value added or employment (see Figure 10.11). The difference between Hungary and EMU seem to be the largest in the case of employment, where the Hungarian figure exceeds well the maximum value in the EMU. In the case of the other three variables, the Hungarian value is very close (turnover and value added) to, or below (total assets) the maximum EMU figure.

Figure 10.11 Proportion of small enterprises (per cent of total)



Source: BACH and APEH databases.

Figure 10.12 Financial ratios of small enterprises



Source: BACH and APEH database.

[12] For a more detailed description of data and calculations see Appendix 2: Data on the balance sheet channel.

More direct indicators of potential financial accelerator effects can be seen from the standard financial ratios (see Figure 10.12). The differences between the enterprise balance sheets in Hungary and in the EMU participating countries does not seem to be terribly large. This is certainly true for the most important single indicator, the financial leverage ratio (Leverage).

However, the widespread opinion of the market participants seem to be supported by our calculation, namely, that Hungarian enterprises rely more heavily on short-term financing as compared to longer-term one (Finance). Thus, the two charts show that Hungarian enterprises are more exposed to short term interest rate variations, including the changes of the policy rate. However, these differences are not pronounced in general, and in the future, we can expect some convergence of these ratios to the EMU ranges and averages.

As for the balance sheet channel we may conclude that with EMU-participation, the increased macroeconomic stability should enhance creditworthiness of companies, especially if – as seems to be the case – there are significant non-linearities in credit markets. A good illustration of this is to look at the long-term segment of the credit markets: in a low inflation environment, longer term finance is much more attractive than in a volatile environment, where long-term finance may not be available at all. However, there seems to be little evidence for the existence of a bank lending channel. The banking sector is in a net excess liquidity position vis-à-vis the central bank. As in the EU – and contrary to the US – not simply the size, but the banks' liquidity proved to be the relevant indicator for bank lending activity. This aggregate net excess liquidity position of the banks probably will change into the reverse upon EMU-participation, but even in that case it would not be an indication of structural shortage liquidity position in the sense that the banks could not raise external funds in EMU financial markets. Rather, it would be a decision variable for banks based on profit motives, instead of being constraint, and could be adjusted according to business interests of banks.

10.6 Conclusions

The aim of this paper was to look at the concerns that have been voiced as regards the potentially asymmetric propagation of monetary policy measures after Hungary will have adopted the euro. These concerns are worth considering, because they point to the risks of a disruptive single monetary policy from the point of view of the Hungarian economy after euro adoption, even if the euro area and Hungary are found to constitute an optimum currency area.

In particular, we have dealt with four major issues in this paper: 1) the interest rate channel 2) the behaviour of wage-bargaining parties and wage-bargaining institutions and their responsiveness to monetary policy signals 3) trade orientation and 4) the credit channel. We have reviewed relevant stylised facts from the euro area and Hungary in order to compare the structural features affecting MTM. To formulate expectations on the changes in the Hungarian MTM after Hungary has adopted the euro we looked at the experience of present day full EMU participants.

Based on this evidence we may conclude that the risk of divergent macroeconomic performance of the Hungarian economy due to asymmetries in the monetary transmission mechanism is fairly small. First, although the interest rate channel may be weak today, we expect significant changes in its scope after euro adoption. The interest rate channel will embrace a broader set of mechanisms after euro adoption than they do today, because the ECB's monetary policy already affects the Hungarian economy through both the large size of euro-denominated loans and the high share of interest sensitive sectors which are mostly foreign owned. These sectors produce durable goods whose financing and sales opportunities strongly depend on the euro interest rate.

Furthermore, the exposure of the Hungarian non-financial sector to changes in interest rates may be greater than we would conclude from data on domestic credit to the private sector, because loans from foreign banks and firms and therefore foreign interest rates play a relatively large role in total non-financial private sector liabilities. Although the level of household borrowing at present is indeed quite low, a dynamic expansion is already underway and it is further underpinned both directly and indirectly by the convergence process and the introduction of the euro.

Last but not least, the ECB monetary policy strongly affects the euro area business cycle, which in turn affects the Hungarian macroeconomic performance. This channel is presently seen as an 'external demand' effect, but after euro adoption it will be better characterised as an impact of interest rate policy on GDP and inflation. The combined effect of these changes in the scope of the interest rate channel is relatively strengthening of this channel after euro adoption.

Looking at the experience of today's euro area countries, neither the historical record, nor the institutional setup of wage negotiations is a strong determinant of the extent to which the wage-bargaining process of a country is able to adapt to the under the new monetary regime. This suggests that there is no reason why Hungarian wage-setting behaviour could not become consistent with price stability even without change in the institutional setup. However, the evidence suggests that a decentralised system is no guarantee for wage developments consistent with price stability, either.

As for asymmetric responses to changes in the exchange rate of the euro, Hungary is likely to be much less exposed than most of the current full participants of EMU as trade relations with the euro area are very strong. This is likely to be further reinforced after Hungary (and other new Member States) will have adopted the single currency. As for the balance sheet channel, some asymmetries may continue to exist for some time between Hungary and the core euro area countries but we expect its effect to be significantly smaller after euro zone entry.

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Appendix: Data on the balance sheet channel

In an attempt to assess the potential importance of credit channel in the Hungarian economy relative to the present EMU participating countries, we tried to compare three financial ratios of the enterprise sectors. Unfortunately, there is no one single such database, which contain all the necessary data for both EMU and Hungarian enterprises. Thus, we had to use the BACH database[13] for the EMU countries and the APEH (Hungarian Tax Authority's) database for the Hungarian companies. The former database had been used by Peersman et al. (2002) to assess the asymmetric effect of financial accelerator in the monetary transmission mechanism among EMU countries.

Although the constructors and data providers of the BACH database try to make the nationally different balance sheets comparable, important differences remain. Moreover, as we have used another database for Hungarian enterprise balance sheets, the comparison with that of the BACH's is even more problematic, as accounting conventions and practices may very well differ. Another problem is that due to large differences in income levels and structural changes in the economy, the Hungarian enterprise sector seem to be undercapitalised and populated dominantly by smaller entities. Despite of this, we have decided to apply the same amount of turnover in constructing the small and large enterprise groups as used for EMU participating countries. The reason for our choice is that inside EMU Hungarian enterprises will have to operate in roughly the same financial environment as the companies of the larger EMU-participating countries. Thus, we took the 7 million euros turnover as the upper limit for small enterprises and 40 million euros as lower limit for the group of large enterprises (using the average HUF/euro exchange rate for conversion). In all cases, the time period is three years, between years 2000-2002, the latest available time period. We decided to use three years averages instead of one single year because in a few cases data have changed quite a lot from one year to another. The Hungarian sample contains all those companies that are obliged to adopt double-bookkeeping, the largest population of companies available for financial analysis.

Due to data limitations, we could obtain data for only 8 EMU participant countries: Austria, Belgium, Finland, France, Italy, the Netherlands, Portugal, Spain. No data was available for Austria and the Netherlands in calculating the proportion of small enterprises in terms of employment, so these proportions are calculated only for the remaining six countries.

The financial ratios used as indicators of potential financial accelerator channel are same as used in Peersman et al. (2002): an indicator for financial leverage (Leverage=total debt over total assets), and indicator of the demand for working capital (Working capital=ratio of working capital – which is itself equal to current assets minus creditors payable within one year less short term bank loans – over value added), another of the coverage of interest rate obligations (Coverage= gross operating profits over total interest rate payments) and finally one for indicating the need for short-term financing (Finance=ratio of short term finance to long-term finance).

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[13] See http://europa.eu.int/comm/economy_finance/indicators/bachdatabase_en.htm.

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