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THE TRANSMISSION MECHANISM OF MONETARY POLICY: ANALYSING THE FINANCIAL MARKET PASS-THROUGH

by

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The transmission mechanism of monetary policy: Analysing the financial market pass-through

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Abstract

This paper uses a structural vector autoregressive approach to identify the effects of monetary policy innovations on different sub-markets of the Icelandic financial system. This forms the first stage of the interest rate channel of the monetary transmission mechanism, with the second stage explaining the propagation of monetary policy from the financial markets to the real economy. The results indicate that an innovation to monetary policy has a significant within-the-month effect on the money market rate. The innovation is then propagated through the money market to the bond market and from there to the bank loan rate market, with the effect peaking one to four months after the initial monetary policy shock and lasting for about eight to nine months. The results suggest that the bond rate is the most important determinant of the marginal cost of loan funding. This could be explained by mark-up pricing of loans over deposits with some type of adjustment costs explaining the sluggish response of the bank loan rate to shocks in the marginal cost of loan funding.

Keywords: Monetary policy transmission mechanism,
Financial market pass-through, Structural VAR models
JEL Classification: E52, C32

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1. Introduction

A successful implementation of monetary policy requires an accurate assessment of how fast the effects of policy changes propagate to other parts of the economy and how large these effects are. This requires a thorough understanding of the mechanism through which monetary policy affects economic activity. The process that describes how changes in monetary policy propagate to other parts of the economy is called the transmission mechanism of monetary policy. It describes how changes in policy transmit through the financial system, via financial prices and quantities, to the real economy, affecting aggregate spending decisions of households and firms, and from there to aggregate demand and inflation.

Given the paramount importance of the transmission mechanism for the understanding of monetary policy it is surprising that, until very recently, relatively little effort has been invested in understanding exactly how the transmission mechanism works. In the words of Bernanke and Gertler (1995, p. 27):

> "[T]he same research that has established that changes in monetary policy are eventually followed by changes in output is largely silent about what happens in the interim. To a great extent, empirical analysis of the effects of monetary policy has treated the monetary transmission mechanism itself as a 'black box'."

The transmission mechanism logically involves two stages. The first stage involves the propagation of changes in monetary policy through the financial system. This stage of the transmission mechanism explains how changes in the market operations of central banks transmit through the money market to markets which directly affect spending decisions of individuals and firms, i.e. the bond market and the bank loan market. This involves the term structure, through which short-term money market rates affect longer-term bond rates, and the marginal cost of loan funding, through which bank loan rates are affected. The second stage of the transmission mechanism involves the propagation of monetary policy shocks from the financial system to the real economy. This explains how monetary policy shocks affect real production and aggregate prices. It seems obvious that in order to fully understand the transmission from central bank actions to the real economy, the first stage needs to be fully understood.[1]

This paper concentrates on the first stage of the transmission mechanism. Furthermore, the paper focuses only on a particular part of the transmission

[1] The interest rate channel discussed here represents only one of many channels through which monetary policy affects the economy. Other channels are the exchange rate channel, the asset price channel and the credit channel. For a survey of the transmission mechanism, see the Fall issue of the *Journal of Economic Perspectives*, 1995.

mechanism, namely the interest rate channel. This implies that other important transmission channels, such as the exchange rate channel, which should be of great importance for a small open economy such as Iceland, are not considered. However, given Iceland's small size and the considerable weight on exchange rate stabilisation in domestic monetary policy, one could expect that world market interest rate shocks would influence interest rate determination in Iceland. Given that capital movements were only fully liberalised in 1995, and the fact that it is only in the last few years that foreign interest rates have started to play a role in Icelandic monetary policy, detecting this effect in the data sample used here might be difficult. In fact, adding a foreign money market rate (using a trade weighted foreign rate) to the analysis did not alter the results of the paper as the foreign rate was found statistically insignificant in the analysis for the other interest rates used. This should, however, not be interpreted as implying that world market interest rates play no role in Iceland.

To analyse the dynamic effects of monetary policy shocks on the money and bond markets and on bank loan rates the paper uses a structural vector autoregressive (SVAR) approach. The basic idea of the SVAR approach is to impose minimal theoretical restrictions on the data to identify the underlying structural shocks of interest, in this case monetary policy shocks. Note, however, that the analysis in this paper, as in all other studies using the SVAR approach, deals only with the effects of the non-systematic part of monetary policy. Thus, the paper analysis the effects of unforeseen monetary policy actions which cannot be attributed to the monetary policy authority's reaction function.

Most of the SVAR literature on monetary policy shocks has concentrated on the second stage of the transmission mechanism. To name only few, see Bernanke and Blinder (1992), Christiano, Eichenbaum and Evans (1996b), Leeper, Sims and Zha (1996) and Gordon and Leeper (1994) for the US, and Sims (1992), Gerlach and Smets (1995) and Fung and Kasumovich (1998) for cross country analyses; see Christiano, Eichenbaum and Evans (1999) for a survey. Studies available, using the SVAR framework for analysing the first stage of the transmission mechanism, are Amisano, Cesura, Giannini and Seghelini (1997) and Redward and Saarenheimo (1996) for Italy and Finland, respectively.

Central to any analysis of the effects of monetary policy changes is the identification of monetary policy shocks. The ideal measure of monetary policy would be one that is under direct control of the central bank and is, in the short run, unaffected by changes in the demand for money. Early studies of the transmission mechanism, such as Sims (1986), used monetary aggregates, while later studies have tended to use measures that are under more direct control of the central bank, such as non-borrowed reserves (Strongin, 1995 and Christiano, Eichenbaum and Evans, 1996a), or some short-term interest rate under control of the central bank (Bernanke and Blinder, 1992 and Sims, 1992).

The choice between these measures of monetary policy obviously depends on the strategy and operating procedures of the central bank. For banks which conduct monetary policy by targeting the liquidity of the financial system, measures such as narrow money or reserves seem appropriate. For central banks which use the interest rate on loans from the central bank to the financial system as the target variable, the appropriate measure of monetary policy is this target rate.

The period analysed here ranges from 1993 to 2000 and represents a period where the Central Bank of Iceland has used the rate on 14 days repurchase agreements between the bank and other financial institutions as the main policy instrument. The appropriate measure of monetary policy is therefore the repo rate. The paper uses three other interest rates, each representing an important sub-market of the Icelandic financial system; the money market, the bond market and the bank loans market.

The remainder of the paper is organised as follows. Section 2 briefly discusses the structural features of the Icelandic financial system relevant for this study, the sample period chosen, and the data and its main features. Section 3 describes a simple model for initial identification of the contemporaneous correlation between the different financial markets. Section 4 reports the main results and interprets the final structural model used for dynamic simulation of different financial market shocks. The final section concludes.

2. The Data and Some Institutional Features

A critical problem in all SVAR analyses is the choice of information set used. Given the relatively small sample size used here and the well known over parameterisation problem of VAR models, a small information set is necessary. However, the need to give sensible answers to questions being raised requires the information set to include variables that summarise the main features of the financial system being studied. The choice of variables in the information set is therefore mainly guided by considerations of the institutional features of the Icelandic financial system.

For the purposes of the analysis in this paper, the Icelandic financial system can be divided into four main groups, or sub-markets. The first group contains policy rates, i.e. those rates directly controlled by the Central Bank. The most obvious choice for the period analysed here would be the 14 days repo rate (r_t), which is the rate on repurchase agreements between the Central Bank and other financial institutions. This is the rate the Central Bank uses to regulate the liquidity of the financial system and, for the most part of the period, reflects the stance of monetary policy.

The second group is the money market, which transmits changes in monetary policy to other parts of the financial system. The rate used to represent this sub-market is the three month treasury bill rate (m_t). The treasury bill rate was chosen on the basis that this is the only available money market rate for the whole period and the most important money market rate for the largest part of the period analysed here.

The two last markets play the role of propagating monetary policy shocks to the real economy. The first is the bond market, which many large firms and government institutes use to finance their expenses. There are many rates that could be used to represent this market. The one that was finally chosen was the rate on indexed five year government bonds (g_t).[2] The last sub-market is the bank loan market, where most consumer and small firm financing takes place. The rate used here is the average rate on indexed loans by deposit money banks (b_t). The rate on indexed loans was preferred to the rate on non-indexed loans since most longer maturity loans are indexed (in 1999 67% of outstanding loans were indexed).[3]

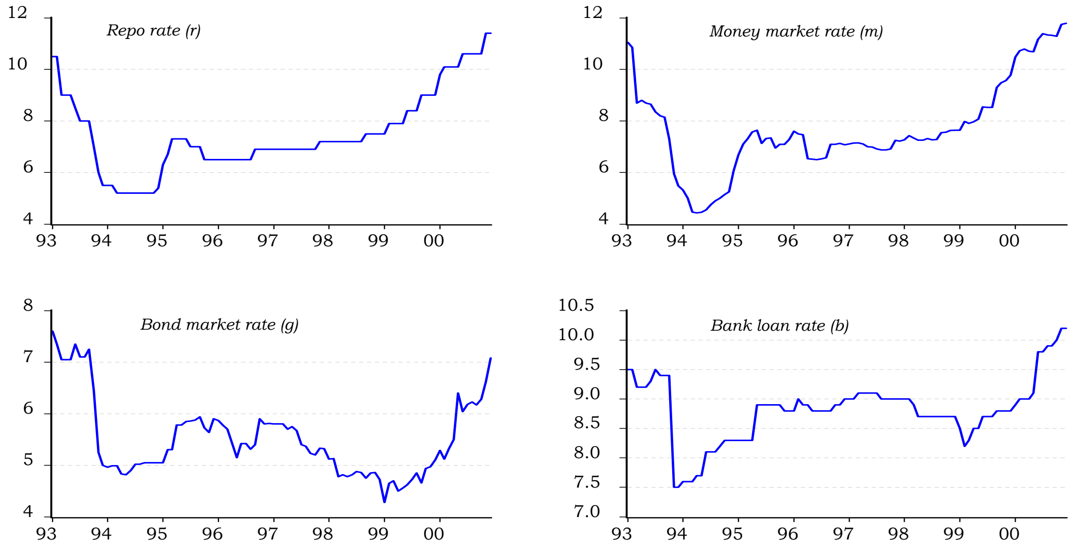

Figure 1. The financial market data (in percentage)

The data used in this paper spans the period January 1993 to December 2000.

[2]A large majority of the bond market in Iceland is indexed. In 1999 indexed government bonds accounted for 86% of total market value of government bonds.

[3]From March 4 1998 the repo rate is the yield on the money market auctions. Before that it is the yield on tap sales. The 3 month treasury bill rate is the Central Bank's bid rate on the Iceland Stock Exchange. The bond rate is the bid rate on 5 year indexed government bonds on the Iceland Stock Exchange. All the data are end of month and are obtained from various publications of the Central Bank of Iceland's *Quarterly Bulletin* and *Monetary Bulletin*.

The reason for not starting earlier is that before 1993 the money market was practically non-existent. Furthermore, the period after 1993 represents a time span of low inflation and relatively homogenous monetary policy. It is therefore considered appropriate to start the analysis in 1993.

The data is plotted in Figure 1. The first thing to note is the somewhat stepwise behaviour of the repo rate and (to a lesser extent) the bank loan rate. This could create problems for the VAR analysis, such as the assumption of normality. The second thing to note is the large downward shift in late 1993. This is due to a structural change in financial market regulation introduced at that time. This is discussed in more detail below. The final thing to note is the steep rise in all rates during the last two years of the sample. This reflects the tight monetary policy stance during this period, attempting to contain an economic boom and rising inflation.

3. Identification of the Transmission Mechanism

3.1. The initial contemporaneous identification structure

Since monetary policy actions are executed directly through changes in the repo rate, innovations to that rate should provide an acceptable measure of monetary policy shocks. Hence, following e.g. Bernanke and Blinder (1992) and Sims (1992) this paper identifies monetary policy shocks (ε_{rt}) as the innovations in the repo equation of the VAR model. This implies that the contemporaneous values of the other rates are not in the information set of the Central Bank when monetary policy decisions are made. This does, however, not imply that the Central Bank does not look at the development of the other interest rates when forming monetary policy. It only implies that the bank does not respond contemporaneously to shocks to these rates. This could be due to high frequency noise in these market rates which the bank avoids looking at. Thus, the bank only reacts to lower frequency movements in these rates, as summarised by its lags in the policy equation. Similar ordering is also assumed in Evans and Marshall (1998), who assume that long interest rates respond contemporaneously to the policy rate but not vice versa. The validity of the ordering used here is tested below.

Innovations in monetary policy have a direct impact effect on the money market rate through the term structure of interest rates which, according to the expectations hypothesis, gives the longer term rate as an average of current and future expected shorter term rates. Hence, the contemporaneous relationship between the innovations in the money market rate and the monetary policy rate is given as

$$e_{mt} = \alpha e_{rt} + \varepsilon_{mt}, \tag{3.1}$$

where e_{mt} is the innovation to the money market rate, $e_{rt} = \varepsilon_{rt}$ are the monetary policy shocks and ε_{mt} is a structural shock affecting the money market. This could, for example, represent a time-varying term premium, new information concerning short-term inflation affecting the money market auctions or foreign money market rate shocks.

The simplest way to model the bond market is again through the expectations hypothesis. As there are two short rates used in the analysis here, the initial identification scheme allows both to directly affect the bond rate.[4] Hence, in terms of innovations this suggests the following contemporaneous relation

$$e_{gt} = \beta e_{rt} + \phi e_{mt} + \varepsilon_{gt}, \tag{3.2}$$

where e_{gt} is the innovation to the bond rate and ε_{gt} is a structural shock to the bond rate. Since the government bond rate used here is on indexed bonds, these shocks are mainly real shocks. These could, for example, reflect a time-varying term premium, shocks to government spending, shocks to the net savings position of the economy or changes in expectations of the overall performance of the economy.

The simple expectations hypothesis implies that all the relevant information on r_t needed to price the long-term bond should be contained in the longer-term rate, m_t. Hence the expectations hypothesis would suggest that $\beta = 0$. This is obviously a testable restriction. $\beta \neq 0$ would suggest that monetary policy innovations have an independent and direct affect on long-term bonds which is not reflected in the money market rate.

Finally, according to the monopolistic competition model of banking (cf. Klein, 1971 and Hannan and Berg, 1991), the bank loan rate should be related to the marginal cost of loan funding. In terms of innovations this would imply the following relation

$$e_{bt} = f(e_{mct}) + \varepsilon_{bt}, \qquad f' > 0,$$

where e_{bt} is the innovation to the bank loan rate, e_{mct} is the innovation to the marginal cost of loan funding and ε_{bt} is a structural shock to the bank loan market,

[4] The fact that the bond rate is the rate on indexed bonds complicates the relationship between the money market and bond rates. However, in the presence of short-term price stickiness and some substitutability of indexed and non-indexed bonds, a positive temporary relationship between m_t and g_t should be expected. Short-term price stickiness will ensure that a rise in money market rates will induce a temporary rise in real rates, including rates on long-term non-indexed bonds. This will also induce a rise in yields on indexed bonds if there is some substitutability between indexed and non-indexed bonds.

which could represent shocks shifting the loan demand schedule or shocks affecting the profitability of the banking sector, such as changes in their pricing strategy, changes in bank regulations or changes in perceived banking sector risk.

To measure the marginal cost of loan funding it is standard to use the money market rate. However, given that most loans in Iceland are long-term indexed loans, the long-term bond yield could contain important information on the marginal cost of loan funding. Furthermore, if bank deposits compete with government bonds for individual savings, the development of the yield on government bonds could have a direct effect on returns on bank loans through the mark-up pricing of monopolistic banks.

Finally, Cottarelli and Kourelis (1994) and Borio and Fritz (1995) suggest that monetary policy rates can have direct temporary effects on bank loan rates. If banks face uncertain withdrawals of deposits or if the domestic money market is undeveloped, central bank financing can be an important determinant of the marginal cost of loan funding. Furthermore, in the presence of monopolistic pricing of bank loans, the policy rate can act as a convenient reference rate since it may be a better indicator of general market conditions than the money market rate, particularly if the money market rate is very volatile.

A simple, linear relation for the bank loan rate innovation is therefore given as

$$e_{bt} = \rho e_{rt} + \mu e_{mt} + \gamma e_{gt} + \varepsilon_{bt}, \tag{3.3}$$

where $f(e_{mct}) = \rho e_{rt} + \mu e_{mt} + \gamma e_{gt}$ is the innovation to the marginal cost of loan funding.

It should be noted that the initial identification of the structural relations given in (3.1)-(3.3) is only thought of as a starting point. The final analysis gives the structural relations after insignificant channels of propagation have been deleted.

3.2. The structural VAR representation

The aim of this paper is to identify the four structural shocks from (3.1)-(3.3) and to analyse the propagation mechanism of innovations to these shocks in the four sub-markets of the financial system in Iceland. To do that one has to identify these shocks from the data. This can be done as follows.

Let x_t denote a $n \times 1$ vector of variables of interest at time t (the vector $(r_t, m_t, g_t, b_t)'$ in our case). A simple VAR model for x_t is given as (disregarding deterministic variables to simplify the exposition)

$$C(L)x_t = e_t, \qquad C_0 = I, \qquad E(e_t e_t') = \Sigma, \tag{3.4}$$

where $C(L)$ is a polynomial in the lag operator, $L^s x_t = x_{t-s}$, and e_t is a $n \times 1$ vector of one-step-ahead linear forecast errors in x_t given information on lagged values of x_t. Equation (3.4) is a reduced form relation and is of little inherent interest, except for forecasting purposes. What is of interest is the set of structural relations leading to (3.4). The purpose of the SVAR analysis is to exploit economic restrictions to draw inference about these structural relations from consistent estimates of $C(L)$ and Σ.

These structural relations are simply given as

$$A(L)x_t = \varepsilon_t, \qquad E(\varepsilon_t \varepsilon_t^{'}) = \Omega = \mathrm{diag}(\omega_j^2), \tag{3.5}$$

where ε_t is an $n \times 1$ vector of behavioural shocks, that are mutually and serially independent by assumptions. As shown, for example in Bernanke (1986) and Sims (1986), if current and past ε_t and x_t span the same space, the two expressions imply a mapping from the VAR innovations e_t to the behavioural shocks ε_t

$$A_0 e_t = \varepsilon_t, \tag{3.6}$$

where A_0 identifies the contemporaneous correlations among the variables in the system. This implies the following restrictions on the covariance structure of the VAR innovations

$$\Sigma = A_0^{-1} \Omega A_0^{-1'}. \tag{3.7}$$

There are $n(n+1)$ parameters in A_0 and Ω that need to be estimated, whereas there are only $n(n+1)/2$ parameters in Σ. To identify the structural model, $n(n+1)/2$ restrictions therefore need to be imposed on A_0. Normalising the diagonal in A_0 to unity gives $n(n-1)$ restrictions, leaving $n(n-1)/2$ parameters in A_0 to be estimated.

Here $n = 4$, thus needing $n(n-1)/2 = 6$ restrictions on the contemporaneous correlations for identification of the four structural shocks. These six restrictions are given by the simple model described in (3.1)-(3.3). In fact they lead to a Wold causal chain structure between the VAR innovations and the structural shocks which gives A_0 as a lower triangular matrix

$$A_0 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ -\alpha & 1 & 0 & 0 \\ -\beta & -\phi & 1 & 0 \\ -\rho & -\mu & -\gamma & 1 \end{pmatrix}, \tag{3.8}$$

providing the six necessary restrictions for identification.[5]

[5] A Wold causal chain is also used in Amisano *et al.* (1997) to identify the financial markets transmission mechanism.

As mentioned above, the Wold causal chain is only used as a first step in identifying the causal ordering among the different sub-markets of the financial system and the transmission mechanism of monetary policy across the rate of returns on these markets. The next step involves deleting insignificant channels in the ordering given in (3.8), leading to an over-identified system, which can be estimated by full information maximum likelihood and allows for statistical testing of the validity of the identification scheme, see Amisano and Giannini (1997). The final identification scheme is therefore closely related to the identification approach suggested by Bernanke (1986).

Furthermore, by over-identifying the system it is possible to investigate alternative channels of transmission, such as intra-monthly feedbacks from the lower ordered rates to the policy rate, which generate non-zero elements above the diagonal in A_0 in (3.8).

4. The Empirical Results

4.1. The reduced form VAR

The starting point of the multivariate analysis is the reduced form VAR in (3.4) of lag order k, augmented with a vector of constants and dummy variables. There are three impulse dummies in the system capturing the most dramatic exogenous shocks not accounted for by the information set used here. All the impulse dummies are unity in a given month and zero elsewhere.

The first impulse dummy is for November 1993, accounting for the effects of changes in the liquidity ratio rules of the Central Bank on November 1, and the changes in the provisions on required reserves and the liquidity ratio on November 8. The second impulse dummy is for April 1996, accounting for the effect of the contractionary policy of the Central Bank on April 10, when the bank reduced its offer on treasury bills without changing the repo rate. This was possible due to the market power of the Central Bank in the money market at that time. The third dummy variable is for May 2000, when market making in the government bond market was temporarily halted, leading to a significant rise in the government bond rate. The reason was that a continuing surplus on the government account had led to increased uncertainty in the bond market with market makers complaining about insufficient information on future issues of government bonds.

The model is estimated in levels with monthly data for the period 1993:1 to 2000:12, with the k initial observations taken as given. The lag order of the VAR is determined using a sequence of likelihood ratio (LR) tests of the significance of each lag and two information criteria. A maximum of six lags was considered in order to preserve a reasonable number of degrees of freedom. The LR-test

Table 1. Specification of the VAR

Panel A. Lag specification of the VAR

Lag	AIC	SIC	$\log L$	$\chi^2_{lag}(16)$
$k=1$	-2.752	-1.863	155.84	–
$k=2$	-2.976	-1.642	181.92	0.000
$k=3$	-2.837	-1.059	191.69	0.448
$k=4$	-2.962	-0.740	213.32	0.001
$k=5$	-2.816	-0.150	222.75	0.611
$k=6$	-2.758	0.352	236.12	0.300

Panel B. Misspecification tests for the VAR(4)

Series	$F_{ar1-1}(1,71)$	$F_{ar1-6}(6,41)$	$F_{arch1}(1,47)$	$\chi^2_n(2)$
r_t	0.958	0.210	0.732	0.001
m_t	0.784	0.755	0.469	0.028
g_t	0.716	0.992	0.830	0.035
b_t	0.470	0.930	0.817	0.000
	$F_{ar1-1}(16,199)$	$F_{ar1-6}(96,180)$		$\chi^2_n(8)$
System	0.754	0.470	–	0.000

AIC is the Akaike information criteria and SIC is the Schwarz information criteria. $\log L$ is the log-likelihood function. The χ^2_{lag} is a LR-test for lag order equal to k against the alternative of lag order equal to $k+1$. The table reports p-values for the null hypothesis adjusted for degrees of freedom (Sims, 1980). F_{ar1-j} is a Lagrange multiplier (LM) test for j-order autocorrelation in the residuals. F_{arch1} is Engle's LM-test for first order autoregressive conditional heteroscedasticity in the residuals. χ^2_n is the Doornik and Hansen test for normal residuals. The table reports p-values for a given test in each equation and the system as a whole.

statistics and the information criteria are given in Panel A of Table 1.

The LR-test sequence indicates that the minimal lag order is four, whereas AIC suggests two lags (although the AIC value for $k=4$ is not far behind) and SIC only one. These more parsimonious systems are, however, found to be inadequate since a significant autocorrelation was detected in the residuals.[6] Based on these results a lag order of four was chosen.

Panel B of Table 1 reports a number of misspecification tests for the VAR(4) model. The test statistics for residual autocorrelation and heteroscedasticity do not indicate any misspecification, but the test for normality of the residuals rejects normality of the m_t and g_t residuals at the 5% critical level and at a lower critical level for the two other residuals. Thus, there is evidence of non-Gaussian errors

[6] The impulse response functions were, however, more or less identical.

in all equations, especially in the r_t and b_t equations. The tests imply fatter tails than is consistent with the normal distribution. This is a common finding when using financial market data. The failure of normality is, however, not considered too severe a problem for the VAR analysis as there is no evidence of a single, or few, large residuals dominating the estimation results.

4.2. The structural form VAR

4.2.1. The Wold causal chain

Figure 2 reports the impulse response functions for a one standard deviation innovation to the four structural shocks for a three year horizon, with asymptotic 95% confidence intervals, using the Wold causal chain from (3.8).[7] As this model is only used as an initial step in the identification of the structural model, the interpretation of the impulse responses is relegated until later. The purpose of the section is to identify potential over-identifying restrictions to be imposed in the final formulation of the system.

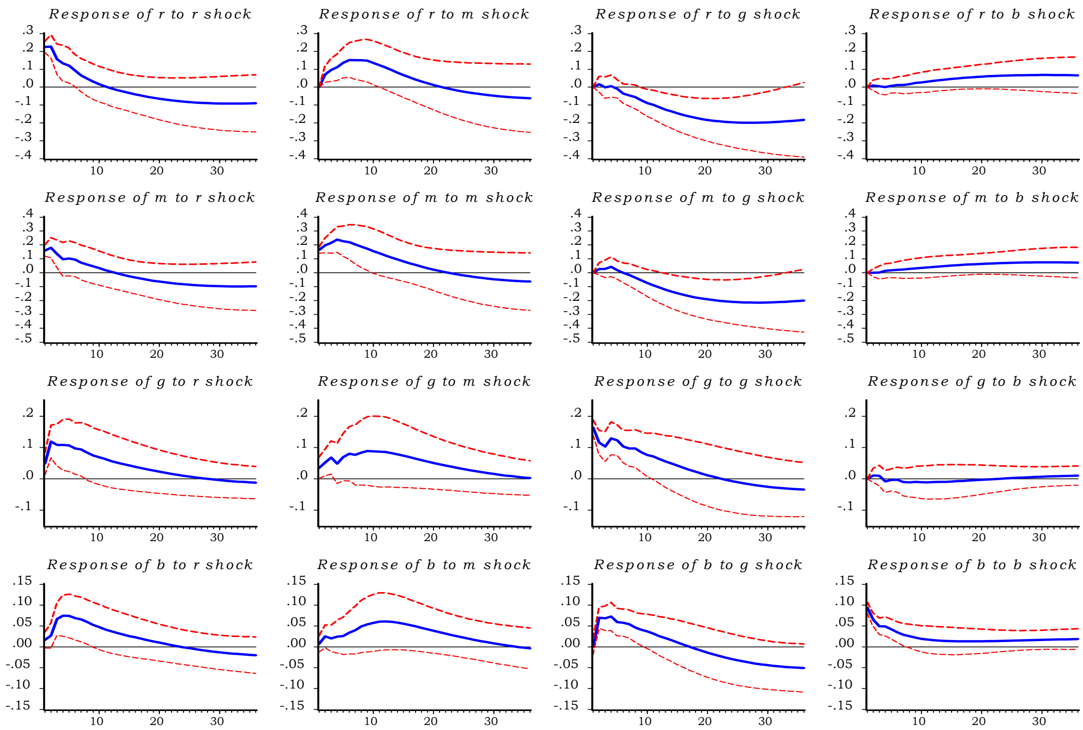

Figure 2. Impulse response functions estimated from the Wold chain

[7]Using Monte Carlo simulations to calculate the confidence bands gave practically identical results.

Table 2. Estimates of over-identified A_0

Parameter	Estimate	Standard error
α	0.708	0.07
β	0.066	0.10
ϕ	0.216	0.10
$H_0 : \rho = \mu = \gamma = 0$	$\chi^2(3) = 3.389$ $(p = 0.335)$	

The Wold causal chain clearly implies that the bank loan rate does not respond to monetary policy shocks within the month, implying that $\rho = 0$ in (3.8). Furthermore, the bank rate does not seem to respond to shocks in the money or bond markets within the month, implying that μ and γ are also zero. This implies a sluggish price strategy for banks in which bank loans respond to changes in the marginal cost of loan funding with a lag. These results therefore suggest at least three potential over-identifying restrictions that can be imposed on the structural model.

4.2.2. The over-identified structural VAR

Table 2 reports the parameter estimates of the over-identified system imposing the three restrictions on the bank loan rate equation.

The over-identifying restrictions are easily accepted. α and ϕ are significant from zero but not β. This is consistent with the simple expectations hypothesis interpretation which suggest that all the information on the short-rate dynamics should be contained in the money market rate.

Thus, the final analysis imposes four over-identifying restrictions of sluggish bank loan responses to innovations in the marginal cost of loan funding and no direct contemporaneous impact effect from the policy rate to the bond rate. This gives the over-identifying structure of the transmission mechanism as

$$A_0 = \begin{pmatrix} 1 & 0 & 0 & 0 \\ -\alpha & 1 & 0 & 0 \\ 0 & -\phi & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}. \tag{4.1}$$

Table 3 reports the final estimate of the over-identified system with the estimated standard deviations of the structural shocks in Ω. The over-identifying restrictions are again easily accepted. The results imply that a monetary policy shock only affects the bond market rate through the money market rate and has no within-the-month affect on the bank loan rate. The point estimates of the simultaneous correlations imply that a 100 basis point innovation in the repo rate

Table 3. Final estimates of over-identified A_0 and Ω

$e_{rt} = \varepsilon_{rt}$	$\omega_r = \underset{(0.01)}{0.225}$
$e_{mt} = \underset{(0.07)}{0.708}\, e_{rt} + \varepsilon_{mt}$	$\omega_m = \underset{(0.01)}{0.164}$
$e_{gt} = \underset{(0.07)}{0.262}\, e_{mt} + \varepsilon_{gt}$	$\omega_g = \underset{(0.01)}{0.163}$
$e_{bt} = \varepsilon_{bt}$	$\omega_b = \underset{(0.01)}{0.094}$

$\chi^2_{or}(4) = 3.790\ (p = 0.435)$

Asymptotic standard errors are in parenthesis. ω_j is the standard deviations of structural error j, $j = r, m, g, b$. χ^2_{or} is a LR-test of the over-identifying restrictions.

leads to a 71 basis point increase in the money market rate within the month. This leads to a contemporaneous 19 ($= \alpha\phi$) basis point rise in the bond rate through changes in the money market rate. The estimates of the standard deviations of the structural shocks suggest a typical monetary policy shock of 23 basis points, with the standard deviations of the other innovations ranging from 9 to 16 basis points.

According to the simple expectations hypothesis of the term structure, the contemporaneous weight on the repo rate in the treasury bill rate equation should be 1/6, since the repo rate is a 14 day rate and the treasury bill rate a three month rate. Hence, according to this hypothesis a 100 basis point shock to the repo rate should lead to a 17 basis point change in the treasury bill rate if the future expected repo rate remains unchanged. The estimate of α in Table 3 thus indicates that a typical 100 basis points innovation in the repo rate leads to a 54 basis point upward revision in the future expectations of the repo rate over the next 2.5 months. If the change in the repo rate was expected to remain permanent, the treasury bill rate should change proportionally to shocks to the repo rate. Thus, the estimate of α implies that the future expected repo rate shifts up after an innovation to the current repo rate and then converges down again towards its steady state value.

It is more difficult to interpret ϕ since the bond rate is a rate on an indexed bond, whereas the money market rate is a nominal rate. The relationship will therefore include both current and future expected nominal interest rates and inflation rates. However, from the maturity structure of these rates, it is clear that the simple expectations hypothesis would attribute only 5 basis points of a 100 basis points innovation in the money market rate directly to the current money market rate (as the bond rate has a maturity of 60 months), if the future expected money market rate and current and future expected inflation remain unchanged. 21 basis points of the 26 basis point estimate, would therefore be attributed to changes in expected future money market rates and current and future expected inflation rates.

Finally, in the loan rate equation, no significant contemporaneous effects from the alternative measures of the marginal cost of loan funding are found. Hence, one has to look at the dynamic responses of the loan rate to different financial market shocks to obtain the most important measure of the marginal cost of loan funding.

Figure 3 reports the final estimates of the impulse response functions for a one standard deviation innovation to the four financial market shocks. These impulse responses are very similar to those from the Wold causal chain, which is not surprising considering how easily the over-identifying restrictions were accepted.

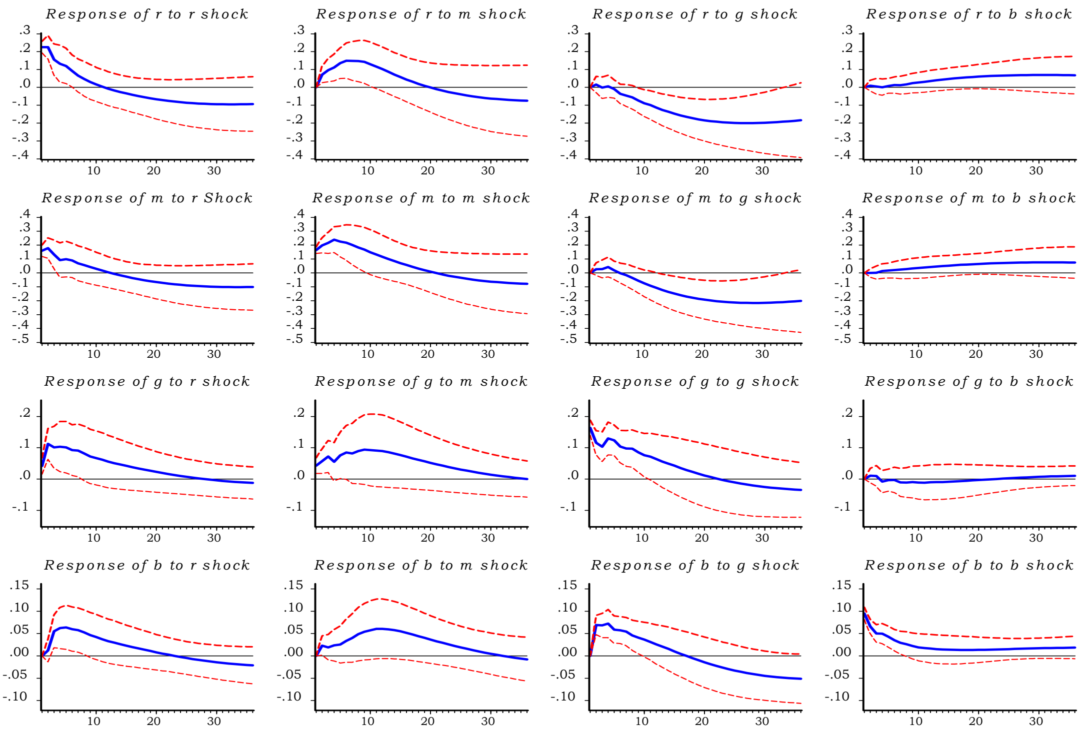

Figure 3. Impulse response functions estimated from the over-identified system

First consider a monetary policy tightening. This is reflected in a rise in the repo rate, which subsequently falls smoothly towards the initial steady state, so within six months approximately half of the initial innovation has disappeared. As expected, the money market rate increases at impact with the effects peaking after one month and lasting for one year. The 95% confidence interval indicates that the effect lasts significantly for three months. The results imply that the spread between the money market rate and the repo rate falls initially, since the effect on the repo rate is more pronounced, but rises subsequently towards its initial steady state. This pattern is roughly consistent with the simple expectations hypothesis of the term structure. Since the market believes that the shorter-term repo rate will decline gradually back to the initial steady state value, the initial rise in the money market rate should be smaller than the rise in the shorter-term rate. Thus, the spread should fall initially and rise subsequently towards the initial steady state, as found here.

As implied by the over-identifying restrictions in Table 3, the monetary policy shock does not have significant direct impact effect on the bond market. Rather, the policy shock passes through the money market to the bond market, with the bond rate rising at impact. The impact of the shock peaks after one month and significantly lasts for about eight months. This suggests some form of short-term price stickiness, since the bond rate is on indexed bonds, and some substitutability between indexed and non-indexed bonds. Hence, a rise in the repo rate induces a temporary rise in real returns on longer term bonds through the money market rate. Finally, following a monetary policy shock the bank loan rate significantly starts rising after two months, with the effect of the monetary policy tightening peaking after about four months and significantly lasting for about nine months.

The second column shows the dynamic response to a money market shock. The repo rate rises in response to a money market shock, suggesting a policy reaction function where the policy rate reacts to the money market shocks with a lag, with an effect lasting for about a year. An example of such a shock could be news about short-term inflation or foreign money market rates, which the Central Bank would offset by raising the repo rate, through its policy reaction function. The bond market rate rises at impact with significant effects lasting for six months after the shock. Finally, the bank loan rate does not respond significantly to money market shocks.

The third column shows the effects of a bond market shock. The repo rate starts significantly falling after about nine months, suggesting that the Central Bank tries to offset real interest rate shocks in setting monetary policy. This could reflect new information on the performance of the economy reflected in higher than expected real rates. The bank would thus lower its policy rate to ease the stance of monetary policy. The corresponding fall in the money market rates reflects the lowering of the repo rate. The figure indicates that following a bond market shock the bank loan rates starts rising after one month with significant effects lasting for ten months.

The final column shows the effect of a bank market shock. This shock has no significant effects on the other three rates, suggesting that the other market rates can be treated as exogenous with respect to the bank loan rate.

The results indicate that the main determinants of the marginal cost of loan funding are the monetary policy rate and the bond rate. There does not seem to be any significant effects from the money market rate. This could be explained by mark-up pricing of banks of loans over deposits which compete for individual savings with government bonds. This could also reflect the fact that the both rates are long term indexed rates. The potential direct effect from the monetary policy rate on the loan rate could be explained by the importance of Central Bank funding for the banks as the money market was rather undeveloped for the main period used in this analysis.

Since there is no significant feedback from the bank loan rate to the other markets, the relative importance of the repo rate and the bond rate can be analysed in a simple regression framework. This basically boils down to a Granger causality testing procedure where the following regression is run (the lag length is the same as in the VAR analysis above)

$$b_t = \theta(L)b_{t-1} + \kappa(L)r_{t-1} + \lambda(L)g_{t-1} + \text{constant and dummies} + u_t.$$

Using a LR-test for $\kappa(L) = 0$ gives a p-value of 0.10, whereas the test statistic for $\lambda(L) = 0$ gives a p-value of 0.00. This suggests that the main determinant of the marginal cost of loan funding is the bond rate rather than the repo rate, although there is weak evidence of effects from the repo rate. Hence, the dynamic effects of monetary policy shocks on the marginal cost of loan funding seem to work mainly through the bond market rate.

4.3. Robustness of identifying assumptions

This final section analysis the robustness of the identifying assumptions used in the structural analysis. One way to do this is by using the degrees of freedom generated from the over-identifying restrictions to test for the presence of intramonth feedback from the lower ordering rates to the upper ones, i.e. from the upper diagonal of the A_0 matrix. The results are reported in Table 4.

None of the elements above the diagonal of A_0 are individually or jointly found significant, implying that there is no evidence of any misspecification of A_0 used to identify the transmission mechanism of monetary policy shocks through the financial system.

An alternative approach to check the robustness of the results is to use the generalised impulse function approach suggested by Pesaran and Shin (1998). These generalised impulse responses from an innovation to the j-th variable are generated by applying a variable specific Choleski factor computed with the j-th variable at the top of the Choleski ordering. These impulse response functions do therefore not depend on the ordering of the variables, as in a standard Choleski factoring, and can therefore be used to check the robustness of the underlying

Table 4. Presence of alternative intra-month effects

	Intra-month effects from				
Equation	m_t	g_t	b_t	Joint test	
r_t	0.68	0.72	0.43	m_t, g_t, b_t	0.30
m_t	–	0.54	0.44	g_t, b_t	0.61
g_t	–	–	0.90	b_t	0.90

The table tests the null hypothesis that the upper diagonal in A_0 for a given equation can be restricted to zero. The numbers reported are p-values.

ordering used to analyse the structural shocks. It should be noted, however, that the generalised impulses are completely atheoretical and therefore do not have any obvious economic interpretation. Figure 4 compares the generalised impulse response functions with the structural impulse functions from Figure 3. The impulse responses, especially from the monetary policy innovations, are practically identical. There are, however, three different impact effects from the generalised impulses.

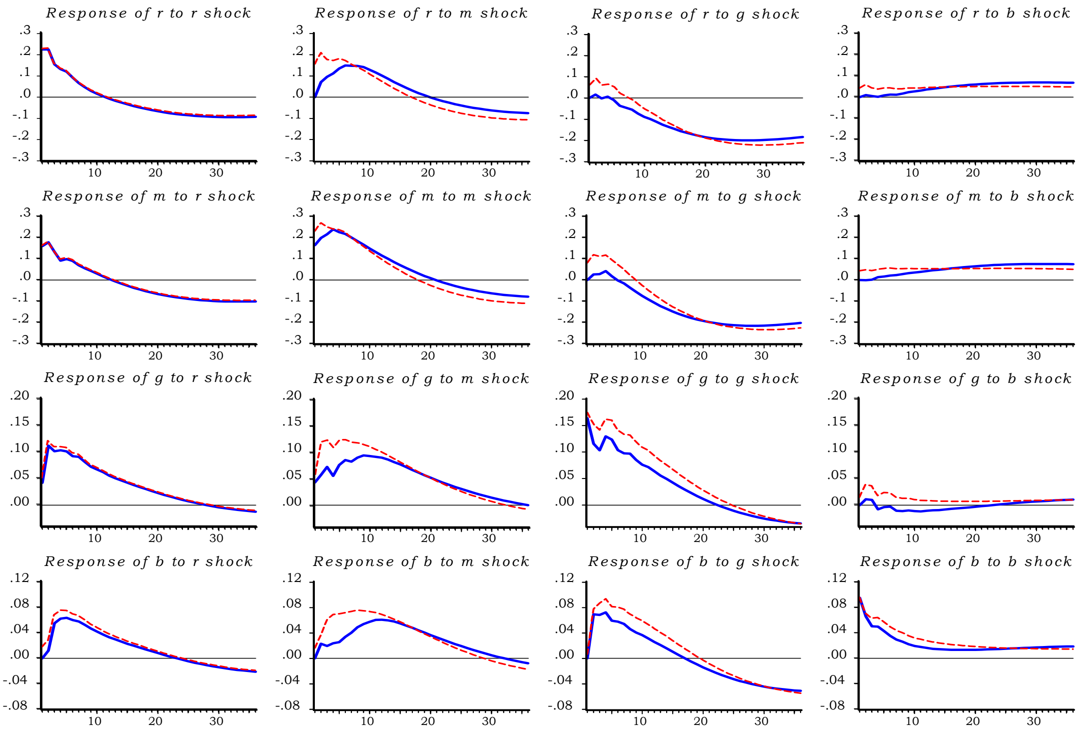

Figure 4. Structural (solid) and generalised (broken) impulse response functions

First, the generalised impulse analysis suggests contemporaneous effects from the money and bond market rates to the repo rate. These were, however, found insignificant in the analysis above. Second, the generalised impulse analysis suggests a contemporaneous effect from the bond market rate to the money rate. This was also found insignificant in Table 4 above. Hence, the robustness analysis supports the identifying structure used in this paper to analyse the financial market pass-through of monetary policy.

5. Conclusion

This paper uses a structural vector autoregressive model to identify the financial market pass-through of monetary policy shocks in Iceland for the period 1993 to 2000, which represents a period where the Central Bank of Iceland has used the rate on repurchase agreements between the bank and other financial institutions as the monetary policy instrument. The other interest rates included in the information set each represent an important sub-market of the Icelandic financial system; the money market, bond market and the bank loans market.

The initial identification structure of the transmission mechanism of monetary policy across the rate of returns on these four sub-markets of the financial system is based on a simple model that generates a Wold causal chain. This assumes the natural ordering that the money market is closest to monetary policy innovations, with the bond market coming next and the bank loan market at the end of the transmission. By eliminating non-significant channels in the contemporaneous correlation structure, an over-identifying system is obtained which is used for interpreting the transmission mechanism of monetary policy and for testing the validity of the specification used.

The main findings are that innovations in the monetary policy rate have a significant within-the-month effect on the money market rate, which, through the term structure, short-term price stickiness (since the bond rate is on indexed assets) and substitutability between indexed and non-indexed bonds, temporarily raises the bond market rate, with the effect peaking after one month and significantly lasting for eight months. Finally, the rise in the bond market rate induces a rise in the bank loan rate which starts to rise after two months with the effect peaking after four months and significantly lasting for about nine months.

These results suggest that investors financing their investments in the bond and bank loan markets will start feeling the effect of monetary tightening within the month of the tightening, with the effect peaking about one to four months after the initial tightening. The results further suggest that the effect of monetary tightening will have significant affects on real rates for about eight to nine months after the initial tightening.

The results also imply feedback responses of monetary policy to money and bond market shocks. A positive innovation in the money market rate leads to a subsequent rise in the repo rate. This could reflect new information about the short-term inflation prospects or foreign money market rates, priced in the money market rate, which the Central Bank would respond to by raising the repo rate. A positive innovation to the real bond rate, however, leads to a subsequent fall in the repo rate. This could reflect new information about the performance of the economy reflected in higher than expected real rates. The bank would thus lower its policy rate to ease the stance of monetary policy.

The bank loan rate rises only with a two month lag, suggesting monopolistic pricing behaviour of banks. This sluggish adjustment could reflect the value of waiting for banks or some types of adjustment costs, such as administrative costs and borrower aversion to fluctuations in incomes and cash flows. Furthermore, the dynamic response mainly work through the bond market, although there is some evidence of a direct channel from the monetary policy rate to the bank loan rate. Thus, the bond rate seems to be the most important determinant of the marginal cost of loan funding in the period analysed here. This could reflect mark-up pricing of banks where they price loans as a mark-up over deposits which are directly competing for individual savings with government bonds.

The fact that the monetary policy rate seems to have a stronger effect on the marginal cost of loan funding than the money market rate might reflect the undeveloped money market for the main part of the period analysed here and the subsequent dominance of Central Bank financing for banks. This might also reflect the lack of competition in the bank loan market as suggested by Cottarelli and Kourelis (1994). They argue that the more competitive the bank loan market is, the closer the link between money market rates and loan rates.

The dominant role of the bond rate, and to a lesser extent the monetary policy rate, for bank loan rate determination might, however, be changing following the introduction of a well functioning interbank market in 1998 which has led banks increasingly to use the money market directly to finance their activities. This is, however, not reflected in the results here since this development occurs late in the sample. Thus, one might expect the money market rate to increasingly take the role of the marginal cost of loan funding with the continuing development of the domestic money market and increased competition in the Icelandic banking system.

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