Speech

Financial Frictions and the Monetary Transmission Mechanism: Theory, Evidence and Policy Implications

Speech given by

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At the Monetary Transmission Network conference, European Central Bank, Frankfurt
18 December 2001

Abstract

This paper provides a brief survey of the role of financial frictions in the monetary transmission mechanism. After noting some of the key stylised facts that any model of the transmission mechanism must be consistent with, we discuss both the classical interest rate channel and the credit and bank lending channels of monetary transmission. We then review the empirical evidence relating to the relative importance of these channels. Finally we consider what impact the presence of significant financial frictions might have on the conduct of monetary policy.

1   Introduction

There is little doubt that central banks pay considerable attention to commercial banks and financial intermediaries more generally. In a recent survey of 89 central banks Fry, Julius, Mahadeva, Roger and Sterne (2000) found that 'analysis of the banking sector' was ranked on average the seventh most important ingredient of the monetary framework, above 'analysis of the real sector'.[1] Of course, this need not imply that central banks consider that the behaviour of financial intermediaries constitutes a key part of the monetary transmission mechanism, as they have objectives other than price stability, specifically financial stability. Thus in the same survey, 'analysis of domestic financial stability' was ranked fifth on average, indicating a concern for financial markets in their own right. But even for the 16 central banks that ranked an inflation target as the single most important ingredient and for whom understanding the transmission mechanism is presumably key, the categories concerning the banking sector received high ranking.

Traditional textbook models that are routinely used in the analysis of monetary policy, such as IS-LM, usually do not spell out the assumptions that underpin the transmission mechanism. And in so far as they do, they pay little attention to financial frictions. The New Keynesian framework set out in Clarida, Gali and Gertler (1999) does describe the foundations more explicitly, yet in the basic framework, capital markets are assumed to be free of frictions and complete. This seems at odds not just with the survey evidence discussed above, but also with recent experiences, such as the crises in East Asia and current developments in Argentina, where developments in financial markets have clearly been important in determining the appropriate design and conduct of monetary policy.

In this paper we discuss the impact and implications of frictions originating in financial markets for the transmission of monetary policy. Drawing on the vast literature on financial market frictions and the monetary transmission mechanism, we address the following questions. What assumptions might underpin a framework where financial market frictions play a role? Is the empirical evidence consistent with

the predictions of that framework? And how important quantitatively are the effects of such frictions?

Our focus is primarily on the transmission mechanism in a developed economy that is operating in 'normal circumstances'. That is we avoid discussion of financial crises, liquidity traps and similar issues that are not central to the focus of this conference. But even with such a relatively narrow focus, a comprehensive survey of the literature is well beyond the scope of this paper. Excellent surveys of this territory can be found in Christiano, Eichenbaum and Evans (1999), Clarida, Gali and Gertler (1999) and Bernanke, Gertler and Gilchrist (1999).

We begin with a brief review of the 'stylised facts' that any representation of the transmission mechanism needs to be compatible with. But these stylised facts, while helpful in providing a broad characterisation of the transmission mechanism, are typically not sufficient to distinguish the relative importance of different transmission channels. Hence, in sections three and four, we move on to discuss first the theoretical underpinnings and then the empirical evidence relating to the transmission mechanism. We then turn our attention to the question of why central bankers should care about all this. For if there is a stable empirical relationship between the policy instrument and the target variable(s), why should (s)he be concerned with the underlying structure of the economy in general, and of financial market frictions in particular? Our answer is that the presence of such frictions is likely to create extra uncertainty about the impact of interest rate changes on activity and thence on inflation. With the aid of a simple model, and invoking recent thinking on policy design under uncertainty, we show how policy should be modified to take account of uncertainty engendered by the presence of financial market frictions.

2   Some stylised facts

To set the scene, we begin by recording some of the empirical regularities that any model of the transmission mechanism should be consistent with. We first provide a

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[1] There are 21 components in this survey. The components deemed more important are independence of central bank, maintenance of inflation expectations, transparency of policy, inflation targets, analysis of domestic financial stability and exchange rate targets.

brief discussion of the key stylised facts for the euro area, the United Kingdom and the United States. Taking the study by Christiano, Eichenbaum and Evans (1999) as our reference point, we then selectively summarise the main conclusions of the literature employing Vector Autoregression (VAR) techniques to characterise the response of the economy to a monetary shock.[2]

Table 1 reports the cross-correlations between the main macroeconomic variables in the three economies. The results for the United States and the euro area are taken directly from Agresti and Mojon (2001), who use the Baxter and King (1999) band-pass filtering procedure. In deriving comparable statistics for the United Kingdom, we have used a frequency domain filter to avoid losing observations at the beginning and at the end of the sample. To economise on space, we do not provide a comprehensive discussion of the sensitivity of our results to differences in choice of filter, sample and data, but for our purposes, the differences between the filters are likely to be negligible. Benati (2001) provides a thorough discussion of the appropriateness of band-pass filtering for establishing stylised facts. We note in passing that our results are similar to those in Blackburn and Ravn (1992) who use a different filtering technique over a different sample.

At a general level, the resulting key features are not dissimilar: consumption is less volatile than investment; investment is about twice as volatile as output; and both consumption and investment are highly pro-cyclical. In contrast to the euro area and the United States, consumption in the United Kingdom is more volatile than output. Also, price levels are counter-cyclical while inflation is somewhat pro-cyclical, whether measured by the GDP deflator or by consumer price indices. Some similarities in financial variables are apparent too: short-term interest rates are positively correlated with GDP at short leads and lags, with higher correlations at short lags. Also, short-term interest rates are more volatile than long rates in all three areas. The yield curve measure, which is simply the difference between the long and the short interest rate, is closely correlated with GDP, but appears to be lagging rather than leading the cycle.

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[2] There is a large literature that discusses differences in the monetary propagation mechanism within current and prospective members of the euro area. We do not pursue that issue here. Mojon and Peersman (this volume) is a recent contribution to this literature.

But there are also some notable differences. Short-term nominal interest rates in the United Kingdom are more volatile than in the euro area and the United States, but this is not too surprising given the changing nature of United Kingdom monetary policy arrangements over the sample. Equity prices in the United Kingdom and the euro area are significantly more volatile than in the United States and seem to lead GDP more strongly in the United States and the United Kingdom. The latter property is perhaps related to the greater extent of direct share ownership in the Anglo-Saxon countries. Real estate prices in the United Kingdom – at least by our measure – are much more volatile in both an absolute and a relative sense than in the euro area and the United States. Our measure of narrow money for the United Kingdom, M0, is clearly a coincident indicator, with a much higher contemporaneous correlation with GDP than M1 has for the euro area or the United States. And, as in the euro area, narrow money appears to be a leading indicator of activity in the US. Broad measures of money generally appear to have weaker indicator properties.

What can these unconditional moments of the data tell us about the nature of the monetary transmission mechanism? Unfortunately the answer is not a lot. Any characterisation of the transmission mechanism necessarily involves taking a stand both on the structure of the economy and on how to identify the shocks that the economy has been subject to. But one conclusion that can at least be drawn from these correlations is that the dynamic behaviour of macroeconomic aggregates in these countries is very broadly similar. This is in spite of the known structural differences in credit, housing and goods markets, and in degrees of openness.

From this general characterisation of the three economies, we turn to the evidence on the transmission mechanism provided by VARs. Most of the literature we cite here achieves identification through some variation on the recursive identification scheme employed by Christiano, Eichenbaum and Evans (1999). That paper provides a comprehensive survey of the literature for the United States, and represents a reasonable reflection of the 'consensus' view. Here we draw on the results in Peersman and Smets (2001) for the euro area and the United States, and on analysis of our own for the United Kingdom.

The recursive identification scheme divides the variables of interest into those that appear contemporaneously in the policymaker's information set, typically GDP, a final goods price index and short-term interest rates, and those that appear only with a lag. Under the recursive identification scheme, variables in the contemporaneous block do not respond immediately to the policy shock, and policy obviously cannot respond immediately to shocks to variables in the non-contemporaneous block. Essentially then, the VAR is identified using the Choleski decomposition, with the contemporaneous block ordered first, the policy equation second, and the non-contemporaneous block last. The key decision the econometrician faces is which set a variable is assigned to, but the responses to a monetary policy shock will be invariant to the chosen ordering within the blocks. The details of the identification schemes vary across studies – and this can have important implications particularly for the short-run responses.[3]

Here we report the baseline VAR estimated by Peersman and Smets (2001) for the euro area and the United States. This VAR includes output, consumer prices and a monetary aggregate in the contemporaneous block, and a real effective exchange rate index in the non-contemporaneous block. For both areas, a commodity price index is also included. The VAR for the euro area includes it as an exogenous variable, while the VAR for the US includes in the non-contemporaneous block. The VAR for the euro area also includes US short-term interest rates and output as exogenous variables, to control for 'world inflation' and 'world demand'. The VAR we report for the United Kingdom is similar to the euro-area VAR, but differs in that we have included a house price index in the endogenous block. We have used the GDP deflator as our measure of prices and a nominal rather than a real effective exchange rate index. Finally, we have used oil prices rather than commodity prices as an exogenous variable.[4]

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[3] This identification scheme is useful, partly because it is so simple. This makes it an ideal tool for a broad-brush cross-country comparison of the response to a monetary policy shock. Other, typically more elaborate, identification schemes may provide a more exact characterisation of an economy's propagation mechanism, by imposing more structure on the VAR. See Leeper, Sims and Zha (1996) and Kim and Roubini (2000) for prominent examples.

[4] The scheme we use here is fairly similar to that used by Aoki, Proudman and Vlieghe (2001), but is by no means the only plausible scheme. Alternative schemes can be found in Dhar, Pain and Thomas (2000), Hall (2001), Millard and Wells (2001) and Millard (2000) who provide more comprehensive discussion of the issues relating to estimating the response to monetary policy shocks in the UK data.

Chart 1 provides the impulse responses to a typical monetary shock for the euro area, the United States and the United Kingdom in columns one to three. The results are unsurprising. In all three regions, the VAR evidence suggests that a contractionary monetary policy shock raises the short-term interest rate on impact, and the effect persists over several quarters. A contractionary monetary policy shock also leads to persistent and large falls in the price level, but the initial response is rather muted – indeed, under some identification schemes, the price level initially increases slightly, giving rise to what is labelled as the 'price puzzle'. In all three areas, prices only start to fall after some time, although on this evidence, the degree of sluggishness in prices varies somewhat. In all regions, aggregate output falls after the shock, but the response is prolonged and hump-shaped, with the peak effect occurring between four and eight quarters. The peak effect in the euro area appears to be somewhat earlier than in the United States and in the United Kingdom.

This exercise takes us a little further towards characterising the key empirical characteristics of the monetary transmission mechanism than do the raw unconditional moments, and further work could explore questions such as the stability of these impulse responses over time. But even with a historically and statistically stable empirical relationship, policy analysis without a theory of the transmission mechanism is obviously incomplete. So it is this we turn to next.

3   Competing views of monetary transmission

3.1   The classical 'interest rate' channel

Under the classical view of the transmission channel, interest rates influence economic activity by affecting various relative prices in the economy. These are primarily the relative prices of capital and of future consumption in terms of current consumption, and the relative price of domestic goods in terms of foreign goods. This description of what constitutes the interest rate channel is fairly broad - it essentially encompasses most mechanisms that are not associated with financial market frictions. The key ingredients are as follows.

First, movements in the policy rate affect fixed investment through the user cost of capital. Higher interest rates raise the required return from investment projects and reduce the rate of business investment. Inventories are affected in much the same way; higher interest rates increase the 'user cost' of holding inventories and lead firms to economise on them.

Second, interest rates also represent the price of future relative to current consumption. Higher interest rates cause households to substitute future for present consumption. Interest rate movements also have an income effect on households. Providing that households are net debtors, higher interest rates reduce the value of lifetime income, further depressing consumption. Finally, by affecting the value of financial assets such as stocks and bonds, in which household wealth is held, interest rate movements can have a wealth effect on private sector spending.

Third, interest rate movements move the exchange rate thereby altering price competitiveness and affecting net exports. Under sticky domestic prices and producer currency pricing, the real exchange rate appreciation raises the relative price of domestic in terms of foreign goods, and induces an 'expenditure switching' from domestic to foreign goods. Under local currency pricing, exchange rate fluctuations are absorbed in firms' margins. This affects the value of firms' equity and, via the wealth effect, aggregate demand. There are also likely to be effects through supply (see below).

Movements in the interest rate will also have an impact on the supply side of the economy. A standard channel is through intertemporal substitution in labour supply. In 'limited participation' models (Christiano, Eichenbaum and Evans, 1997; Christiano and Gust, 1998; Dhar and Millard, 2000), movements in real interest rates generate supply effects through their effect on the cost of firms' working capital. The open economy introduces a further channel for short-term supply effects of monetary policy. To the extent that domestic firms' production depends on imported intermediate goods, exchange rate movements will also have supply effects (McCallum and Nelson, 2001). And when there is local currency pricing, persistent movements in exchange rates may have a supply effect as exporting firms enter or exit from the market.

But what features do we need for the interest rate channel to be economically significant? The underlying mechanism implies a causal link from movements in short nominal rates to movements in (short and long) real interest rates, which are then transmitted to real variables and inflation. Then the quantitative importance of the interest rate channel relies on the extent to which the central bank can control the short-term *real* interest rate, and the extent to which movements in that short rate can cause persistent movements in real variables.

The central bank's control over the short-term real interest rate depends on a slow responsiveness of inflation: without a slow response of inflation to a change in the nominal policy rate, real rates will be unaffected. A slow responsiveness can come from the presence of nominal rigidities (such as wage or price stickiness) combined with substantial real rigidities, which blunt the impact of demand on firms' costs. We will return to this point below.

Limited participation models provide an alternative mechanism through which the central bank can influence the short-term real interest rate. The crucial assumption in these models is that some agents can adjust their portfolios continuously while others must choose their money holdings in advance. Following an increase in the quantity of money, the unconstrained agents have to be induced to increase their borrowing, which can only happen if the real interest rate falls.

Provided that the central bank can affect real interest rates, the effect of monetary policy will depend on the interest-rate sensitivity of demand and supply in the economy. Consumer and investment spending will respond strongly to interest rates when the intertemporal elasticity of substitution in consumption is high and there are weak diminishing returns to capital. Also to the extent that durable/capital goods expenditure depends on long, rather than, or in addition to, short rates, we need some form of the expectations theory of the term structure to hold, so that short rate movements are transmitted to long rates. Term premia may affect the extent to which changes in short rates are translated into changes further along the yield curve: if term premia respond systematically to offset movements in short rates, then this will tend to weaken the effect of policy changes.

Finally, the net export channel only functions to the extent that the price of foreign currency moves inversely with the domestic interest rate. This will ensure that a contractionary monetary shock generates an exchange rate appreciation. Although this link is standard in open conomy macroeconomic models, via uncovered interest parity, in recent times it has sometimes proved to be a rather unreliable one.

Bernanke and Gertler (1995) identify three main puzzles for the conventional interest rate channel view of the way aggregate demand responds to interest rate changes:

- *Composition*. Why do brief movements in short-term interest rates affect spending on durable goods (such as housing), which presumably should depend on the long rate?[5]
- *Propagation*. Why do real variables continue to adjust after most of the rise in short rates has been reversed?
- *Amplification*. How do interest rates lead to such pronounced movements in output while 'cost of capital' measures appear insignificant in explaining individual expenditure components?

We can add a number of other shortcomings to the interest rate transmission channel. The uncovered interest parity condition is rejected by the data at business cycle frequencies (Meese and Rogoff, 1983), implying that the net export channel of monetary shock transmission (at least in its conventional form) is likely to be weak. Also, there is strong evidence that there is imperfect pass-through from exchange rates to final domestic prices – the evidence suggests that exchange rate variations, at least to some extent and for some time, are absorbed in firms' margins rather than prices. Finally, Kocherlakota (2000) adds *asymmetry* as another facet of monetary transmission that cannot be explained by the interest rate channel.

Christiano, Eichenbaum and Evans (2001) show that an appropriately calibrated model with only an interest rate channel can in fact reproduce the dynamic response of the economy to a monetary policy shock. They find that a model that has sticky

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[5] This puzzle presumes that there are frictions in durable/capital goods markets: if there are perfect second-hand markets and firms and individuals face no costs of adjusting their stock of durables/capital, then the opportunity cost of holding the good is given by the *short* interest rate.

wages, variable capacity utilisation, and adjustment costs in investment and consumption has both the amplification and propagation needed to match the data. However, their model can match the dynamic response of investment to a monetary shock only by assuming a very large elasticity of investment with respect to the long rate. This is inconsistent with microeconomic evidence discussed below that shows a very small interest sensitivity of investment. And since the volatility of investment spending is a dominant feature of developed country business cycles, the inability of the interest rate channel to reconcile aggregate data with microeconomic evidence is a significant failure.

As a consequence, subsequent research has attempted to explain these puzzles by appealing to frictions in financial markets, all of which rely on departures from the Modigliani-Miller axioms so that finance is more than just a 'veil'. The theoretical literature has identified two main ways in which the financial system can act to amplify and propagate the effect of monetary shocks: the 'bank lending' channel; and the 'broad credit channel'. The first applies to models that focus on the behaviour of financial intermediaries in affecting the quantity of credit. The latter applies to models that focus on the nature of the relationship between borrowers and lenders, and consequently on the terms under which loans are supplied.

3.2 The bank lending channel

The bank lending channel attributes the effects of monetary policy to movements in the supply of bank credit. The first generation of bank lending models motivated the departures from the Modigliani-Miller axioms on the basis of asymmetric information between borrowers and lenders about the characteristics of individual projects. Stiglitz and Weiss (1981) assume that entrepreneurs have private information about their projects, which have the same expected return but different probabilities of success. Because of limited liability, borrowers can default on their loans in the event that the project does not succeed. Hence, at high levels of interest rates, the only entrepreneurs who would find borrowing attractive are high risk ones, with a low

probability of repayment. The resulting equilibrium is characterised by credit rationing and underinvestment[6].

However, subsequent research has shown that the Stiglitz and Weiss result is not robust once sorting devices are allowed. The credit rationing result is an example of a pooling equilibrium. Following Spence (1973), Rothschild and Stiglitz (1976) and others, such equilibria can be eliminated by the use of a suitable sorting device, which forces agents to reveal their types. Bester (1985) and others have shown that collateral can be used as a sorting device, since 'safe' borrowers will be more willing to undertake secured borrowing than 'risky' ones. The resulting separating equilibrium involves no credit rationing.

More recent contributions focus on the imperfect substitutability between retail deposits and wholesale deposits/debt on the liability side of the banks' balance sheets. In Bernanke and Blinder (1988) a number of borrowers are bank-dependent in the sense that their only providers of outside finance are banks. This assumption can be rationalised on the grounds that there are fixed costs of direct financial market participation, and certain borrowers (i.e. small firms) will find those uneconomical. Furthermore, Bernanke and Blinder assume that banks themselves suffer from information problems in the market for equity and corporate debt, which implies that they cannot raise outside capital to replace lost retail deposits. This imperfect substitution between retail and wholesale deposits (debt) means that a fall in retail deposits induced by a monetary contraction tends to be followed by a decline in loans rather than an increase in the wholesale deposits. Bernanke and Blinder show that such structures tend to amplify the effects of monetary policy shocks.

A new strand of the literature has attempted to provide fresh microfoundations for the bank lending channel. Van den Heuvel (2001) examines bank behaviour in the presence of a 'capital-adequacy ratio' and a constraint on new equity issues. He shows that banks which face these two constraints will react differently to shocks compared to the case when they can readily issue new equity to ensure that they always satisfy

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[6] DeMeza and Webb (1987) consider a different form of uncertainty about entrepreneurs' projects that leads to overinvestment in equilibrium. They assume that each project receives the same return R if

the capital-adequacy ratio. The paper demonstrates using numerical simulations that following a shock to their equity, banks will contract potentially profitable lending if they get sufficiently close to the capital-adequacy ratio. And since banks hold short-term liabilities and long-term assets, monetary policy shocks will act as shocks to bank equity. Furthermore, this 'bank capital channel' can work in a highly non-linear fashion, implying significant potential for asymmetries in monetary transmission.

The essential feature of the bank lending channel is thus that the central bank can affect the supply of credit by financial intermediaries by altering the quantity of base money, thus raising the cost of capital to bank-dependent borrowers. This effect is additional to that induced by the change in the official interest rate operating via the interest rate channel.

For a special role for banks in monetary transmission, we need at least some borrowers in the economy to be bank-dependent for their external finance. Fixed costs to direct financial market participation is a frequently cited motivation for the existence of bank-dependent borrowers. Banks can economise on the fixed costs of monitoring, which makes them the natural provider of finance for borrowers that are too small to be able to issue securities directly to the market. Hence, any changes in banks' willingness to lend will influence such borrowers directly, generating a bank lending channel of transmission. Finally, minimum capital requirements (MCR) offer one plausible mechanism that may affect banks' willingness to lend when their capital is close to the regulatory minimum.

The quantitative significance of the bank lending channel will depend partly on the size of the lending contraction for a given monetary policy shock. This contraction will be greater, the more interest elastic is the demand for money. With elastic money demand, deposits (and hence loans) will show more variation in response to a policy shock. Furthermore, the larger is the pool of bank-dependent borrowers, the bigger will be the effect of the lending contraction on the real economy.

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successful but have different probabilities of success. The result is over-investment as high probability projects subsidise low probability ones.

3.3 The broad credit channel

Much of the recent theoretical research on the role of credit in economic fluctuations has focused on 'moral hazard' problems in the principal-agent relationship that characterises debt contracts. These models derive a role in the monetary transmission mechanism for credit in general, and not just bank lending. Bernanke, Gertler and Gilchrist (1999) and Carlstrom and Fuerst (2000) are perhaps the most widely cited papers in this literature. In their models, there are 'bad' states of the world, when it would be efficient for firms to default on their debts. But because of limited liability, borrowers may prefer to default on their borrowings in other states of the world too. And because 'state verification' is costly, lenders have to pay a cost to ascertain whether the true state of the world warrants default or not. Lenders will therefore demand an external finance premium in steady state to compensate them for this 'state verification cost'. The consequence of these credit market imperfections is that firms will find it cheaper to invest out of retained funds than out of borrowed funds. Hence, stronger firm cash flow will lead to higher investment. In general equilibrium, this mechanism has the potential to provide amplification and propagation, because aggregate demand shocks will affect firm cash flow, causing persistent movements in firms' average cost of capital and investment.

Kiyotaki and Moore (1997) assume incomplete contract enforceability and show that entrepreneurs will be credit constrained. They argue that if the value of investment projects is highly dependent on human/entrepreneurial capital, lenders will only issue loans up to the value of physical capital. The reason for this is that physical capital can be foreclosed upon, unlike human capital. The aggregate consequences are similar to that of Bernanke, Gertler and Gilchrist: investment is highly dependent on the value of collateral, which can generate amplification and persistence following monetary shocks.

Cooley, Quadrini and Marimon (2000) also assume incomplete enforceability and examine the structure of long-term incentive-compatible contracts between entrepreneurs and lenders. They find that the incentive-compatible contract involves higher investment and higher growth by new firms than by old, and that the investment of new firms depends on cash flow. The intuition is the following: when

the firm is 'young' and/or current cash flow is high, there is an incentive for the entrepreneur to repudiate the contract, and appropriate the entire cash flow. Hence, the optimal contract has to provide sufficient incentives to the entrepreneur not to default. This is achieved through growth in the value of the firm, which is achieved through higher investment. In general equilibrium, the incentive-compatible financial contracts that Cooley, Quadrini and Marimon examine can prolong and amplify shocks.

So, to summarise, all these models of the broad credit channel rely on the presence of moral hazard problems in debt markets. The appropriate design of financial contracts under moral hazard leads to significant departures from the Modigliani-Miller axioms and generates a role for credit in economic fluctuations. Incomplete insurance markets are a further necessary condition for a role for credit in monetary transmission. If private agents could buy an insurance policy against a 'credit crunch' none of the above mechanisms would exert any effect on the economy; such insurance naturally does not exist.

The broad credit channel influences economic conditions by leading to variations in firms' cost of capital in line with the financial health of firms. Hence this transmission channel will be quantitatively stronger when the terms of debt contracts are re-negotiable. For example, floating rate loans/bonds at a fixed spread over government or money market instruments will not be affected by deterioration in credit quality (instead the bond-holder will realise a loss on his initial investment). On the other hand, loans/bonds where lenders can frequently change the spread (such as those with embedded options) will be affected in line with the predictions of credit channel theories. But even when most loans are at a fixed, long-term rate, the effect of the credit channel will be increasing in the 'churn' in the debt stock – i.e. that proportion of the debt stock that is new each period.

4   The empirical evidence

In the previous section we outlined the interest rate channel view of monetary transmission and discussed the puzzles that motivated research on the role of credit in

economic fluctuations. We showed that there were two main ways through which credit affects the economy. The 'bank lending channel' predicts that banks will contract the supply of loans following a monetary shock. And the 'broad credit channel' predicts that financial factors such as cash flow and net worth will be among the determinants of firms' expenditure. In this section we review some of the main empirical findings relating to the role of financial frictions in the transmission mechanism.

4.1 Evidence for the bank lending channel

The bank lending view of monetary transmission is strongly motivated by the observation that a number of borrowers are dependent on banks for their sources of external finance. Kashyap and Stein (1994), using data from the *Quarterly Financial Report* for US manufacturing firms, have shown that in 1991, small firms were dependent on banks for 82.9% of their external finance. For medium sized firms, the share of bank debt was also very high, at 77%. This evidence, by itself, suggests that the behaviour of banks may be extremely important for the transmission of monetary policy.

A number of papers have studied the co-movements of output and total bank lending following a monetary policy shock. Bernanke and Blinder (1992) have shown that bank loans decline following a contractionary monetary policy shock and have argued that this provides evidence for the existence of a bank lending channel. Aggregate lending to corporates in the United Kingdom is also positively correlated with investment, and leads GDP growth.

There is, however, a serious identification problem in econometric work that uses aggregate data. Since loan demand is a function of the interest rate even under neo-classical capital markets, the interest rate channel is also capable of explaining the fall in lending aggregates following a monetary policy shock. What bank lending channel proponents need to demonstrate is that the fall in the quantity of lending was caused by a fall in loan supply (which is consistent with the bank lending view) rather than by a fall in loan demand (which is the 'frictionless capital markets' alternative hypothesis).

Kashyap, Wilcox and Stein (1993) have attempted to solve this identification problem by looking at the relative movements of bank lending and commercial paper issuance. Their results show that the ratio of commercial paper to bank loans rises following a monetary policy contraction. The authors argue that because large companies that are unlikely to be credit constrained issue commercial paper, this form of non-bank borrowing can provide a proxy for changes in demand for loans. Hence, Kashyap et al argue that changes in the composition of debt indicate a contraction of bank loan supply, which is consistent with an important bank lending channel.

However, Oliner and Rudebusch (1995) argue that, rather than indicating a contraction in bank loan supply, Kashyap et al's results are driven by a rise in commercial paper issuance, and a reallocation of bank lending from small firms to large firms. Hence, according to Oliner and Rudebusch, there is no evidence of a reduction in the supply of bank lending across the board, although there is some evidence that certain types of firms (e.g. small firms) do suffer a reduction in lending following monetary contractions.

In line with the rest of the literature on financial market frictions, that on bank lending has resorted to microeconomic data to get a better understanding of their role in the transmission mechanism. Kashyap and Stein (2000) examine a large panel of US banks spanning 20 years of quarterly data. They examine the way bank lending responds to changes in monetary policy and find significant links between the size of a bank's lending contraction and the bank's balance sheet liquidity position as measured by the ratio of securities to total assets. The authors argue on the basis of their results that up to a quarter of the response of lending to a monetary shock is due to banks' liquidity constraints. These numbers suggest that the bank lending channel plays a significant role in the monetary transmission mechanism.

4.2   Evidence for the broad credit channel

Although bank lending is a very important source of external finance for firms, it is not the sole one, and much of the empirical literature on credit frictions has

concentrated on identifying the importance of credit in general and not just bank lending.

The behaviour of financial variables provides one possible source of information that could be used to identify the effects of financial market frictions. Bernanke, Gertler and Gilchrist (1999) show that corporate spreads over risk-free government rates increase sharply in response to a contractionary monetary shock – this behaviour is a key element of their theory of the credit channel. Evidence for the United Kingdom in Hall (2001) actually suggests the opposite, i.e. that spreads *fall* in response to a contractionary monetary policy shock.

But even taken at face value, the results of Bernanke, Gertler and Gilchrist do not lend convincing support to the broad credit channel. Corporate spreads will fluctuate even in the absence of credit frictions, simply because corporate risk or the market price of risk changes. In addition, as Cooper, Hillman and Lynch (2001) show, evidence from corporate bond spread indices is suspect, because individual spreads are a highly non-linear function of individual debt-to-equity ratios. Consequently, changes to the financial health of a small sub-sample of firms could affect aggregate spreads, while being entirely consistent with frictionless credit markets.

But by far the largest literature on credit constraints has grown out of the failure of the simple Q model of investment to match the data. According to neo-classical investment theory with added adjustment costs, investment should depend on marginal Q – the ratio of the additional value created by a unit of capital to the cost of capital. And as Hayashi (1982) has shown, under the assumption of perfectly competitive product markets, constant returns to scale and quadratic adjustment costs, marginal Q will be equal to Tobin's (average) Q – the ratio of the stock market value of the firm to the replacement cost of its capital stock. This result has motivated a number of papers to test whether an average Q model can adequately account for firms' investment behaviour. But the results of these empirical tests have not been encouraging, with small or insignificant coefficients on average Q and low explanatory power of the regressions.

These poor empirical results are, in some studies, taken as evidence of misspecification caused by omitting the effects of credit constraints on investment. If average Q fails to be a sufficient statistic for investment, and if other variables, such as cash flow turn out to be significant in explaining investment, this is interpreted as evidence in favour of a broad credit channel. Obviously, any test of the sufficiency of average Q is a joint hypothesis of the assumption of no credit frictions *and* the remaining assumptions underpinning average Q theory: there is plenty of scope for other types of mis-specification (see Hubbard, 1998, for a recent survey).

The main approach of the literature to testing for the significance of credit constraints on investment has been to split firms into credit-constrained and unconstrained on 'a priori' grounds and then test for the significance of financial variables in explaining the investment decisions of both sets of firms. Below is a very brief sketch of the approaches in the literature.

In a pioneering study, Fazzari et. al. (1988) split their sample of US firms into firms that pay high dividends and/or issue new shares (the credit unconstrained firms) and into firms that pay low dividends and do not issue new shares (the constrained firms). They find that their constrained firms are more sensitive to cash flow than the unconstrained firms. Devereux and Schiantarelli (1990) split their sample of UK firms according to firm size. However, their results are more mixed, with large firms more sensitive to cash flow than small ones. Other studies such as Gilchrist and Himmelberg (1995) have avoided using stock market derived measures of average Q. Instead they have derived forward-looking proxies for the profit opportunities of the firm using VAR forecasts. Gilchrist and Himmelberg find that the results from the rest of the literature on credit constraints in investment equations continue to hold. Bond and Meghir (1994) allow the firms to be subject to time-varying credit constraints by defining a dummy variable, which depends on the financial policy of the firm. The authors find that the investment of firms that pay low dividends and do not issue new equity remains more sensitive to cash flow than the investment of other (unconstrained) firms.

The literature has also attempted to analyse the behaviour of lending around changes in monetary policy. Oliner and Rudebusch (1996) study the link between cash flow

and the investment of small and large firms around identified episodes of monetary tightening. They find evidence that the link between cash flow and investment becomes stronger for small firms following a monetary tightening, but does not change following a monetary expansion. At the same time, they find that the role of cash flow for the investment decisions of large firms is unrelated to monetary policy. Oliner and Rudebusch interpret their results as evidence for the operation of the broad credit channel.

Recent contributions to the literature have offered an alternative interpretation to the presence of a statistically significant cash flow effect in investment. Cummins, Hasset and Oliner (2000), Bond and Cummins (2000) and Bond et. al. (2001) have argued that the above studies are using the wrong measure of Tobin's Q. The stock market derived measures used in the literature are only good proxies for the investment opportunities faced by firms if the stock market reflects the net present value (NPV) of firms' future profits at all times. If equity prices are noisy, they will only provide a very imperfect measure of the underlying economic concept of Tobin's Q. The authors construct an alternative measure of Tobin's Q based on investment analysts' profit forecasts, and show that it is significant in investment equations, while cash flow becomes insignificant. In this interpretation, the significance of cash flow is not in itself sufficient evidence for the presence of a broad credit channel.

4.3   Summing up the evidence

The brief literature survey above has quoted some (albeit not uncontroversial evidence) for the existence and importance of the credit channel. A number of studies have shown that credit effects are particularly important for small firms during periods of monetary tightening. These results are appealing from a theoretical point of view since small firms are most likely to be facing severe informational problems, and consequently credit constraints. Moreover, there are clear links between bank lending behaviour and bank balance sheet liquidity, which suggests that the bank lending may turn out to be a very significant source of monetary transmission when the banking system is relatively illiquid.

However, the recent literature on investment equations has cast some doubts on whether the significance of cash flow in Tobin's Q regressions can be interpreted as evidence for credit constraints. It is possible that the significance of cash flow in investment equations may simply proxy for unobserved (to the econometrician) future profit opportunities. Nevertheless, the results of studies such as Bond and Meghir (1994) do suggest that the story may be more complex than this. Since cash flow is more significant for firms that are likely to be credit constrained, this leaves us with the possibility that the standard interpretation of credit constraints is the correct one. And as Hubbard (1998) has shown, a number of other interpretations on the significance of lagged cash flow in investment equations are possible. What we need in order to separate the effects of future profit opportunities and credit on investment is a theory of how credit constraints affect Tobin's Q. More empirical and theoretical work is needed in this area.

5 Why should a policymaker care?

In this section we shift the focus of the discussion to the implications of credit frictions for the conduct of monetary policy – the 'why should we care' question. We centre the discussion on two broad sets of issues. First, how should the presence of such frictions in financial markets modify the conduct of monetary policy? Here we focus on the optimal commitment equilibrium in a simple macroeconomic model as the extent of financial frictions varies. Second, these frictions may have asymmetric and temporary effects, leading to uncertainty about the timing and magnitude of the transmission mechanism. The approach we adopt here is a robust control one.

5.1 The model

We take a simple closed economy New Keynesian macroeconomic model (which as a baseline will not have a credit channel), of the Clarida, Gali and Gertler (1999) type. We then ask how the presence of a credit channel will modify it, and how this in turn will affect optimal monetary policy. The model's equations are:

(1) $$y_t = E_t y_{t+1} - \sigma(R_t - E_t \pi_{t+1}) + v_t$$

(2) $$\pi_t = \beta[\omega E_t \pi_{t+1} + (1-\omega)\pi_{t-1}] + \mu y_t + u_t$$

where y_t is the deviation of output from potential, π_t is inflation, R_t is the nominal interest rate, v_t is an aggregate demand shock, and u_t is a cost shock. Equation (1) is an IS/aggregate demand equation, e.g. derived from an intertemporal optimality condition for consumption. Equation (2) is a New Keynesian aggregate supply schedule embodying a Buiter and Jewitt (1982)/Fuhrer and Moore (1995) model of overlapping contracts. A period should be thought of as a quarter. We assume that the monetary authorities care about the variability of output, inflation and the nominal interest rate. The policymaker's loss function is:

(3) $$\Omega = \sum_{t=0}^{\infty} E_0 \beta^t [(\pi_t)^2 + (y_t)^2 + \gamma(R_t)^2]$$

where for concreteness we have assumed equal weights on the variability of output and inflation.

In what follows we do not explicitly model financial frictions. As noted earlier, there are a variety of candidate models of financial frictions, each of which may lead to a somewhat different modification of the model. But our objective is to draw some general lessons for policy, so instead we merely note that financial frictions tend to generate two key features: greater *persistence* in demand and output movements; and an *amplified* response of demand to changes in interest rates. It is these features that we then introduce into the model to capture the impact of financial frictions. Obviously this ignores certain important aspects of frictions, in particular that their effect may be non-linear or asymmetric. However, introducing such features is complex and would take us well beyond the rather limited ambitions of the present paper.

To see how persistence is generated, and following Kiyotaki and Moore (1997) and Cooley, Quadrini and Marimon (2000), suppose that the economy consists of some

firms that have access to credit markets and others that are credit-constrained.
Expected profitability and the cost of borrowing will determine the investment
decisions of the former. Those of the latter will, by contrast, also depend on past
profits and cash flow. This will introduce extra persistence into the economy because
strong corporate performance generates improved cashflow, providing credit-
constrained firms with increased funds for future investment. Higher investment at
the firm level then leads to stronger economic growth and additional improvements to
profitability, cash flow and net worth, leading to further investment, and so on.
Hence, the presence of credit constrained firms, which invest mainly out of retained
profits will produce an IS curve with more output persistence:

(1')
$$y_t = \alpha E_t y_{t+1} + (1-\alpha) y_{t-1} - \sigma(R_t - E_t \pi_{t+1}) + v_t$$

Of course, as Clarida, Gali and Gertler (1999) argue, there may be a number of
features, other than credit constraints, which can generate endogenous output
persistence. For example, investment adjustment costs and habit persistence in
consumption can both be used to motivate persistence in the IS curve. But even so,
the presence of financial frictions should generate greater persistence than in their
absence.

With regard to amplification, in credit channel models the interest rate faced by firms,
R^f_t, typically depends on the policy rate and an external finance premium which is
increasing in the debt-to-equity ratio, D_t/E_t, of the firm

(4)
$$R^f_t = R_t + f_t(D_t / E_t) \qquad (f' > 0)$$

But the value of equity will itself be a function of the interest rate and expected future
equity values. If, as is likely, equity prices fall when the interest rate increases, the
external finance premium will rise, magnifying the impact of policy on the economy.
We therefore capture the impact of the external finance premium by increasing the
parameter σ.

As our results are intended to be illustrative, we do not attempt a precise calibration of the model. Instead, we employ plausible parameters drawn from the existing literature on simple rules in small macroeconomic models, although note these are themselves usually informed by empirical research. Thus the weight on expected inflation in the supply curve, ω, is set to 0.2 in line with Batini and Haldane (1999) and Batini and Nelson (2000). The response of inflation to activity, μ, is set to 0.1, which is broadly consistent with the estimates of Bean (1998) for the United Kingdom (recall that a period is a quarter).

The parameters of the aggregate demand schedule will vary depending on the strength of the credit frictions. In order to capture the degree of financial frictions in the economy we vary α between 0 and 1, with a low α indicating strong credit frictions. Chart 2 demonstrates the effect of varying α by plotting the auto-correlation functions for output in the model conditional on a standard Taylor rule. As the chart shows, the auto-correlation function (ACF) of output displays more persistence in the 'credit frictions' case. The other parameter we use to calibrate the credit channel is σ , where a high value indicates high interest rate sensitivity. For the parameter σ there are a substantial number of estimates available. Estimates for the US range from 0.16 (McCallum and Nelson, 1999) to 6.0 (Rotemberg and Woodford, 1997). The real business cycle literature normally sets σ equal to unity. We set the benchmark value of σ to 0.6, in line with Neiss and Nelson (2001). We set our range at between 0.1 and 1.5, encompassing all but the very largest estimates of σ for the US or the UK.

There is less evidence on α. To get a feel for the appropriate value, we estimated (1') with UK data, conditional on σ = 0.6, using instrumental variables. This suggested a value close to 0.5. To get a feel for the time variation in this parameters, we then estimated a set of rolling regressions where we allowed α to vary, conditional on σ = 0.6. This procedure suggested relatively little time variation in the point estimate for α, but with very substantial standard errors. On the basis of that, we calibrate the 'strong credit frictions' model with α set to 0.1 and the 'no credit frictions' model with α set to 0.9, with a benchmark value of 0.5.

With regard to the policymaker's preferences, we set γ to 0.25, implying some concern about interest rate variability, but to a much lesser extent than with the variances of output and inflation. Finally both the shocks are assumed to be white noise, with a standard deviation of 0.5%.

5.2   Optimal monetary policy under different degrees of financial friction

We start by considering how the optimal monetary policy differs from one economy to another according to the extent of financial frictions, i.e. how policy is affected by the values of σ and α. We do not consider the more complex question of how policy should respond during the transition from one steady state to another, e.g. during a financial liberalisation.

Throughout, we assume the policymaker has access to an appropriate commitment technology. Following Woodford (1999), the optimal commitment equilibrium (also described as the 'timeless perspective' by McCallum and Nelson, 2000) involves minimisation of the loss function at 'the beginning of time'.[7] This gives an optimal contingent plan for the interest rate, which by assumption the policymaker can commit to.

The policy problem is thus:

(5) $$\min_{\pi,y,R} \sum_{t=0}^{\infty} E_0 \beta^t [(\pi_t)^2 + (y_t)^2 + \gamma(R_t)^2],$$

subject to the IS curve (1') and the supply curve (2). The first-order conditions characterising the optimum under commitment are:

(6a) $$\frac{dL}{d\pi} = (1-\omega)\beta^2 E_t \kappa_{t+1} - \kappa_t + \omega\kappa_{t-1} + \sigma\beta^{-1}\lambda_{t-1} - \pi_t = 0$$

(6b) $$\frac{dL}{dy} = (1-\alpha)\beta\lambda_{t+1} - \lambda_t + \alpha\beta^{-1}\lambda_{t-1} + \mu\kappa_t - y_t = 0$$

(6c) $$\frac{dL}{dR} = \gamma R_t + \sigma\lambda_t = 0$$

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[7] McCallum and Nelson (2000) argue that the commitment equilibrium can be interpreted as a binding commitment on the central bank that was made at some indefinite point in the past.

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(6d) $$\frac{dL}{d\lambda} = y_t - \alpha E_t y_{t+1} - (1-\alpha)y_{t-1} + \sigma(R_t - E_t\pi_{t+1}) = 0$$

(6e) $$\frac{dL}{d\kappa} = \pi_t - \beta\omega E_t\pi_{t+1} - \beta(1-\omega)\pi_{t-1} - \mu y_t = 0$$

where L is the Lagrangian and λ and κ are the Lagrange multipliers on, respectively, the IS curve and the supply curve. Equations (6a) to (6e) form a system of second-order difference equations, which we solve using the Klein/Minimum State Variable solution algorithm. We then use the solved model to plot dynamic time paths for the endogenous variables following shocks.

Chart 3 shows the dynamic response of the system to a cost shock for two pairs of IS curve parameters: $\sigma = 0.4$ and $\alpha = 0.9$, which we take as the 'no frictions' case; and $\sigma = 0.8$ and $\alpha = 0.1$, corresponding to strong frictions. The chart shows that the variability of the output gap and inflation are little affected by the removal of frictions. This is because there are offsetting influences on the second moments of these variables. The reduction of the potency of monetary policy increases variability holding everything else constant. Acting in the opposite direction is the increase in flexibility brought about by the reduction in credit market frictions. This tends to stabilise output and inflation because firms and households become less sensitive to current economic conditions. The behaviour of policy does, however, change dramatically. The nominal interest rate rises less initially, but the rise is more persistent. As Chart 3 shows, the nominal interest rate becomes considerably less volatile when financial frictions diminish. This is related to the result in Woodford (2000), where binding commitment can affect output and inflation volatility now. So when firms are unconstrained in their investment decisions, gradual movements in the policy rate following a shock will, through the expectations channel, affect output and inflation now. This allows the central bank to stabilise output and inflation with lower instrument variability. In contrast, when financial markets are subject to significant imperfections, monetary policy needs to be more aggressive in order to prevent persistent fluctuations in inflation and output.

Chart 4 plots the two economies' response to a negative demand shock. The chart shows that policy is more aggressive in the 'credit frictions' case – the fall in interest

rates is larger than in the 'no credit frictions case'. The chart also shows that, in the optimal equilibrium, policy avoids volatility of output and inflation in the credit constrained economy. In contrast, the unconstrained economy is characterised by overshooting of both output and inflation. This is again related to the benefit of commitment – when firms and households are forward-looking and unconstrained in their decisions, policy can affect their current decisions through a binding commitment to future policy actions.

Table 2 shows the steady-state standard deviations of the endogenous variables in our model. The table shows again that the main effect of financial change in our simple framework is to reduce the variability of interest rates needed to stabilise inflation and output. But overall, provided the policymaker knows the values of α and σ, it seems that it does not matter whether frictions are present or not, at least far as stabilisation is concerned. Of course, the presence of financial frictions will affect the level of potential output – typically reducing it below the symmetric information efficient equilibrium – so the application of other policies to attenuate frictions caused by informational asymmetries, etc., may well be welfare enhancing.

5.3   Policy when the impact of financial frictions is uncertain

In this section, we recognise that there is considerable uncertainty about the impact of financial frictions on the transmission mechanism and explore the consequences of that uncertainty for policy design. Of course, even if policy affects the economy solely through the classical interest rate channel, there may still be uncertainty about the interest elasticity of investment and other key parameters. But as more evidence accumulates one might hope to be able to pin these down more precisely. By contrast, the potentially asymmetric and episodic nature of financial frictions is likely to lead to uncertainty that cannot be resolved purely through the passage of time and the accumulation of more aggregate data. There are at least two reasons for this. First, following Kocherlakota (2001), credit constraints are fundamentally an asymmetric propagation mechanism, because they are most often binding when firms want to increase their borrowing in a downturn. Ascertaining the extent to which they bind requires detailed microeconomic evidence that is unlikely to be available to the policymaker. Secondly, following van den Heuvel (2001), the supply of credit is

likely to be influenced by the health of the financial system as well as the shocks hitting it at any point in time. Hence, to the extent that policymakers do not have precise knowledge of the state of the financial system, they will face considerable uncertainty when trying to evaluate the likely response of the economy to changes in monetary policy.

In what follows, we attempt to capture this innate uncertainty by thinking of α and σ as time-varying parameters that respond both to aggregate shocks hitting the financial sector over the course of the business cycle and to developments at the microeconomic level. Ideally, one would make them functions of the endogenous variables in the model (such as output and the real interest rate), but this results in a non-linear system greatly complicating the problem of finding the optimal policy. Such a task, while worthwhile, lies beyond the limited ambitions of this paper.

The standard approach to policy design under parameter uncertainty follows the classic paper by Brainard (1967). That approach assumes the policymaker also knows, or can formulate, a distribution for the unknown parameters; optimal control procedures can then be applied in the standard way. In practice the policymaker may not feel sufficiently well informed to formulate such a distribution. This is particularly relevant in the current context where detailed microeconomic evidence would probably be required to formulate such a distribution. For that reason we adopt a robust control approach, along the lines of Hansen and Sargent (2000) and Giannoni (2001). In particular we suppose that, due to the complexity of the financial sector, the monetary authority does not know, and cannot formulate, a probability distribution over the key parameter values. Instead they only know the range of possible parameter realisations (assumed fixed for all time). This replaces the Brainardian problem of uncertain and time-varying parameters with one of Knightian parameter uncertainty.

Following Hansen and Sargent (2000) and Giannoni (2001), the robust policy rule in these circumstances is the one that minimises the objective function in the worst case scenario (the min-max Nash equilibrium). This can be thought of as a game between the policymaker and a Malevolent Nature, with the policymaker choosing a policy

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that minimises the loss function, and Nature picking a parameter combination designed to maximise the loss, given that policy is conducted optimally.

Chart 5 below gives a diagrammatic representation of the solution. We define ranges for α and σ ($\alpha \in [0.1, 0.9], \sigma \in [0.1, 1.5]$), and compute the welfare loss in the commitment equilibrium for each parameter combination. So each point on the chart corresponds to the minimised social welfare loss conditional on a given set of parameters. It is easy to see from the chart that Nature will pick $\alpha = 0.1$ and $\sigma = 0.1$, the parameters which give the highest minimised welfare loss.

We argued above that financial frictions tend to increase σ (through the effect of the external finance premium) and reduce α (by increasing credit constraints), and that low financial frictions would thus be characterised by a relatively small σ and a large α. But the worst case scenario involves low σ and *low* α. So this case corresponds to one where the external finance premium is unaffected by the change in the policy rate; see equation (4). In turn this will be the case if either the external finance premium is only weakly responsive to the debt-equity ratio or the valuation of equity is relatively unaffected by changes in official rates.

5.4   Robustness versus performance

A robust policy like that derived here ensures relatively good outcomes in the worst case scenario. But it may produce relatively poor outcomes for other realisations of the parameters. And in many cases, including that considered here, the robust policy optimises performance at the boundary of the support of the parameters. It is consequently very sensitive to where these boundaries are located. There is something rather unsatisfactory in assuming that the policymaker can say with great confidence what the range of feasible parameter values is, whilst at the same time positing total ignorance about the relative likelihood of different parameter values occurring within the distribution. What we really seek, therefore, is some sort of half-way house between Brainardian and Knightian uncertainty.

To see the force of the first of these points, suppose that the policymaker is willing to take the view that the "most likely" realisation of the parameter values corresponds to the intermediate values $\sigma = 0.6$ and $\alpha = 0.5$. As an alternative strategy (we make no claims for optimality here), consider setting policy to minimise the expected loss assuming that the parameters take these values (the 'Modal rule'). Chart 6 shows the relative welfare loss (on the vertical axis, in log differences) under the Robust rule and under the Modal rule across the parameter space. Negative values in the chart indicate that the Robust rule delivers lower expected loss than the Modal rule (and vice versa). The key conclusion to be drawn here is that the Modal rule performs better than the Robust rule for most of the parameter space, but its performance deteriorates rapidly as monetary policy loses its potency and credit constraints bite. However, the deterioration only occurs at values of σ and α below 0.2 – the very extreme of the parameter range we consider.

Charts 7 and 8 illustrate the same point in two dimensions. Chart 7 computes the expected losses under the Robust and Modal rules (we discuss the 'Intermediate rule' below) as we vary σ for three different values of α. Chart 8 computes the expected losses as we vary α for three different values of σ. Again, we can see how the Robust rule is dominated by the Modal rule for most of the parameter space. The Robust rule, however, delivers insurance against the worst case scenario.

Now suppose that the policymaker has *some* prior knowledge on the distribution of the parameters, but is unwilling or unable to fully specify it. We consider a modification of the Robust control approach in which the policymaker is prepared to make some statement about the relative likelihood of different parameter values and a Malevolent Nature then chooses the *worst possible distribution*. The policymaker then minimises the expected loss, using the standard approach, and given that distribution.

To illustrate this, suppose that the policymaker knows the most likely outcome (σ_M) and the support of the distribution of σ ([σ_{LOW}, σ_{HIGH}]), but not its shape. However, (s)he is prepared to state that values closer to the mode are at least as likely as values far away from the mode. As discussed above, the conduct of policy becomes more difficult for smaller values of σ. So, Nature would like to place as much probability

as possible into the lower tail of the distribution of σ. But she is constrained in her choice of distribution, because values closer to the mode must be at least as likely as values further away from the mode. Then it is easy to see that the worst distribution Nature can inflict upon the policymaker is a uniform distribution over the support $[\sigma_{LOW}, \sigma_M]$; see Chart 9. Conditional on this distribution, the policymaker then solves a standard optimal control problem over the relevant subset of the parameter space. We refer to this policy as the Intermediate rule, as it combines elements of both standard policy optimisation and robust control.

To see what effect this might have in the present model, assume the support of σ and α is as above, and that the modal values are also as given above. Then Malevolent Nature picks a uniform distribution defined over {σ, α}, {[0.1, 0.6], [0.1, 0.5]}. The policymaker then minimises the expected loss, given this parameter distribution. This last step is a little complex in even this relatively simple set up, but to get a feel for the implications of the approach we have calculated the expected welfare losses where the optimal policy is calculated assuming that σ and α are equal to their means with respect to the distribution selected by Nature, i.e. just the average of σ_M and $\sigma_{LOW,}$ and α_M and $\alpha_{LOW,}$ respectively. This rule, of course, does not correspond to the optimal rule calculated over the entire subspace, but it is probably a reasonable approximation.

Chart 10 compares the performance of the Modal and Intermediate rules over the feasible parameter range. The Intermediate rule gives roughly comparable performance to the Modal rule, while still providing some insurance against the worst case scenario. Of course, as Chart 11 comparing the Robust and Intermediate rules shows, this insurance is not complete: the Robust rule still performs better in the worst case. But the Intermediate rule performs better than the Modal rule under a wider range of parameter values than the Robust rule, and is hence less sensitive to extreme values. Charts 7 and 8 help to make the comparison between the rules clearer. Again, we can see that the Intermediate rule combines good performance across the permissable parameter range with (limited) insurance properties in the worst case.

6 Concluding Remarks

In this paper we have surveyed some of the ways that financial frictions can augment the classical interest rate channel whereby changes in monetary policy affect the economy. The difficulty of providing a satisfactory explanation of the magnitude and persistence of the effects of changes in the official interest rate relying solely on the classical channel suggests that financial frictions may be an important, and possibly very important, part of the transmission mechanism. However, these frictions may be manifested in a variety of ways, as witnessed by the variety of theoretical models in the credit channel and bank lending literatures.

Sorting out the relative importance of these different channels is hampered by the fact that the competing theories often have similar implications, at least on aggregate data. However, the microeconomic evidence does suggest that both the credit channel and bank lending channel are operative.

With respect to the implications for the conduct of monetary policy, a key feature of financial frictions is that they tend to increase persistence and also amplify the effect of changes in official interest rates. In our New Keynesian macroeconomic model, the presence of such frictions means that policy has to be rather more aggressive. This is because the forward-looking elements in the transmission mechanism are relatively less important when there are frictions, so that expectations of future movements in interest rates have a more muted effect on the economy today.

The nature of these financial frictions, and their potentially asymmetric and episodic character, are also likely to introduce (even greater) uncertainty into the magnitude and timing of the response of the economy to changes in monetary policy. Here we drew on the recent robust control literature to explore how optimal policy under Knightian uncertainty would be affected. That approach suggests that the policymaker should act on the assumption that credit constraints are important (so persistence is high) but that the external finance premium is not very responsive to the level of interest rates (so that demand is not particularly responsive to interest rates). Arguably, the robust control approach places too much weight on avoiding bad

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outcomes in extreme cases. We therefore considered a case that is intermediate between robust control and standard optimal control where the economy is subject to a known stochastic law of motion. In our intermediate case the policymaker can say something, but not everything about the nature of the distribution (s)he is faced with. This approach potentially moderates the sensitivity to extreme events found under the standard robust control approach.

Clearly there is still much more to be said and written on this topic. However, we hope that the papers at this conference will lead to advancement in our understanding in this area.

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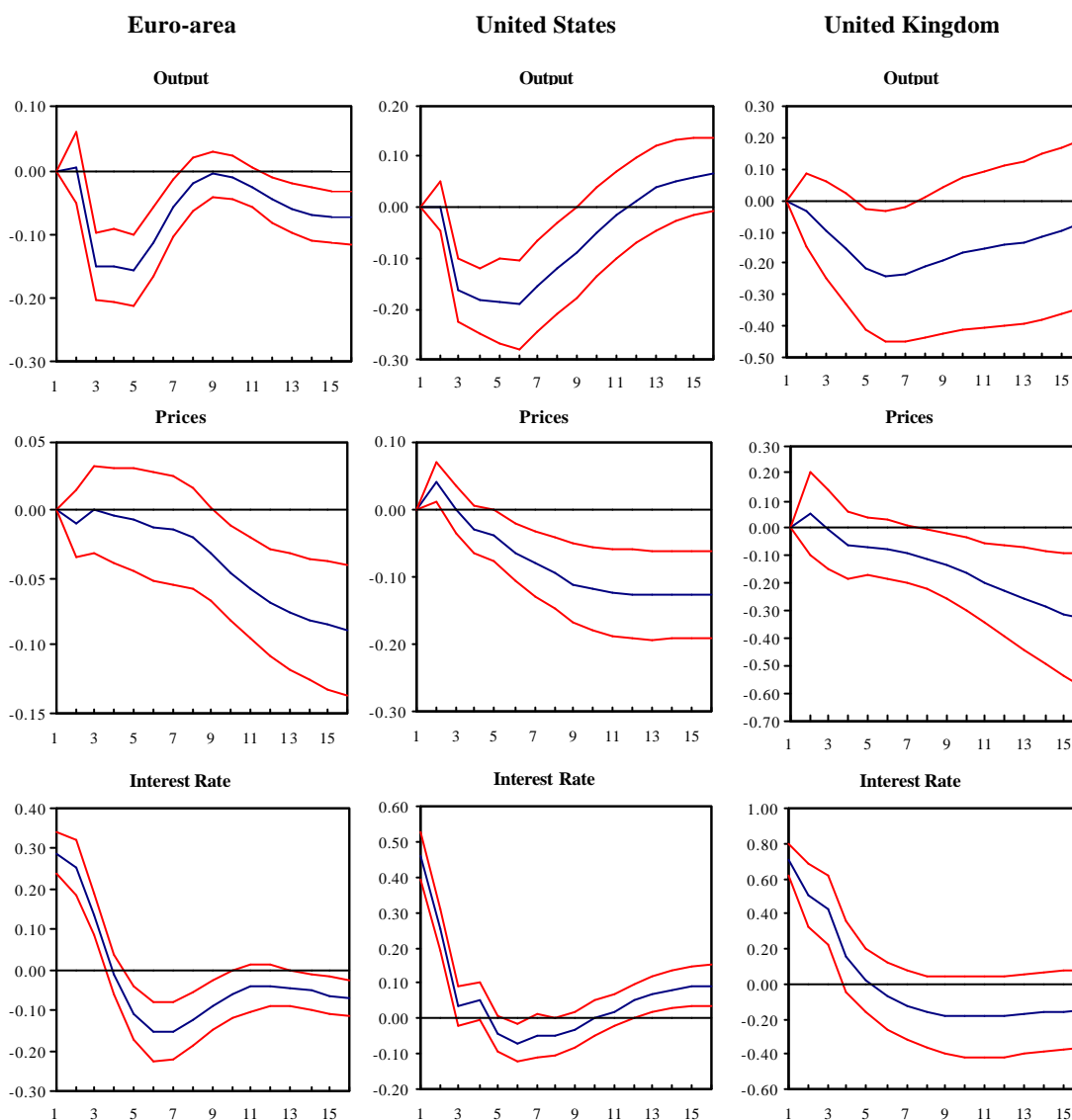
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Chart 1: The effects of a monetary policy shock in the Euro-area, the United States and the United Kingdom

Euro-area　　　　　**United States**　　　　　**United Kingdom**

Output　　　　　**Output**　　　　　**Output**

Prices　　　　　**Prices**　　　　　**Prices**

Interest Rate　　　　　**Interest Rate**　　　　　**Interest Rate**

Note: Results for Euro-area and US obtained from Peersman and Smets (2001). Confidence bands are at 90% levels. Standard error for the Euro-area and the US obtained using a bootstrap procedure, while those for the UK are asymptotic standard errors.

Chart 2: The auto-correlation function for output

ACF(y)
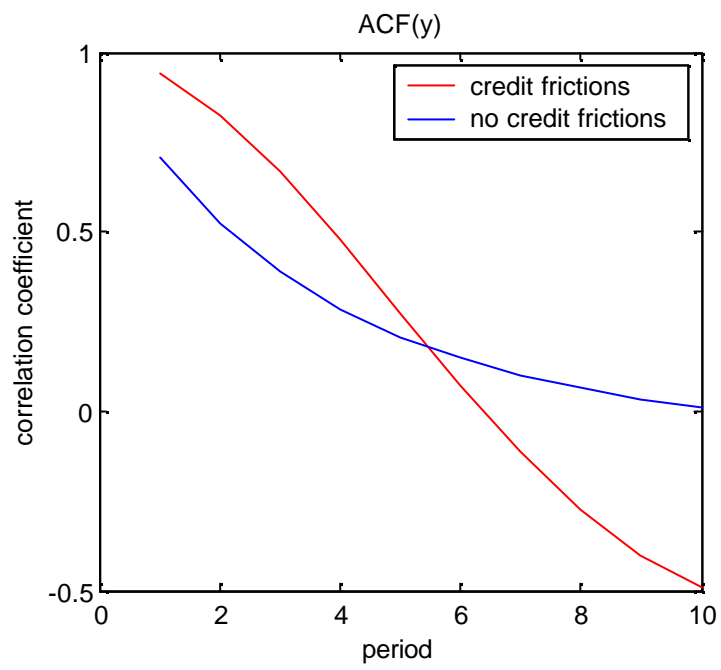
Chart 3: Response to a unit cost shock

Output gap response

Nominal interest rate response

Inflation response

periods after the shock
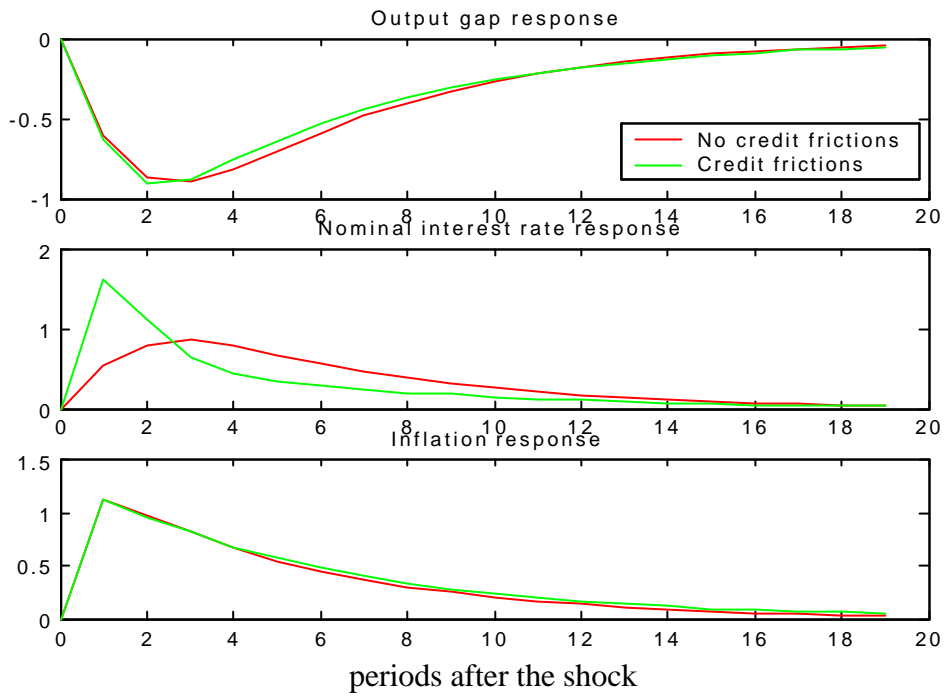
Chart 4: Optimal equilibrium under a demand shock

Output gap response

Nominal interest rate response

Inflation response

| No credit frictions |
| Credit frictions |

periods after the shock
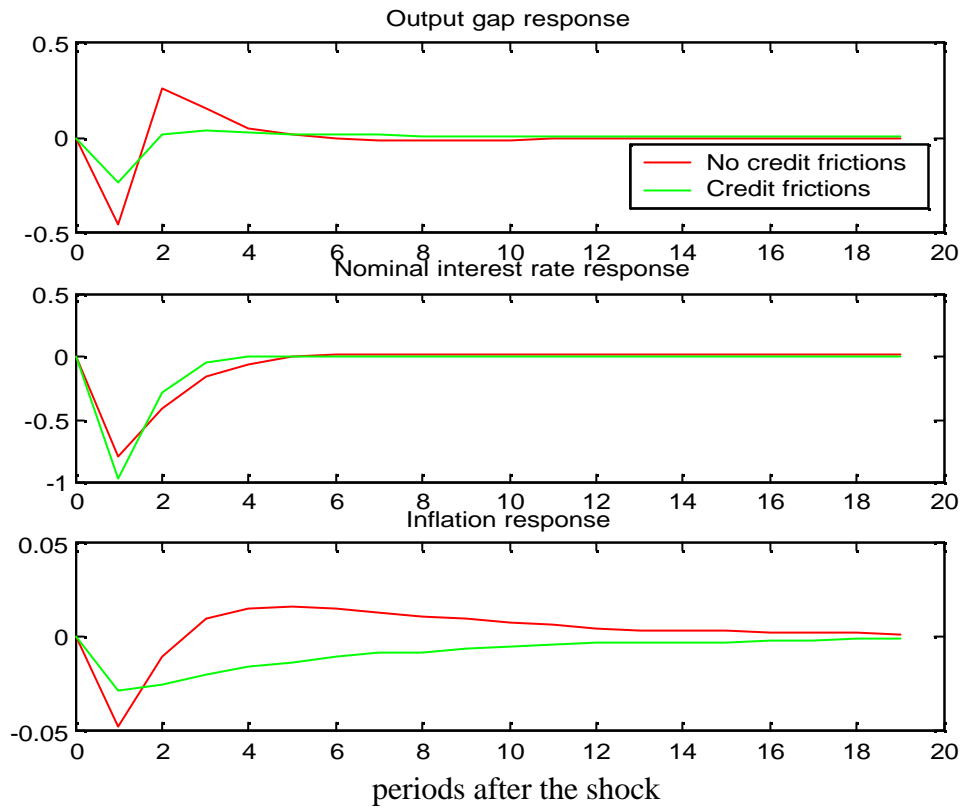
Chart 5: The optimal commitment loss surface

Chart 6

Relative losses: Robust-Modal rule

Chart 7: The performance of Robust, Modal and Intermediate rules under parameter uncertainty (1)

Chart 8: The performance of Robust, Modal and Intermediate rules under parameter uncertainty (2)

Chart 9: The worst case distribution

Density

Chart 10

Relative losses: Intermediate-Modal rule

Chart 11

Relative losses: Robust-Intermediate rule

Table 1.a: Business fluctuations of the UK economy (1970-2000)

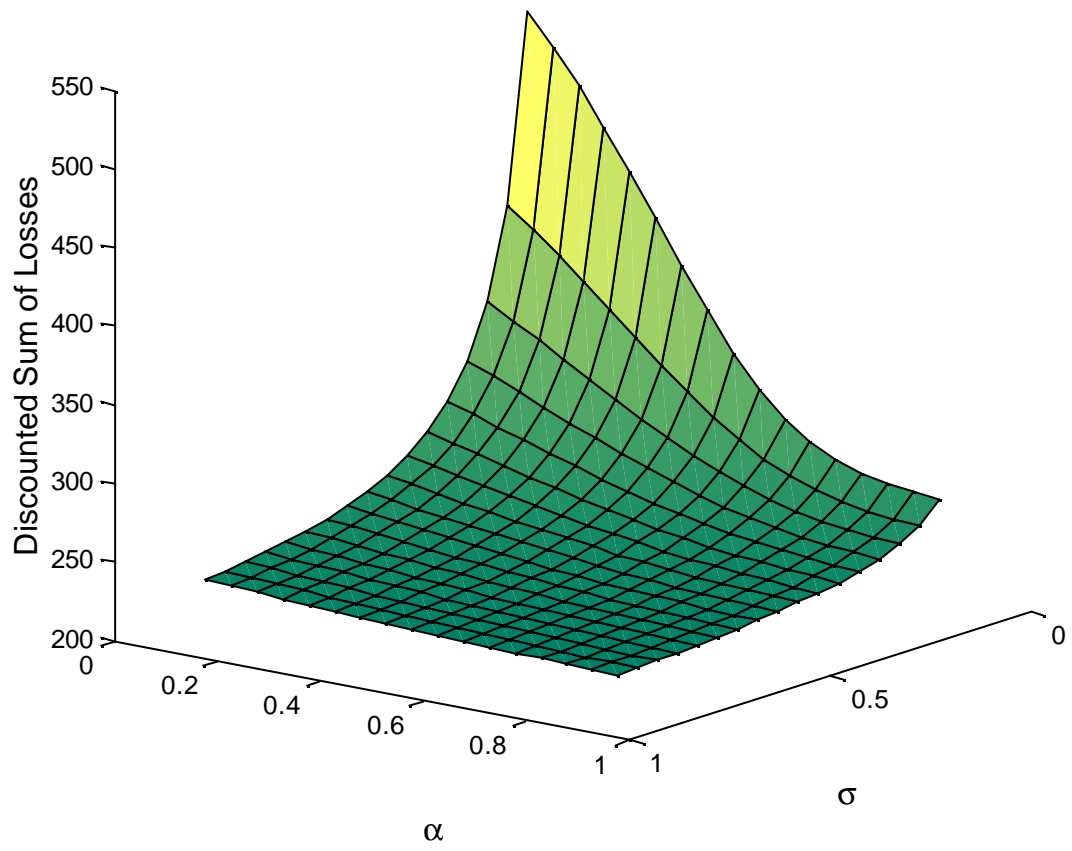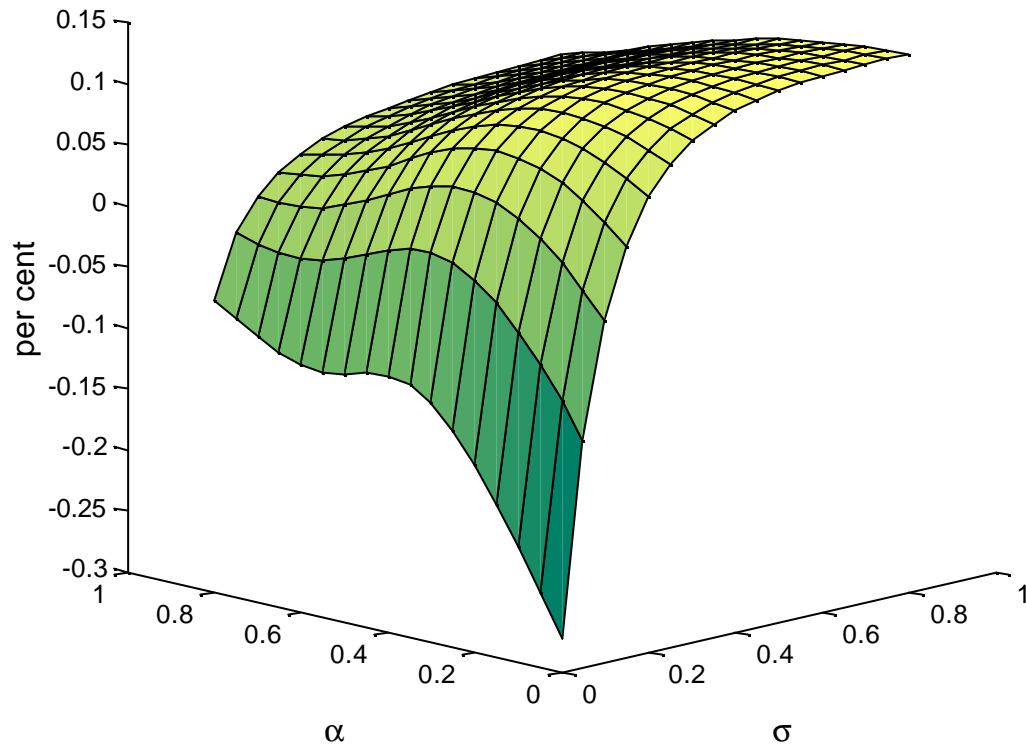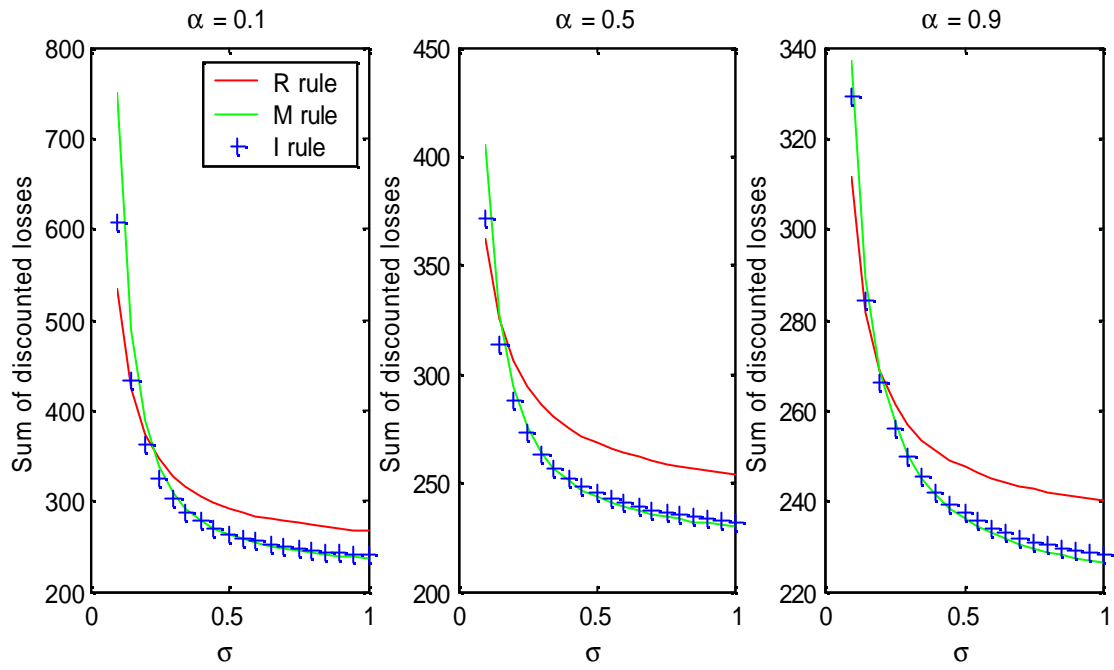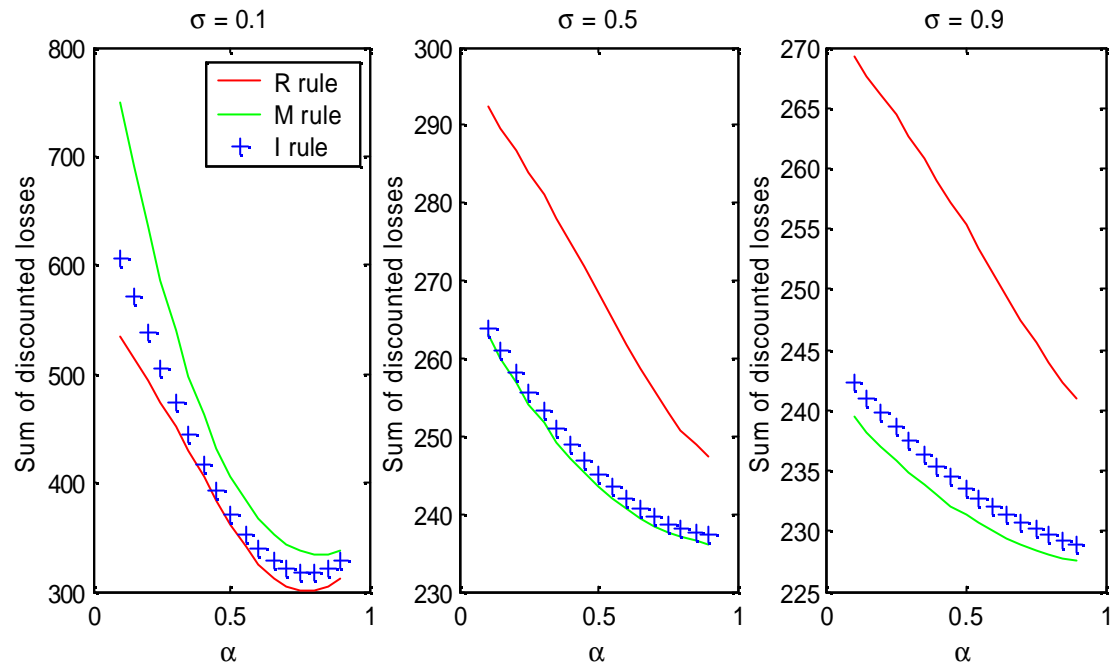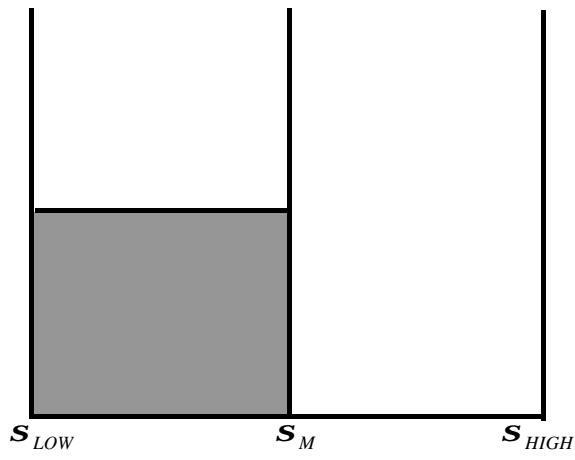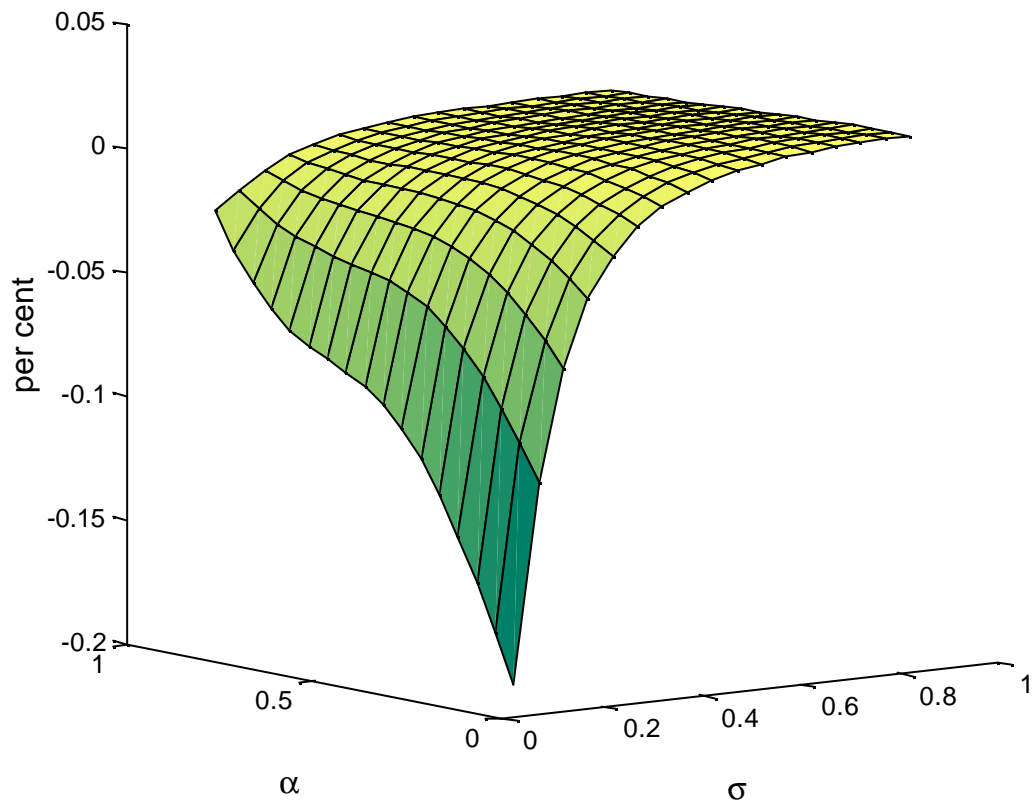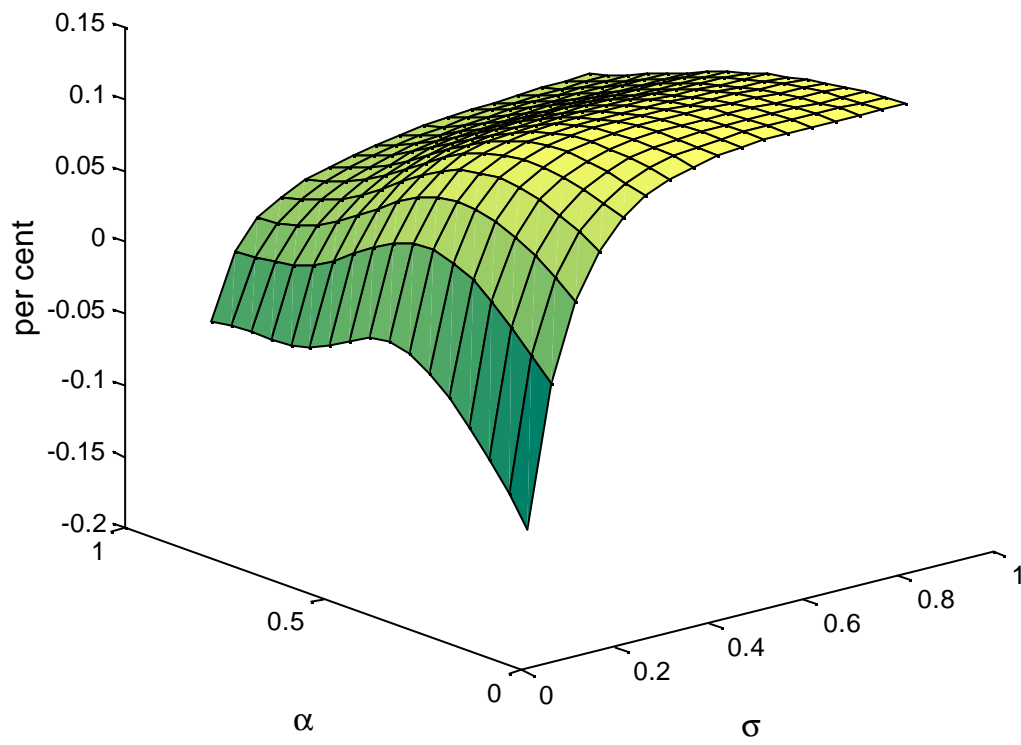| Variables (t)	Std (X)	Std (X) / Std (GDP)	Cross correlation with GDP at (t+k)								
			-4	-3	-2	-1	0	1	2	3	4
GDP	2.00	1.00	0.48	0.66	0.83	0.95	1.00				
Consumption	2.19	1.09	0.54	0.64	0.73	0.80	0.82	0.76	0.63	0.46	0.26
Investment	4.97	2.48	0.63	0.74	0.81	0.84	0.82	0.74	0.62	0.48	0.33
Cumulated inventories	3.05	1.52	0.93	0.91	0.83	0.70	0.53	0.35	0.18	0.03	-0.10
M0	2.51	1.25	0.72	0.69	0.64	0.57	0.46	0.35	0.21	0.06	-0.07
M4	3.10	1.55	0.50	0.45	0.38	0.29	0.19	0.06	-0.07	-0.21	-0.35
M4-lending individuals	2.25	1.12	-0.20	-0.17	-0.13	-0.09	-0.05	-0.02	0.00	-0.02	-0.06
M4-lending PNFC	8.75	4.36	0.46	0.41	0.33	0.21	0.08	-0.07	-0.22	-0.36	-0.48
GDP deflator	2.72	1.36	0.06	-0.11	-0.27	-0.41	-0.52	-0.57	-0.58	-0.53	-0.45
GDP deflator Inflation	3.42	1.70	0.50	0.41	0.30	0.18	0.04	-0.08	-0.16	-0.20	-0.21
RPI	3.65	1.63	-0.20	-0.31	-0.42	-0.53	-0.63	-0.71	-0.78	-0.82	-0.83
RPI inflation	2.85	1.27	0.51	0.47	0.40	0.29	0.14	-0.02	-0.15	-0.26	-0.33
RPIX	3.64	1.62	-0.35	-0.45	-0.54	-0.62	-0.69	-0.74	-0.78	-0.79	-0.78
RPIX inflation	2.57	1.14	0.42	0.35	0.26	0.13	-0.02	-0.17	-0.29	-0.38	-0.42
House prices	8.99	4.49	0.58	0.59	0.58	0.54	0.44	0.30	0.13	-0.06	-0.25
Equity prices	13.88	6.92	-0.16	-0.12	-0.06	0.02	0.13	0.25	0.35	0.42	0.42
Short-term interest rates	2.10	1.05	0.64	0.62	0.56	0.46	0.30	0.10	-0.10	-0.28	-0.42
Long-term interest rates	1.08	0.54	0.33	0.25	0.17	0.08	-0.03	-0.15	-0.27	-0.37	-0.41
"Yield curve"	1.67	0.83	-0.59	-0.61	-0.60	-0.52	-0.39	-0.23	-0.05	0.12	0.27
ERI	6.44	2.87	0.16	0.09	0.02	-0.07	-0.16	-0.24	-0.31	-0.35	-0.37
Dollar sterling	10.95	4.88	0.58	0.53	0.45	0.35	0.23	0.10	-0.01	-0.11	-0.20
Correlation M0 and investment			-0.18	-0.08	0.02	0.13	0.24	0.32	0.38	0.41	0.43

Table 1.b: Business fluctuations of the euro area economy (1970-2000)

Variables (t)	Std (X)	Std (X) / Std (GDP)	Cross correlation with GDP (t+k)								
			-4	-3	-2	-1	0	1	2	3	4
GDP	0.84	1.00	-0.19	0.18	0.58	0.88	1.00				
Consumption	0.55	0.65	-0.13	0.09	0.37	0.63	0.79	0.80	0.66	0.40	0.09
Investment	1.85	2.20	0.06	0.34	0.62	0.81	0.86	0.75	0.51	0.21	-0.09
Cumulated inventories	2.40	2.86	0.65	0.83	0.82	0.59	0.22	-0.19	-0.52	-0.70	-0.70
GDP deflator (level)	0.58	0.70	0.29	0.27	0.16	-0.04	-0.30	-0.55	-0.72	-0.76	-0.67
CPI (level)	0.68	0.81	0.28	0.26	0.16	-0.03	-0.26	-0.50	-0.66	-0.72	-0.66
CPI (inflation)	0.31	0.37	0.35	0.34	0.27	0.21	0.20	0.26	0.31	0.30	0.19
Stock prices	12.00	0.14	-0.10	-0.07	-0.01	0.05	0.08	0.06	0.01	-0.03	-0.02
Real estate prices	1.36	1.62	0.53	0.52	0.50	0.45	0.39	0.31	0.20	0.06	-0.08
Short-term rate nominal	1.09	0.01	0.27	0.54	0.73	0.76	0.61	0.30	-0.08	-0.43	-0.67
Short-term rate real	0.76	0.01	0.49	0.65	0.68	0.55	0.26	-0.11	-0.43	-0.61	-0.59
Long-term rate nominal	0.57	0.01	0.22	0.38	0.48	0.47	0.33	0.09	-0.17	-0.37	-0.46
Yield curve	0.83	0.01	-0.20	-0.45	-0.63	-0.68	-0.58	-0.34	-0.01	0.32	0.56
Real ef. exchange rate	3.58	4.27	0.22	0.33	0.36	0.30	0.17	0.01	-0.12	-0.18	-0.18
DM-USD exchange rate	5.23	6.22	0.13	0.36	0.56	0.61	0.48	0.22	-0.08	-0.34	-0.46
M1	1.00	1.19	-0.22	-0.26	-0.20	-0.05	0.16	0.39	0.58	0.68	0.67
M3	0.72	0.85	0.45	0.23	0.01	-0.17	-0.26	-0.27	-0.19	-0.06	0.07
Total loans	0.85	1.01	0.59	0.55	0.48	0.37	0.23	0.10	0.00	-0.06	-0.08

Note: Table reproduced from Agresti and Mojon (2001).

Table 1.c: Business fluctuations of the US economy (1970-2000)

Variables (t)	Std (X)	Std (X) / Std (GDP)	Cross correlation with GDP (t+k)								
			-4	-3	-2	-1	0	1	2	3	4
GDP	1.34	1.00	-0.09	0.24	0.60	0.89	1.00	0.89	0.59	0.23	-0.09
Consumption	1.01	0.75	-0.24	0.03	0.34	0.64	0.84	0.87	0.74	0.51	0.27
Investment	3.26	2.44	0.11	0.44	0.75	0.94	0.95	0.80	0.53	0.20	-0.10
Cumulated inventories	2.35	1.76	0.74	0.89	0.88	0.69	0.35	-0.02	-0.32	-0.48	-0.48
GDP deflator (level)	0.67	0.00	0.00	-0.16	-0.31	-0.42	-0.48	-0.49	-0.46	-0.42	-0.39
CPI (level)	1.02	0.50	0.23	0.10	-0.07	-0.24	-0.41	-0.52	-0.56	-0.54	-0.49
CPI (inflation)	1.29	0.77	0.48	0.59	0.63	0.56	0.38	0.15	-0.09	-0.25	-0.31
Stock prices	7.92	5.93	-0.50	-0.50	-0.37	-0.12	0.16	0.39	0.47	0.40	0.22
Real estate prices	2.12	1.59	-0.18	-0.21	-0.16	-0.06	0.08	0.21	0.24	0.17	0.03
Short-term rate nominal	1.31	0.98	0.38	0.56	0.68	0.67	0.50	0.21	-0.14	-0.44	-0.62
Short-term rate real	1.11	0.83	-0.11	-0.03	0.07	0.14	0.15	0.07	-0.06	-0.22	-0.36
Long-term rate nominal	0.82	0.61	-0.03	0.14	0.28	0.35	0.30	0.14	-0.07	-0.28	-0.41
Yield curve	1.09	0.82	-0.51	-0.60	-0.63	-0.56	-0.39	-0.15	0.12	0.33	0.45
Real ef. exchange rate	2.96	2.21	0.08	0.11	0.08	0.00	-0.07	-0.12	-0.12	-0.08	-0.01
DM-USD exchange rate	6.66	4.98	0.19	0.23	0.23	0.23	0.27	0.37	0.45	0.42	0.27
M1	1.78	1.33	-0.22	-0.23	-0.18	-0.08	0.05	0.16	0.22	0.24	0.22
M3	0.87	0.65	0.25	0.37	0.42	0.39	0.28	0.12	-0.03	-0.13	-0.15
Total loans	1.99	1.49	0.75	0.78	0.68	0.48	0.19	-0.11	-0.34	-0.45	-0.45

Note: Table reproduced from Agresti and Mojon (2001).

Table 2: The effects of financial change

	Financial frictions	No financial frictions
Loss	240.4	238.7
St. dev. (p), %	4.19	4.11
St. dev. (y), %	0.99	1.05
St. dev. (R), %	4.91	4.27