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INTERNATIONAL CHANNELS OF TRANSMISSION OF MONETARY POLICY AND THE MUNDELLIAN TRILEMMA

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ABSTRACT

This lecture argues that the Global Financial Cycle is a challenge for the validity of the Mundellian trilemma. I present evidence that US monetary policy shocks are transmitted internationally and affect financial conditions even in inflation targeting economies with large financial markets. Hence flexible exchange rates are not enough to guarantee monetary autonomy in a world of large capital flows.

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1 Introduction

The Mundellian trilemma states that it is not feasible to have at the same time a fixed exchange rate, full capital mobility and monetary policy independence. Only two of the three may coexist. The Trilemma is a useful concept. But studying more closely recent developments in the international economy, particularly the functioning of international financial markets, it may be time to revisit its analytical underpinnings and to qualify its meaning in a significant way. I will make a step in this direction in this lecture.

The trilemma argument builds on an arbitrage condition in international markets, the uncovered interest parity (UIP) condition, which equates returns across bond markets in a world of perfect capital mobility. There is no question that under a fixed exchange-rate regime and full capital mobility, policy makers cannot set the interest rate at the level they believe appropriate for monetary conditions in their economy. Should they try to free their policy rate from foreign influences, they would be quickly flooded by large capital flows reversing their measures. On the other hand, a freely floating exchange rate in principle gives a central bank an additional degree of freedom. According to the Mundell-Fleming logic, once the exchange rate has taken care of foreign influences, the domestic interest rate is all that is needed to achieve the internal policy target, output stabilization. This is why the literature testing the empirical validity of the trilemma has focused on testing the comovements of countries' policy rates with the center country rate across exchange-rate regimes. If the domestic policy rate does not follow closely the center country, this is taken as evidence of monetary policy autonomy vis-a-vis the center. Policy rates (usually short-term interest rates) can of course be less correlated under a floating exchange-rate than under a fixed exchange-rate regime when there is free capital mobility. It is reassuring that a series of papers by Obstfeld, Shambaugh and Taylor (2005), Klein and Shambaugh (2013), Goldberg (2013) and Obstfeld (2015) have consistently found that short rates are less correlated to the base country rate for flexible exchange rate countries than for fixed exchange rate countries[1]. But that is not enough to show that countries can have independent monetary policies when

[1]Long rate correlations however seem independent of the exchange-rate regime (see Obstfeld (2015).

they have a floating exchange rate.

The Trilemma misleads us by assuming that domestic monetary and financial conditions shaping the macroeconomic situation of a country can be conveniently summarized by this one single variable, the short-term interest rate (see also Rey (2013)). If that were the case, the extra degree of freedom gained through exchange-rate flexibility would indeed be enough to neutralize any effects of foreign financial conditions on the domestic macroeconomy. Yet, in a world of globalized finance with different types of capital flows and financial market imperfections, key countries' monetary policies may affect other countries' monetary conditions and financial stability in several ways. Financial imbalances may arise and, as a consequence, domestic output may be affected later on. Or the presence of foreign debt may lead to powerful balance sheet effects that will alter the effect of a monetary loosening, say, in the domestic economy. In such a world, letting the exchange rate float may not be enough to insulate the domestic economy, even if it is a large country, from global factors and permit monetary policy independence[2].

The key question is how big this issue is and how far the trilemma morphed into a dilemma. Are domestic monetary and financial conditions largely determined by global factors, even in economies with freely floating exchange rates when there are large capital flows? Is there an international credit or risk-taking channel of monetary policy and how would it affect financial stability? Is that transmission channel more potent for some currencies due to their special roles in international financial markets? Any answer must clarify the different dimensions along which domestic monetary and financial conditions can vary and how far each of them is affected by domestic monetary policy versus global factors in a context of free capital mobility. Achieving this would make it possible to assess fully the potency of the domestic monetary policy tool (the short rate) for open economies, large or small, with flexible exchange rates in our world of large capital flows. I will not be able to provide the answers to all these questions in this lecture, but I hope at least to advance the research agenda.

[2]This is of course not a statement that exchange rates or exchange-rate regimes do not matter at all nor that the Mundell-Fleming Model should be discarded.

I begin by discussing different transmission channels of monetary policy in open economies in models with and without financial frictions. I then sketch how important the dollar is as an international currency in banking and asset management, and how this may matter for the transmission of international monetary shocks. In a third part, I show that there is a global financial cycle that is influenced by the key country in the international monetary system, the United States. I then present evidence that US monetary policy shocks are transmitted even to advanced countries with a fully flexible exchange rate. I conclude with some observations on the usefulness of additional policy instruments such as macro-prudential policies.

2 Transmission channels of Monetary Policy

The literature (keynesian and neo-keynesian models, models with financial market frictions) has analysed different transmission channels of monetary policy. I do a brief review of these channels and draw some implications regarding models of monetary policy for open economies.

Mundell-Fleming and New Open Economy Macroeconomics

Keynesian models, such as the Mundell-Fleming model, feature a strong exchange-rate channel for monetary transmission. In the case of a monetary loosening in the center country, demand in the center country goes up, boosting in particular exports from the periphery to the center (demand-augmenting effect). The return on the center country's bonds falls relative to the return on foreign ones, which induces an exchange rate depreciation. This makes the center country's goods cheaper than periphery goods thereby leading to expenditure switching out of the goods of the periphery (expenditure-switching effect). These two effects partly offset each other for the periphery. As previously discussed, periphery economies can pick their interest rate to stabilize output whenever their exchange rate is freely floating. Financial spillovers are however not modelled.

The international transmission channel of monetary policy works differently in the bench-

mark neo-keynesian model[3]. As noted by Obstfeld and Rogoff (2000, 2002), Corsetti and Pesenti (2001) and Benigno and Benigno (2003), the optimal monetary policy trades off the stabilization of the output gap and the strengthening of the terms of trade. In these models, gains from international cooperation are usually found to be small if "one's house is in order", i.e. international spillovers are not large.[4]

Models with financial market frictions

The recent crisis has put the spotlight on financial market frictions and their importance for monetary policy transmission and financial stability. I focus on two channels broadly defined: the "credit channel" and the "risk-taking channel".

The literature has long ago recognized agency problems as an important source of business cycle amplification (Bernanke and Gertler (1989)). When agency costs between borrowers and lenders are important, there is a wedge between the opportunity cost of internal finance and the cost of external finance: the external finance premium. This reflects the deadweight costs associated with the principal-agent problem and makes credit more expensive for a borrower. This external finance premium may depend on the stance of monetary policy. Expansionary monetary policy leads to an increase in asset prices, particularly equity prices, which increases net worth of borrowers. This mitigates adverse selection and moral hazard problems, decreasing the size of the wedge between internal funds and external funding costs. That then leads to an increase in lending and a increase in aggregate demand. I will use the term "credit channel" to describe this transmission channel (alternatives are "net worth channel", "balance sheet channel", "bank lending channel" and probably more)[5]. In the

[3]See Woodford (2003) and Gali (2008) for a precise description of the model. For a recent survey on monetary trasmission mechanisms see Boivin et al. (2010).

[4]The older literature on international monetary cooperation (see Bryant et al. (1988)) has also typically found low gains from coordination. Farhi and Werning (2014) show that it may be optimal for central banks to smoothe their terms of trade in a way that cannot be achieved solely with the policy rate (not enough instruments for all the targets). Bergin and Corsetti (2014) consider a model with a production externality, which may make gains from international cooperation higher.

[5]The financial accelerator mechanism (Bernanke, Gertler and Gilchrist (1999)) has been mostly studied in the context of closed economies and initially applied to non-financial corporations and households (Kiyotaki and Moore (1997)). There is a rapidly growing literature modeling some type of balance sheet constraints: Lorenzoni (2008); Fostel and Geanakoplos (2009), Christiano, Motto and Rostagno (2005). Recently, there has been a flurry of models featuring explicitly financial intermediaries (e.g. Gertler and Karadi (2011),

presence of occasionally binding constraints, there may be fire sales and excess risk-taking: there is a pecuniary externality as agents do not internalize the decrease in prices caused by fire sales when they lever up.

In the "risk-taking channel" of monetary policy as described by Borio and Zhu (2012) and Bruno and Shin (2015b), financial intermediation plays a key role and measured risk enters the financial friction. Models usually feature risk-neutral leveraged intermediaries subject to a value-at-risk constraint[6]. A positive shock raises demand for assets and this compresses risk premia. In turn lower risk premia relaxes further the value-at-risk constraint of intermediaries, which enables them to lever further. In such an environment, a looser monetary policy lowers financing costs and triggers this feedback loop. Some papers tend to emphasize "excessive risk-taking" due to a myopic value-at-risk constraint computed using recent measured risk parameters, others endogeneous movements in the exchange rate that loosen the constraint. All emphasize the procyclicality of leverage induced by the constraint, which may not be optimal from a macroeconomic point of view.[7] One could think of other ways of modeling excessive risk-taking such as government guarantees (bail out expectations) and limited liability and risk shifting.

Empirical evidence

Recent empirical evidence on the risk-taking channel for loan books has been provided by Jimenez, Ongena, Peydro and Saurina (2012), and DellAriccia, Laeven and Suarez (2013). Gertler and Karadi (2015) present evidence of an effect of monetary policy shocks on various domestic spread measures (US mortgage and corporate spreads) as well as on the term premium. Miranda Agrippino and Rey (2012) show that US monetary policy affects risk premia as well as leverage and credit growth in the rest of the world. This evidence can be consistent with the credit channel or the risk-taking channels of monetary policy.

Curdia and Woodford (2009), Kiyotaki and Gertler (2014), Brunnermeier and Sannikov (2014), He and Krishnamurthy (2013), Adrian and Boyarchenko (2014), Coimbra (2015).

[6]See Adrian and Shin (2014) for a microfoundation of this constraint.

[7]Another potentially related channel of transmission of monetary policy is the "search for yield" (Rajan (2005)). In a low interest rate environment, investors take on additional risk in order to secure higher yields. This could explain portfolio shifts from short run to long run assets and to emerging market assets when policy rates remain low for extended time periods.

To sum up, the "credit channel" and the "risk-taking channel" are potentially important channels of monetary policy transmissions. Both matter for financial stability, as they have implications for leverage of intermediaries, credit growth and asset pricing and may lead to "excessive risk-taking".[8] While the credit and risk-taking channels have been mostly studied in a closed economy context[9], evidence is building up that they might be relevant in an international context as well. In an environment with foreign debt (often US dollar debt) on balance sheet, monetary policy in the domestic economy faces a tradeoff between stabilization of output and balance sheet effect. In this case, when the US increases interest rate, the domestic exchange rate depreciates, which stimulates domestic exports. On the other hand, this leads to an adverse balance sheet effect since the value of foreign debt goes up. As a result of this tradeoff, even with flexible exchange rates, the interest rate is not enough to achieve monetary autonomy. Aoki et al. (2015) find that the the benefit of a second instrument (macroprudential tools) for the domestic economy is larger the bigger the variance of the foreign interest rate shock[10].

Monetary policy in the center country may therefore transmit itself internationally and be amplified via frictions in the capital markets affecting balance sheet and/or financial stability in the rest of world. This phenomenon will be all the more important for US monetary policy the more dominant the US dollar in international financial markets.

3 The geography of US dollar finance

There is a large literature discussing the importance of the dollar as an international currency and emphasizing its various roles in invoicing, pegging, issuance of financial assets, as vehicle

[8] It is worth remembering that credit booms have been found to be the best predictor of financial crises (Gourinchas and Obstfeld (2012), Schularick and Taylor (2012))

[9] Bruno and Shin (2015b) is an exception for the "risk-taking channel"

[10] Farhi and Werning (2015) study a range of models with aggregate demand externalities or pecuniary externalities. In particular they analyse a model with nominal rigidities, market incompleteness and foreign currency debt. They too find that additional tools (in their case taxing foreign currency debt) is optimal

currency in foreign exchange markets and in commodity trade[11]. There is considerable work on the functioning of the international monetary system with the dollar as a key currency[12] discussing the role of the US as a world banker, insurer or liquidity provider. The transmission of US monetary policy and of crises in the context of a fixed exchange rate regime (the Gold Standard) has been analysed by Eichengreen (1992). But since the collapse of Bretton Woods, the importance of the dollar in international banking, its use as a funding currency for banks and asset managers and the importance of pools of dollar assets worlwide in the context of the transmission of US monetary policy shocks are still under-researched [13].

McCauley, Mc Guire and Sushko (2014) point out that dollar credit extended by banks and bond investors to non-financial borrowers outside the US stands at approximately $7 trillion in 2014, which represents approximately 13% of non-US GDP. Perhaps surprisingly, these authors find that the top three stocks of dollar credit are in jurisdictions that are not usually thought of as "dollarised", i.e. the euro area, China and the United Kingdom. As a point of comparison, the stock of off-shore euro credit was only about $3.9 trillion.

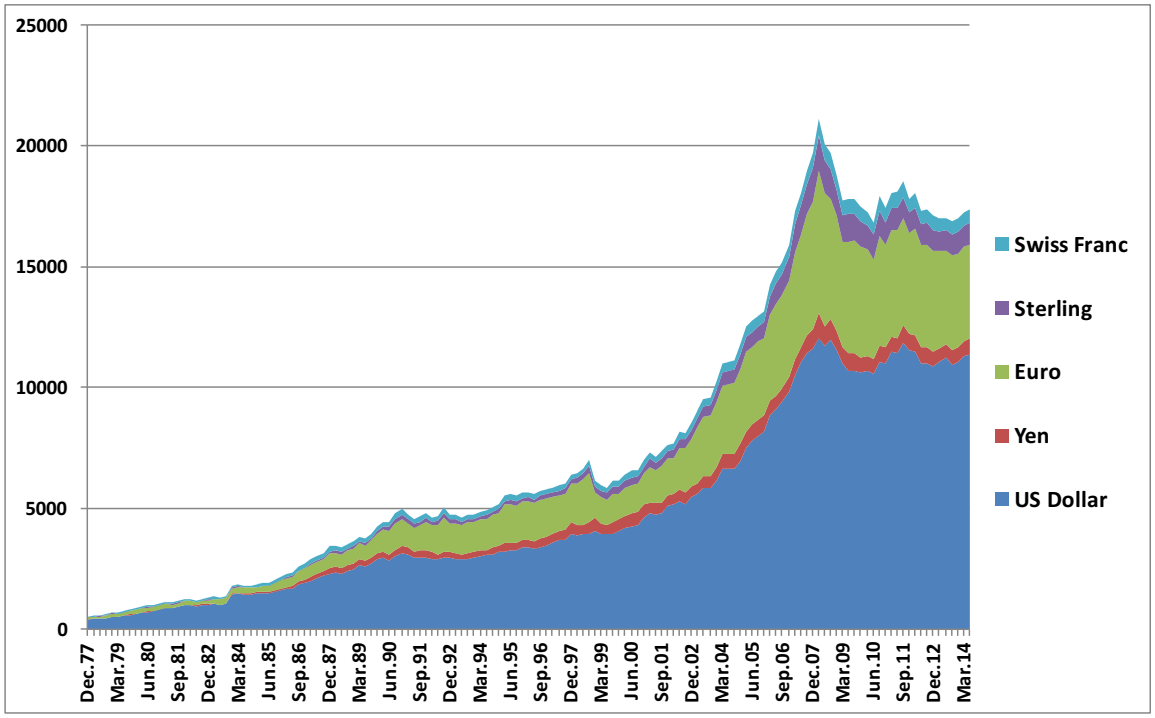
As Figure 1 shows, the total amount of credit in USD issued by non-US banks locally and cross-border (but excluding credit to the US) has grown very rapidly from the beginning of the 2000s. It completely dwarfs similar offshore credit in sterling, yen, Swiss franc or even euro. Global banks, in particular European-based ones, have played a major role in intermediating this dollar credit. According to Mc Cauley et al. (2015), as of March 2014, 84% of dollar-denominated international bank credit has been extended by non-US banks. In the recent period dollar credit has been extended in large proportions via the international bond markets, and non-banks have been purchasing heavily those dollar assets. Unfortunately, there are no data available yet to assess the amount of dollar holdings in asset managers' balance sheets by jurisdictions. But since the launch of QE in 2009, hard currency

[11] See e.g. Krugman (1980), Portes and Rey (1998), Chinn and Frankel (2005), Papaoiannou and Portes (2008), Eichengreen (2011), Prasad (2014).

[12] See Despres, Kindleberger and Salant (1965), Kindleberger (1966), Gourinchas and Rey (2007a,b), Gourinchas, Rey and Govillot (2012) and Maggiori (2013).

[13] See Cetorelli and Goldberg (2013), Shin(2012), Passari and Rey (2014).

Figure 1: cross-border and local positions in foreign currencies.



Notes: cross-border positions and local positions by reporting banks in foreign currency disaggregated by currency (bn). Source: BIS.

emerging market fund assets (mostly dollars) have grown by 350%. The top 10 global asset management firms account in 2014 for more than $19 trillion in assets under management.

As stipulated by the "credit channel", banks, companies and households find it easier to borrow when they have high net worth, as they can more easily meet required financial ratios or collateral requirements or can make higher down payments. In the international economy, the dollar is used around the globe as an investing currency and a funding currency. When borrowers have short-term or floating-rate debt, decreasing the Fed funds rate directly reduces interest payments; this improves the cash flow of the borrower. Furthermore, a decrease in the discount rate increases the value of dollar assets and their collateral value. By these two effects, monetary loosening by the Fed improves the net worth of households, companies and financial intermediaries, which decreases the external finance premium, regardless

of what domestic monetary policy is trying to achieve. This may stimulate investment and aggregate demand. A contrario, when the Fed tightens, the domestic central bank faces a tradeoff whenever there is a lot of dollar debt in domestic balance sheets. A depreciation of the domestic exchange rate increases net exports and demand but creates adverse balance sheet effects.

Similarly in models in which financial intermediaries operate under value-at-risk constraints, cheap funding will tend to compress spreads, lower measured risk, relax the constraint and enable further leverage (Borio and Zhu (2012)). This positive effect on the balance sheet could be further strengthened by an appreciation of the domestic currency (see Bruno and Shin (2015a))[14]. Given the prevalence of dollar funding in the international economy as well as the importance of dollar assets in many portfolios around the globe, the credit channel or the risk-taking channel broadly defined could be a potent channel of international transmission of monetary policy. I now proceed to look for it in the data.

4 Smoking gun: the Global Financial Cycle

There is a growing literature documenting a high degree of comovement in risky asset prices, credit growth, leverage and financial aggregates around the world, a phenomenon I called the Global Financial Cycle in Rey (2013)[15].

Risky asset prices around the globe, from stocks to corporate bonds, have an important common component (Miranda Agrippino and Rey (2012))[16]. So do capital flows which are highly correlated with one another and negatively correlated with the VIX or other indices of "market fear" (see also Forbes and Warnock (2012)). Leverage and leverage growth are

[14]Because of the size of the US market in the world economy, a monetary loosening by the Fed may have a non-negligible effect on US imports, which in turn will affect the income and net worth of exporting firms in other countries.

[15]The global financial cycle is different from the national financial cycles described by Drehmann et al. (2012) who emphasize the domestic cycles in credit and real estate prices.

[16]Longstaff et al. (2011) find a very large role for a global component in sovereign CDS. They show that sovereign credit spreads are more related to the US stock and high-yield markets than they are to local economic measures.

negatively correlated with the VIX. Monetary conditions of the center country (the United States[17]) have an impact on changes in aggregate risk aversion and volatility, capital flows and the leverage of the financial sector in many parts of the international financial system (Miranda Agrippino and Rey (2012)).[18] While seeing a lot of comovement in asset prices worldwide may just be reflecting market integration, the fact that these comovements are to some extent caused by US monetary policy is important.

As capital flows respond to US monetary policy, they may not be appropriate for the cyclical conditions of many economies. For some countries, the Global Financial Cycle can lead to excessive credit growth in boom times and excessive retrenchment in bad times. As the recent literature has confirmed, excessive credit growth is one of the best predictors of crisis (Gourinchas and Obstfeld (2012); Schularick and Taylor (2012)). The Global Financial Cycle can be associated with surges and dry outs in capital flows, booms and busts in asset prices and crises. One definitely needs a structural model to establish formally how detrimental the Global Financial Cycle is. The empirical results on capital flows, leverage and credit growth are suggestive of an international credit channel or risk-taking channel and point towards potential financial stability issues.

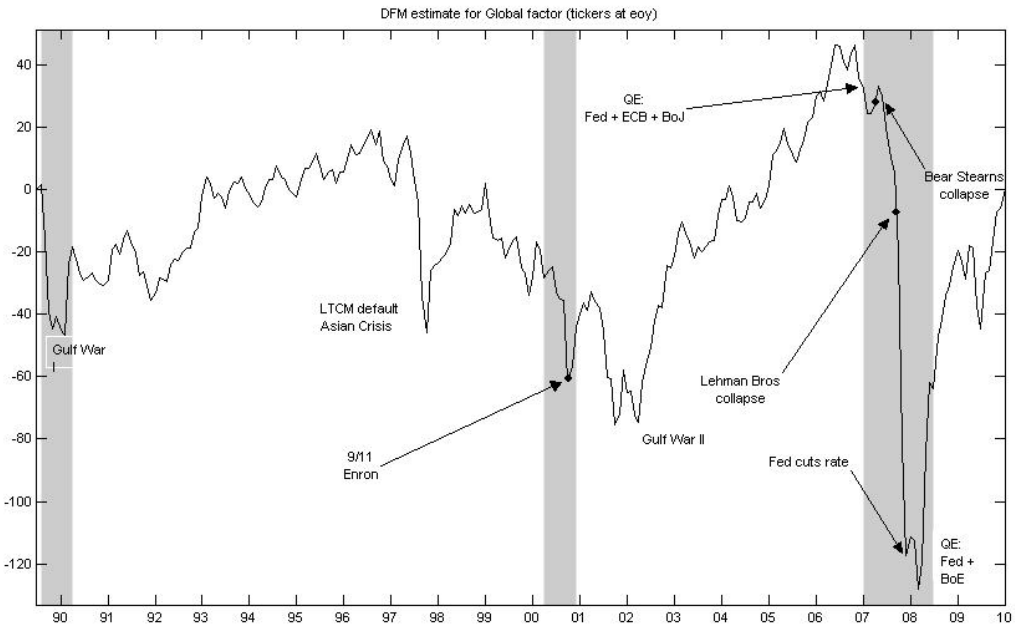
Figure 2 shows the common global factor extracted from a large cross-section of risky asset prices (equity and corporate bonds). This global component is an important part of the variance in asset prices around the world. As shown in Miranda-Agrippino and Rey (2012), it is highly negatively correlated with indices of "market fear" around the world: VIX (US), VSTOXX (EU), VNKY(JP), and VFTSE (UK). Given the prevalence of dollar funding and of dollar assets in world balance sheets and the reliance on some type of collateral constraints or value-at-risk constraints in many parts of the financial system, assessing the effect of US monetary policy on the dynamics of this global component is of interest to test for the existence of an international credit or risk-taking channel. Unlike in a domestic context

[17]Other large monetary and financial areas are also likely to have an influence. The euro area, Japan China the UK and possibly Switzerland come to mind. I only study the US in this lecture which is justified given the key role of the US in the international financial and monetary system.

[18]Bekaert et al. (2012) analyse the effect of US monetary policy on the VIX, decomposing it into a risk aversion component and a volatility component.

where the credit channel is viewed as an "enhancer" of the monetary policy of the central bank (Bernanke and Gertler (1995)), in the international context the credit or risk-taking channel may operate in parallel to the domestic monetary policy, as the external finance premium may be determined at least in part by an interest rate which is different from the domestic one (there are large and persistent deviations from UIP). It is also possible that the domestic policy rate reacts to the base country monetary shock out of "fear of floating" (see Calvo and Reinhart (2002)), in which case the credit or risk-taking channel via the domestic rate and the center country rate may reinforce one another. Both cases would indicate some loss of monetary and financial autonomy by the flexible exchange rate country.

Figure 2: Global Factor in risky asset prices



Notes: The Global Factor is estimated in Miranda-Agrippino and Rey (2012). See also Rey (2013). Shaded areas are NBER recessions.

4.1 Identification of US monetary policy shocks in VARs

As underlined by Stock and Watson (2008, 2012), the identification problem in structural VAR analysis is how to go from the moving-average representation in terms of the innovations

to the impulse response function with respect to a unit increase in the structural shock of interest, which is here the US monetary policy shock. One classic answer to this problem has been to impose economic restrictions such as timing restrictions (some variables move within the month, others are slower moving). This has permitted identification of the coefficients of interest (see Bernanke and Gertler (1995), Christiano et al (1995)). Romer and Romer (1989, 2004) introduce an alternative identification strategy: the "narrative approach". They use information from outside the VAR to construct exogenous components of specific shocks. Those are often treated as exogenous shocks. However, technically they are instrumental variables for the shocks: they measure (typically with some error) an exogenous component of the shock, so that the constructed series is correlated with the shock of interest but not with other structural shocks. Hence those are "external" instruments, because they use information external to the VAR for identification[19]. It is very clear that when one tries to identify the credit channel of monetary policy (broadly defined), movements in asset prices and spreads are key, as they are related to agency problems or risk shifting or to the operation of value-at-risk constraints depending on the friction considered in the model. Hence, it is important to use an identification strategy which allows for immediate responses in asset prices, as there is probably little delay in those market reactions. As shown in Gertler and Karadi (2015) with monthly data, an identification strategy based on timing restrictions may sometimes fail to identify the credit channel.

In this paper, I mostly follow Gertler and Karadi (2015) and Mertens and Ravn (2013) for the methodology and use the Gurkaynak et al. (2005) surprise measures as external instruments. These are clever instruments, as they measure surprises as changes in prices of Fed funds futures in tight windows around monetary policy announcement times. As Fed funds future prices aggregate all available information about expected monetary policy rates prior to FOMC meetings, any change in their prices at the time of the meeting very likely reflects a monetary policy surprise. It is unlikely that any other event dominates fluctuations in the price of Fed funds futures in a 30-minute window around the announcement. I use

[19]The discussion follows closely Stock and Watson (2008).

these surprises to instrument the one-year US interest rate or the effective Fed funds rate in VARs. The advantage of instrumenting the one-year rate (as opposed to the Fed funds rate[20]) is that the effect of forward guidance can be taken into account in the estimates. This is important in a period where the Fed funds rate has hit the zero lower bound. For each VAR, I test for the strength of the instruments using an F-test and implement the specification accordingly.

The structural VAR is

$$AY_t = \sum_{j=1}^{p} C_j Y_{t-j} + \varepsilon_t$$

where the variables of interest for the US VAR are the one-year rate (instrumented), the CPI, Industrial Production (IP), a measure of mortgage spread, a measure of commercial paper spread and the VIX. The structural white noise shocks are ε_t.

The reduced form VAR can be written as:

$$Y_t = \sum_{j=1}^{p} B_j Y_{t-j} + u_t$$

with

$$u_t = S\varepsilon_t = A^{-1}\varepsilon_t;\ B_j = A^{-1}C_j$$

and the variance covariance matrix of the reduced form VAR is

$$E_t\left[u_t u_t'\right] = E_t\left[SS'\right] = \Sigma$$

Following Gertler and Karadi (2015), the one-year rate is instrumented by the surprises in Fed funds future prices around FOMC announcements. I add up surprises within a month to construct monthly observations. Unlike them however, I do not assume that shocks persist for 30 days (as this introduces some persistence in the time series of the surprises). For the impulse responses of economic and financial variables to a monetary policy shock, one needs

[20] One could also in principle instrument for the two-year rate. Gertler and Karadi (2015) do extensive robustness checks and show that the strength of the instrument is higher for the one-year rate.

to recover the relevant structural shock:

$$Y_t = \sum_{j=1}^{p} B_j Y_{t-j} + s\varepsilon_t^p$$

I am interested in computing the impact of a monetary policy shock to the one-year rate ε_t^p (not in the effect of other structural shocks). The instrumental variables Z_t should be correlated with the structural monetary policy shock ε_t^p and uncorrelated with the other structural shocks.

$$\begin{aligned} E\left(Z_t \varepsilon_t^{p'}\right) &= \alpha \\ E\left(Z_t \varepsilon_t^{q'}\right) &= 0 \end{aligned}$$

I obtain estimates of u_t from the OLS regression of the reduced form representation. Denote by u_t^p the reduced form residual for the policy indicator and u_t^q the reduced form residual from the equations for variables $q \neq p$. Call s^q the response of u_t^q to a unit increase in the policy shock ε_t^p.

I can get an estimate of s^q/s^p from the TSLS regression of u_t^q on u_t^p and by using the instrumental variables Z_t[21]. It is possible to test for the strength of the instrument by doing a simple F-test. This methodology has the advantage of estimating the effect of monetary policy shocks over time, as opposed to event studies which do not account for endogenous dynamics.

4.2 Effects of US monetary policy shocks on the US economy and on global factors

I start by estimating a monthly VAR looking at the effect of US monetary policy shocks on the standard real economy variables (US CPI and US IP) but also including financial variables able to capture risk-taking or the credit channel: US mortgage spread, corporate

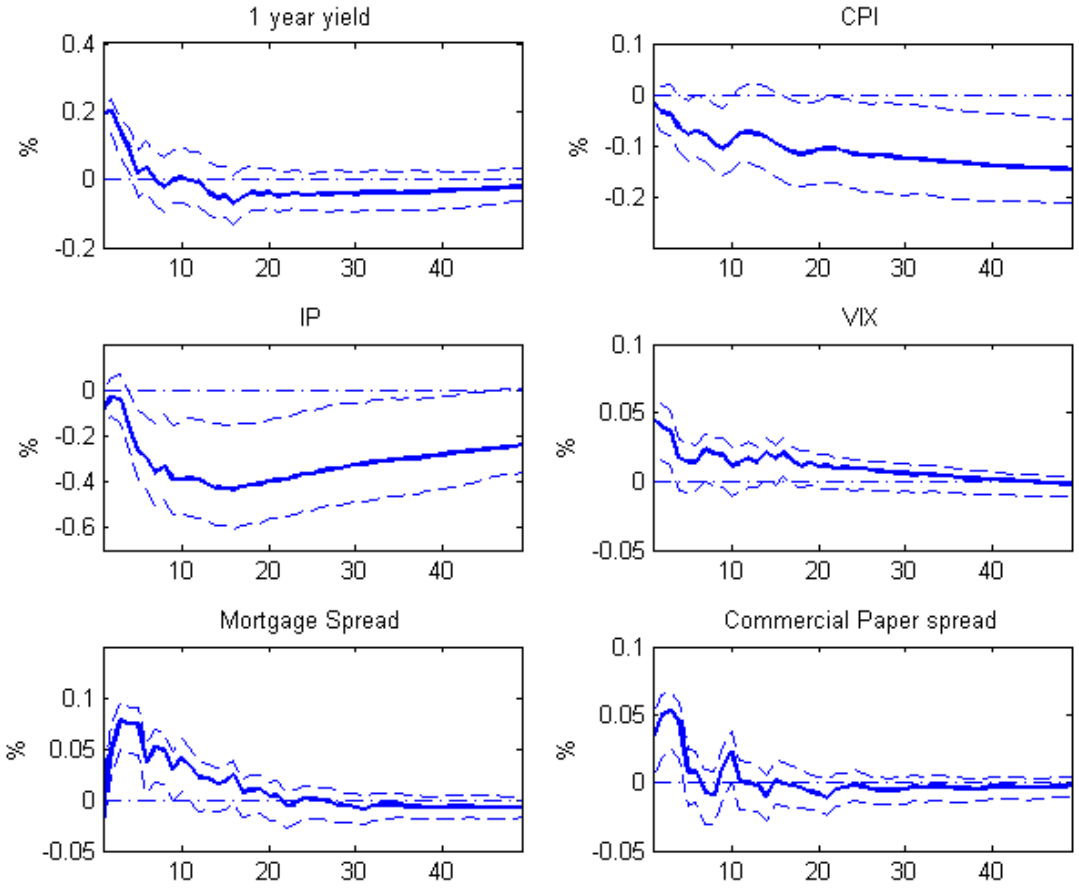
[21] For more details see Mertens and Ravn (2013).

spread and the VIX. I also include a variable reflecting conditions in international financial markets: the global factor in risky asset prices. For a detailed account of all the data sources, see the Appendix. I replicate the results of Gertler and Karadi (2015). As instruments, I use, like them, the three month ahead monthly Fed Funds futures (FF4) but, as explained above, I do not assume that surprises persist for 30 days. I also check the robustness of all the results using the current month's Fed funds futures (FF1) (they are all robust; when FF1 is clearly the stronger instrument I use it instead of FF4). The instruments are strong with F-stats generally well above 10 (they are reported for each figure). I report 90% confidence bands. In Figure 3, I find, for a 20 bp shock to the one-year rate, a significant and almost immediate reaction of the mortgage spread (peak about 8 bp) and of the commercial paper spread in the US (about 5 bp). Meanwhile, the CPI goes down with some delay (I have no price puzzle) and IP also declines with a lag, as our economics texbooks say it should. As in Rey (2013), I find that the VIX (in log) is significantly influenced by US monetary policy shocks. A 20 bp tightening shock in the one year leads to a 4 bp increase to the VIX (a standard deviation in the log VIX is 0.152). Finally, in Figure 4, I include my global asset price factor to capture spillovers to international asset markets. A monetary surprise leading to a 20 bp tightening in the one-year rate leads to a 8 percentage point decrease in the global asset price factor (whose standard deviation is about 50).

I read these impulse response functions as being consistent with the credit or risk-taking channels of monetary policy, broadly defined. There are substantial frictions in financial markets, and they are affected significantly by changes in monetary policy. Importantly these channels operate at home but also in world financial markets, as evidenced by the strong and significant responses of the global asset price component. In case of a monetary tightening by the Fed, the VIX goes up and the global asset price goes down significantly.

When using quarterly data, it is possible to include more variables which are closely associated with the risk-taking and the credit channels of monetary policy, such as the leverage of the financial sector in different geographical areas, cross-border credit flows, world credit growth. In Miranda Agrippino and Rey (2012), we use a medium-scale Bayesian

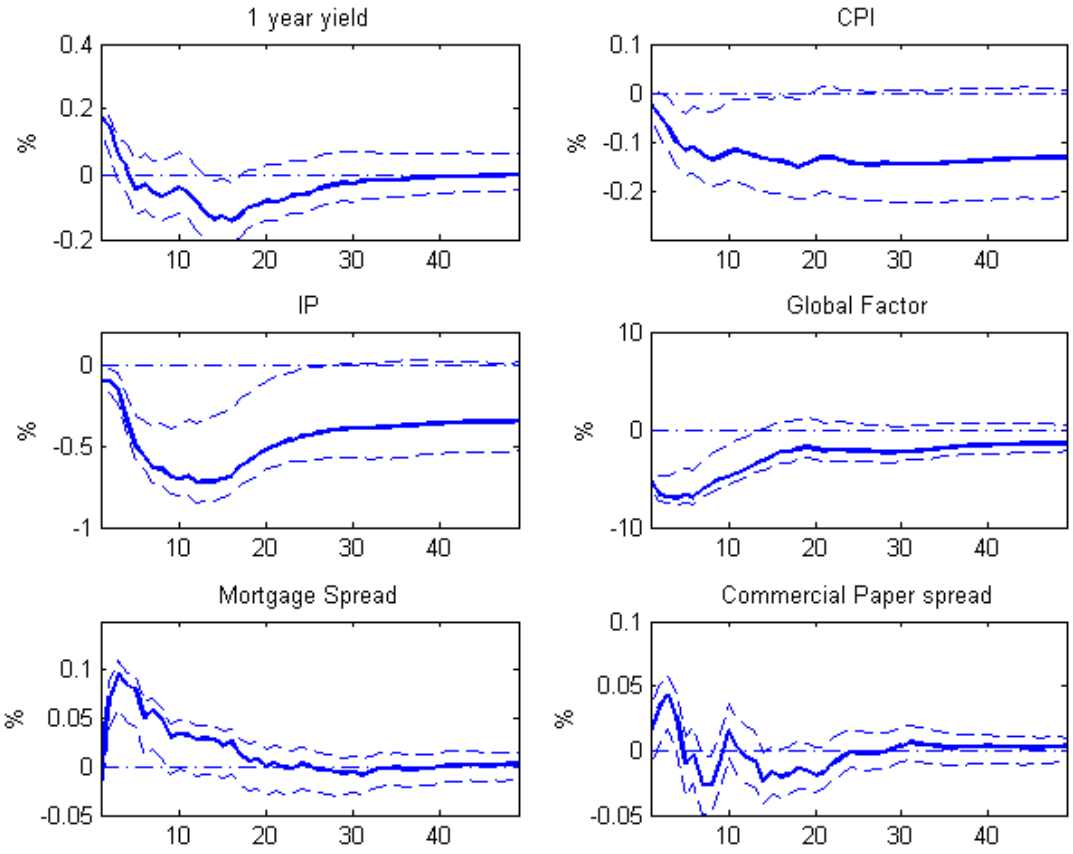
Figure 3: Effect of US monetary policy on US financial variables



Notes: Monthly data over the period 1979:07 to 2012:06. The instruments (Fed Funds futures FF4) are available from the period 1991:01 through 2012:06. The F-stat is 20.86. I report 90% confidence intervals.

VAR with between 20 and 25 variables (quarterly data) to study the effect of US monetary policy on the Global Financial Cycle. A subset of these variables reflects the real economy (industrial production, various measures of investment, housing starts, consumer and deflator price indices) and another subset reflects US and international financial variables (global factor in risky asset prices, the Gilchrist Zakrajsek (2012) risk premium, credit variables...). We instrument shocks to the Fed funds rate with the Romer and Romer narrative approach (2004) extended to 2009 when the zero lower bound is reached. We find significant effects of US monetary policy shocks on broker dealer leverage in the US but also on European Globally Systematically Important Banks, whether in the euro area or the UK. cross-border

Figure 4: Effect of US monetary policy shocks on US financial variables and the Global Factor in risky asset prices



Notes: Monthly data over the period 1979:07 to 2010:12. The instruments (Fed funds futures FF4) are available from the period 1991:01 through 2012:06. The F-stat is 18.76. I report 90% confidence intervals. The Global Factor is estimated in Miranda-Agrippino and Rey (2012). For that variable, data end in 2010:12.

credit and global credit measures are also powerfully affected by US monetary policy. Up to the 2008 crisis, cross-border flows were dominated by bank flows. The picture changes after the crisis, when portfolio flows and non-bank players seem to be increasingly important. To the extent, however, that those financial intermediaries are subjected to similar frictions as banks (via value-at-risk constraints or collateral constraints), the effect of monetary policy on asset prices, risk premium and leverage is likely to remain an important transmission channel.

5 Estimating the effect of US monetary policy shocks on open economies with flexible exchange rate regimes

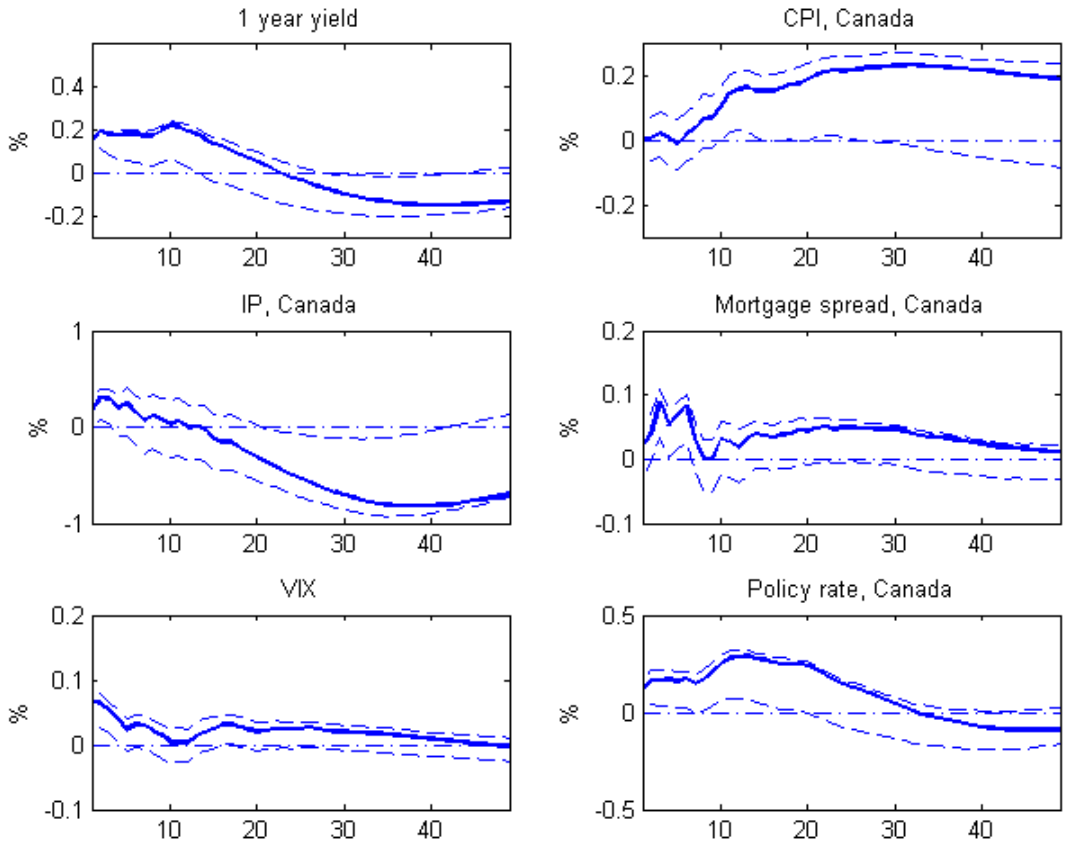
Are the results on international spillovers mostly driven by countries which have a fixed or semi fixed exchange rate regime? After all, as Eichengreen showed in the context of the 1930s, fixed exchange rate regimes can powerfully transmit monetary conditions across countries. The ubiquity of the Global Financial Cycle seems to indicate that flexible exchange rate regime countries are not insulated from global factors, but it is worth exploring this important question in more detail [22]. In this section of the paper I look at the issue directly and estimate the effect of US monetary policy shocks on activity, inflation and asset prices for a range of advanced open economies with flexible exchange rate regimes. These countries are inflation targeters, have freely floating exchange rates and have developed domestic financial markets. Some of them are large economies, some have resource-based currencies. My sample consists of Sweden, Canada, New Zealand, and the UK.

I rely on the same estimation strategy as above, identifying US monetary policy shocks via the use of external instruments (for the one year US rate or the Federal funds rate). The variables in the VAR for each country are Industrial Production or GDP, the CPI, the domestic policy rate, the mortgage spread (as this is the most widely available series with a reasonable time span across countries) and the VIX. The specification is as close as possible to the one of the US VAR performed in the previous section. Using the mortgage spread has an additional advantage: the real estate market is central for financial stability and has been shown to be very important in boom-bust cycles around the world. In the Appendix, I present another set of impulse responses for all these countries where I replace the VIX with the exchange rate (defined in US Dollar per local currency, so that a decrease is a depreciation of the local currency). For New Zealand only quarterly data are available for industrial production and price index. Because I have fewer observations, I reduce the size of

[22] In Passari and Rey (2014), we show that comovements in gross capital flows are important regardless of the exchange rate regime. Additionally we show that in the cross section, sensitivities of the local stock market and of credit growth to the VIX are not significantly affected by exchange rate regimes.

my VAR to 5 variables instead of 6. I use the Gurkaynak et al. (2005) instruments as above in monthy data and the Romer and Romer ones for quarterly data. Results are presented in Figures 5 and 9 for Canada, Figure 6 and 10 for Sweden, Figures 7 and 11 for the UK, Figure 8 and 12 for New Zealand (Figures 9 to 12 are in the Appendix).

Figure 5: Effect of US monetary policy shocks on Canada



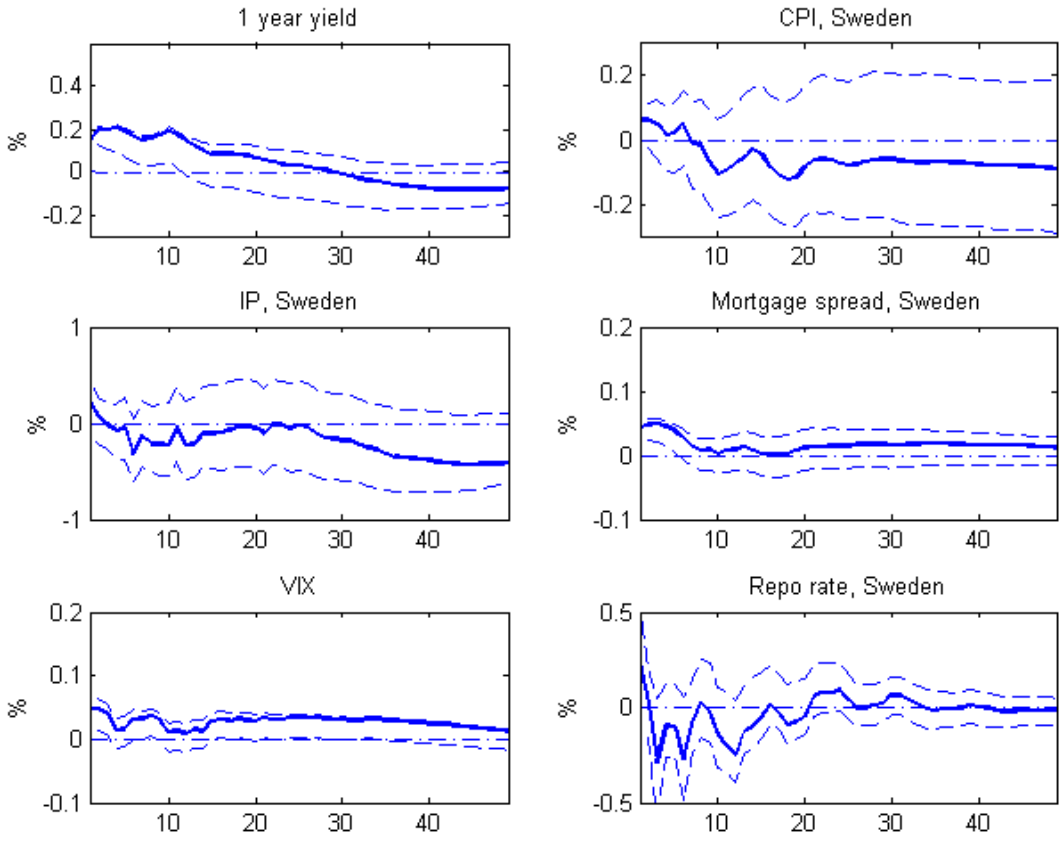
Notes: Monthly data over the period 1985:03 to 2012:06. The instruments (Fed funds futures FF4) are available from the period 1991:01 through 2012:06. The F-stat is 12.34. I report 90% confidence intervals.

What do we learn from the results?

In the domestic US context, a 20 bp increase in the US one-year rate leads to an 8 bp increase in the mortgage spread very rapidly (in the first 3 months or so). In each of these countries, a US tightening has a significant and almost immediate effect on mortgage spreads.

It peaks at around 9 bp in Canada within 2 months of the tightening. It peaks at about

Figure 6: Effect of US monetary policy shocks on Sweden

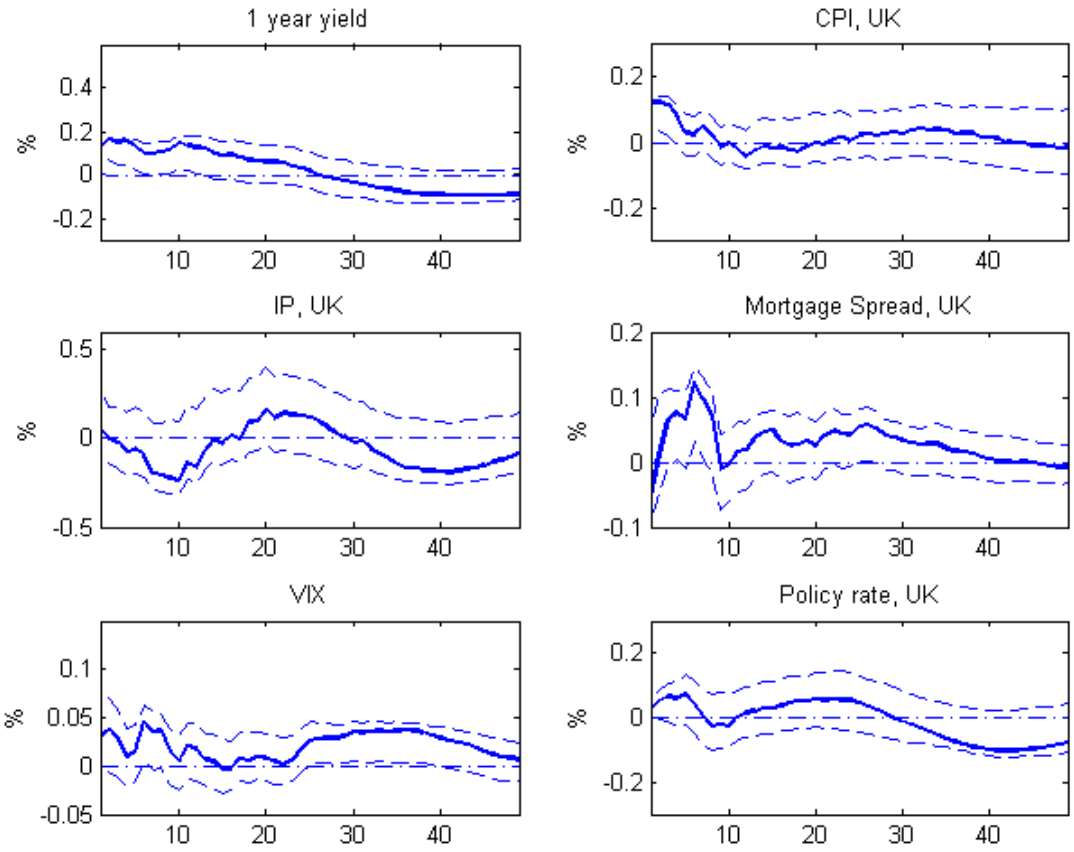


Notes: Monthly data over the period 1987:01 to 2012:06. The instruments (Fed funds futures FF1) are available from the period 1991:01 through 2012:06. The F-stat is 13.87. I report 90% confidence intervals.

4bp in Sweden after around 3 months. It peaks at about 12 bp in the UK within about 6 months. It peaks at around 20 bp in New Zealand in the first 2 quarters. The same reponses are observed when the VIX is replaced by the local exchange rate, though magnitudes may vary slightly (see Figures 9 to 12 in the Appendix).

The magnitude of the effect of US monetary policy shocks on mortgage spreads of those advanced economies which are all inflation targeters is therefore heterogeneous across countries but is roughly of the same order of magnitude as the effect estimated within US borders. The smallest response (for Sweden) is still about half of the US mortgage spread response to the US home monetary policy shock, and the largest response (for New Zealand) is equal

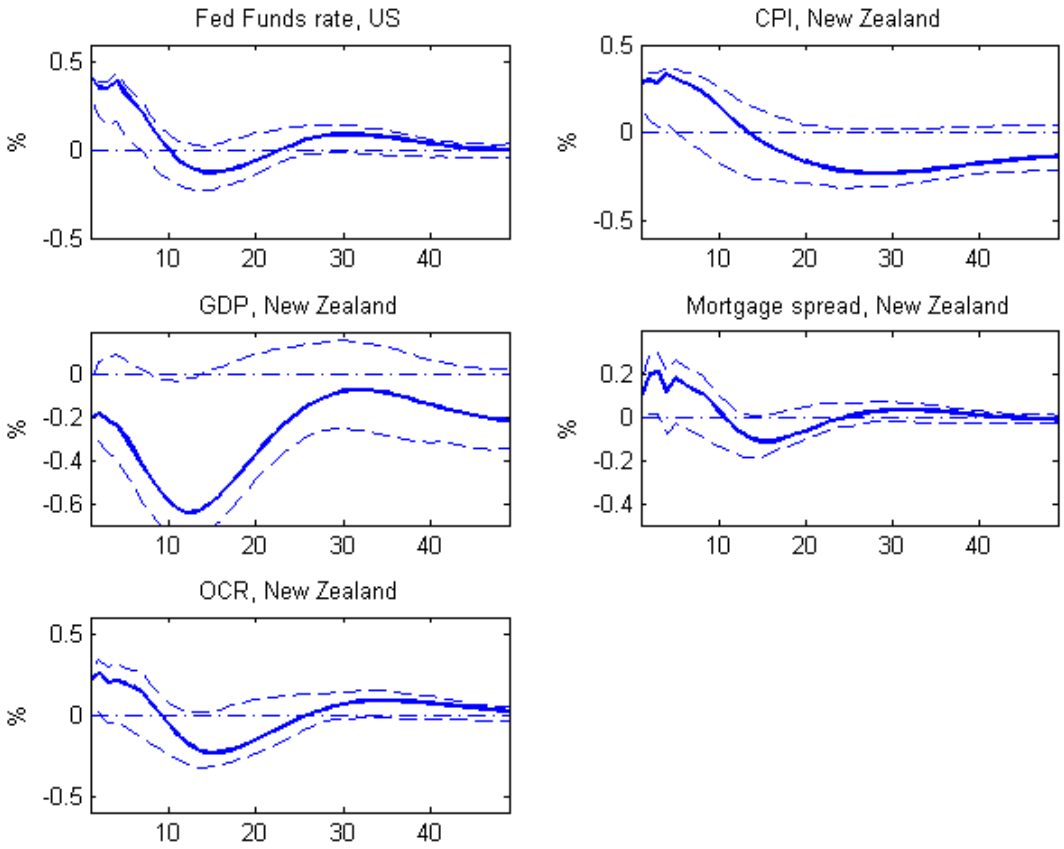
Figure 7: Effect of US monetary policy shocks on the UK



Notes: Monthly data over the period 1995:01-2012:06 (due to lack of mortgage series on a longer sample). The instruments (Fed funds futures FF1) are available from the period 1991:01 through 2012:06. The F-stat is 9.75. I report 90% confidence intervals.

to more than twice the US response. The UK response is also larger than the US one, so that a US monetary policy shock seems to affect the UK mortgage market more than the US one. Without putting too much faith on each of these point estimates, there seems to be a general pattern in the data: credit conditions, as measured by mortgage spreads, respond to US monetary policy shocks rapidly in this set of inflation targeting advanced economies. Whether one considers these findings as evidence of a very potent international transmission channel of monetary policy has to depend on whether one thinks that channel is an important one within US borders. If the answer is positive, then this international transmission channel is of a similar magnitude. It would be desirable to be able to estimate more measures of the

Figure 8: Effect of US monetary policy shocks on New Zealand



Notes: Quarterly data over the period 1987 Q3 to 2012 Q3. The instruments (Romer and Romer) are available through 2009:Q1. The F-stat is 15.29. I report 90% confidence intervals.

finance premium (corporate spreads, effect on the term premium). Obstfeld (2014) finds a large correlation between movements in long rates across countries regardless of exchange rate regimes.

The dependence of the open economy monetary conditions on the policy stance of the base country could come through at least two main channels. First, the "fear of floating channel", whereby central banks facing large capital flows could try to reduce the interest rate differential and tighten their policy rate as the Fed is tightening; this in turn will have an effect on the mortgage spread via the domestic credit or risk-taking channel. Second, the "international credit channel", broadly defined, whereby domestic financial conditions are affected by the change in monetary policy of the Fed via the effect of the dollar intertemporal

price on collateral prices, funding costs in dollars, etc....

The VARs give us some idea of the strength of these two channels by analysing the response of the policy rate to the US policy shock. In two economies, Canada and New Zealand, the policy rate seems to be reacting to US monetary policy shocks. For the other economies, there seems to be no significant response (Sweden, UK). Local currencies tend to depreciate against the US dollar when there is a surprise tightening by the Fed (Canadian dollar, Swedish krona, sterling), while the New Zealand dollar tends to appreciate.

There is also interesting heterogeneity in the response of real economy variables, though the magnitude and significance of these results does not appear as robust across specifications (for some of them) than the results on the mortgage spreads. Nevertheless, the shape of the impulse responses is similar across specifications.

As shown in Figure 5 Canadian IP tends to go down after 20 months while the CPI tends to increase by about 20 bp after 10 months (but those results are not as strong in Figure 9). In Figure 9, we note that the Canadian dollar tends to depreciate immediately after a surprise tightening of US monetary policy, and this happens despite an increase in the Canadian policy rate.

Swedish IP does not seem very much affected and there is also little effect on the CPI. These results are consistent across specifications. The Swedish krona has a small immediate depreciation (see Figure 10).

UK IP does not seem much affected (though in some specifications it goes down after about 10 months) while the UK CPI goes up by about 10bp, and this is consistent across specifications. Sterling depreciates following a tightening but does so with a delay, unlike the Canadian dollar and the Swedish krona (see Figure 11).

New Zealand GDP's response is not very stable across specifications while the CPI goes up in all specifications. The New Zealand dollar tends to appreciate, unlike the other currencies (see Figure 12).

To summarize, a US monetary policy tightening has immediate effects on domestic financial conditions in Wellington, Ottawa, Stockholm and London. The magnitude of these

effects is similar to the magnitude of the effect of the US domestic monetary policy shock on its own mortgage spread. It is accompanied only in some of the economies by a response of the policy rate and in most cases by an exchange rate depreciation. Mortgage spreads are an important indicator of financial conditions, as real estate markets are often at the center of financial stability considerations.

None of this means that the exchange rate regime is irrelevant. It means only that a flexible exchange rate is not enough to insulate a country from the Global Financial Cycle. It also means that measuring monetary autonomy via the metric of correlation of short-term rates will have little to say about the potency of the international credit or risk-taking channel. The trilemma, by focusing exclusively on the interest rate, seems to miss a potentially important channel of transmission of monetary policy in international markets.

If the international credit channel is potent, then the trilemma becomes more like a dilemma. More tools need to be added to restore some monetary and financial autonomy. This is the topic to which I now turn.

6 International spillovers and macroprudential policies

If the international credit or risk-taking channel is important, the Global Financial Cycle cannot be tamed by relying on the domestic interest rate alone to achieve both output stabilization and financial stability. Hence there is a need for additional instruments: macroprudential tools and may be sometimes capital controls. My discussion of macroprudential policies is limited to the points coming out of the analysis of international spillovers.

The role of the dollar as a funding currency (short-term dollar debt and floating-rate debt) deserves special attention. Beyond the usual problems of currency mismatch on balance sheets, of carry-trade excesses, of possible coordination failures among investors creating runs, the transmission of imported monetary conditions may sometimes be overly permissive, sometimes overly restrictive for an economy. When there are excesses, tighter regulation (for

example higher risk weights on some positions) or restrictions on some types of offshore financial instruments could be considered.

On the asset side, particular attention should be paid to the real estate market, where assets often act as important collateral. Here we have an increasingly conventional toolkit (Loan to Value, Debt to Income or Debt Service ratios, adjustment of risk weights, etc..). But the contribution of monetary policy to the relaxation of VaR for banks and non-banks should also be considered, and the adequacy of the modeling of correlation matrices in internal models and their sensitivity to cheap liquidity (and tightening) should be scrutinized. This is particularly important for the pool of low-liquidity assets and derivatives whose prices are often determined by models. As a general principle, constraining the fluctuations of leverage in the financial system would probably tend to decrease the magnitude of the international credit or risk-taking channel.

In this lecture I mostly discussed the existence of an international channel of monetary policy transmission in the context of floating exchange rates. But this channel could be all the more powerful in the case of fixed exchange rates, when it acts in conjunction with the domestic credit and risk-taking channels. In that case, the country sees its constraints being relaxed not only because of a loosening of Fed policies but also via its own policy rate. Macroprudential policies could be used as a way to modulate the strength of monetary transmission across jurisdictions with fixed exchange rates or even across different markets within a currency union, with the aim of avoiding the buildup of devastating financial imbalances as in the 2007-8 crisis and the subsequent euro area crisis. It is very important to keep in mind that the "international credit channel" is not only about the banking sector but is much broader. The non-bank sector (insurance, asset managers, non-financial corporates, households) are, to some extent, subject to similar collateral and VaR constraints. No doubt we would benefit from a more granular modeling of these actors. Finally, proper calibration and timely implementation of macroprudential measures will probably be the dominant policy issue.

7 Conclusion

Central banks transmit their monetary policy within their jurisdictions and across jurisdictions via several channels.

The neo-keynesian models emphasize how short-term rates and expectations of the path of future rates affect inflation expectations and hence short-term and long-term real rates. The broadly defined credit and risk-taking channels affect the external finance premium (or relax a value-at-risk constraint) and as a consequence affect aggregate demand and risk-taking. In the open economy literature, monetary policy transmission across jurisdictions has been analysed mostly through the trade-off of terms of trade versus output gap stabilization (New Open Economy Macroeconomics) or in the Mundell-Fleming world. In that world, monetary policy in the center country affects the periphery via fluctuations of demand in the core country and export substitution effects. The Mundellian trilemma states that flexible exchange rates guarantee monetary autonomy when there is free capital mobility. The potentially pernicious loop of high interest rates, more inflows and credit booms (followed by busts) is a fascinating subject of study (see Diaz-Alejandro (1985) and Portes and Vines (1997)).

In this lecture, I am connecting those lines of thinking by stressing the idea of an "international credit or risk-taking transmission channel" of monetary policy. In its purest form it operates though the very special role that a currency (here the US dollar) plays in international financial markets and international banking. Because the dollar is an important funding currency around the world and many financial intermediaries draw on short-term dollar credit and issue floating-rate dollar debt, US monetary policy has an immediate cash flow effect: it changes the net worth of economic actors worldwide and their ability to leverage. Because of the presence on many balance sheets of dollar-denominated assets or dollar linked-assets, US monetary policy affects the net worth of banks, asset managers, households, corporates and their ability to borrow via collateral effects (see Aoki et al. (2015)) or value-at-risk constraints. When asset prices are high, spreads are low and measured risk

is low, hence there is a negative correlation between indices of risk and leverage. Via the credit and the risk-taking channels US monetary policy is transmitted across jurisdictions and matters for global financial stability and economic activity. This discussion should clarify that looking at correlations of short term policy rates across countries to assess the degree of monetary independence and test the validity of the trilemma provides little information on the strength of the financial spillover channels discussed here.

The international credit and risk-taking channels can interact with the well-known "fear of floating" channel. Following a Fed loosening, if another central bank also loosens its policy rate or intervenes to prevent its exchange rate from appreciating because of large capital inflows, the domestic credit channel in the recipient country will tend to reinforce the international credit channel, leading to potential credit booms. The role of the exchange rate is ambiguous, as sustained appreciation and deviation from uncovered interest parity may tend to reinforce the balance sheet effect of increased asset prices and increased value of collateral in the recipient countries, relaxing further value-at-risk constraints (see Bruno and Shin (2015b)). Those same mechanisms may work also in reverse and lead to potential busts.

The empirical evidence points towards some combination of these channels of monetary policy transmission both within and across juridisctions. In the sample of advanced open economies I selected, most economists would probably expect that, thanks to the well-established regime of inflation targeting and a freely floating exchange rate, external influences on monetary autonomy are minimal or non-existent.[23]. I consistently find, however, that my measure of the external finance premium (mortgage spreads) is affected in a significant manner by the US monetary policy shock. The magnitude of the response is similar to the ones found in studies focusing on the domestic credit channel for the US. No doubt many more VARs need to be run, but I interpret these first results as supporting the existence of a potent "international credit or risk-taking channel" of transmission of US

[23]For a subset of these economies, there is no sign that the domestic policy rate reacts to US monetary policy shocks. The systematic part of the US and other countries monetary policies may of course be correlated because of fundamental linkages and common shocks.

monetary policy to economies with floating exchange rates.

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Data Appendix

UK

Data are monthly: 1995:01-2012:06 (short series due to the non availability of a long mortgage series). IP (seasonally adjusted), CPI (seasonally adjusted) and FX are from FRED St Louis (Board of Governors of the Federal Reserve System (US)). Rates are from Bank of England website. Policy rate is the "Official Bank Rate". Mortgage spread: monthly interest rate of UK monetary financial institutions (excl. Central Bank) sterling 5 year (75% LTV) fixed rate mortgage to household - Yield from British Government Securities (5year).

Canada

Data are monthly: 1985:03 to 2012:06. IP (seasonally adjusted), CPI (seasonally adjusted) and FX are from FRED St Louis (Board of Governors of the Federal Reserve System (US)). Rates are from Bank of Canada website (http://www.bankofcanada.ca/rates/interest-rates/selected-historical-interest-rates/). Policy rate is "Bank Rate" (V122530). Mortage rate is "Chartered bank administered interest rates- conventional mortgage 5 year" (V122521). To construct the mortgage spread I used 5 year yield ("selected government of Canada benchmark bond yields-5 year", V122540).

Sweden

Data are monthly from 1987:01 to 2012:06. IP (seasonally adjusted), CPI (seasonally adjusted) and FX are from FRED St Louis (Board of Governors of the Federal Reserve System (US)). Interest rates data are from: http://www.riksbank.se/en/Interest-and-exchange-rates/search-interest-rates-exchange-rates/. Policy rate is constructed as Marginal rate (01/1987-05/1994) and Repo rate (06/1994-06/2012). Mortgage spread is constructed as Mortgage Bond (5 year) - Swedish Government Bonds (5 year).

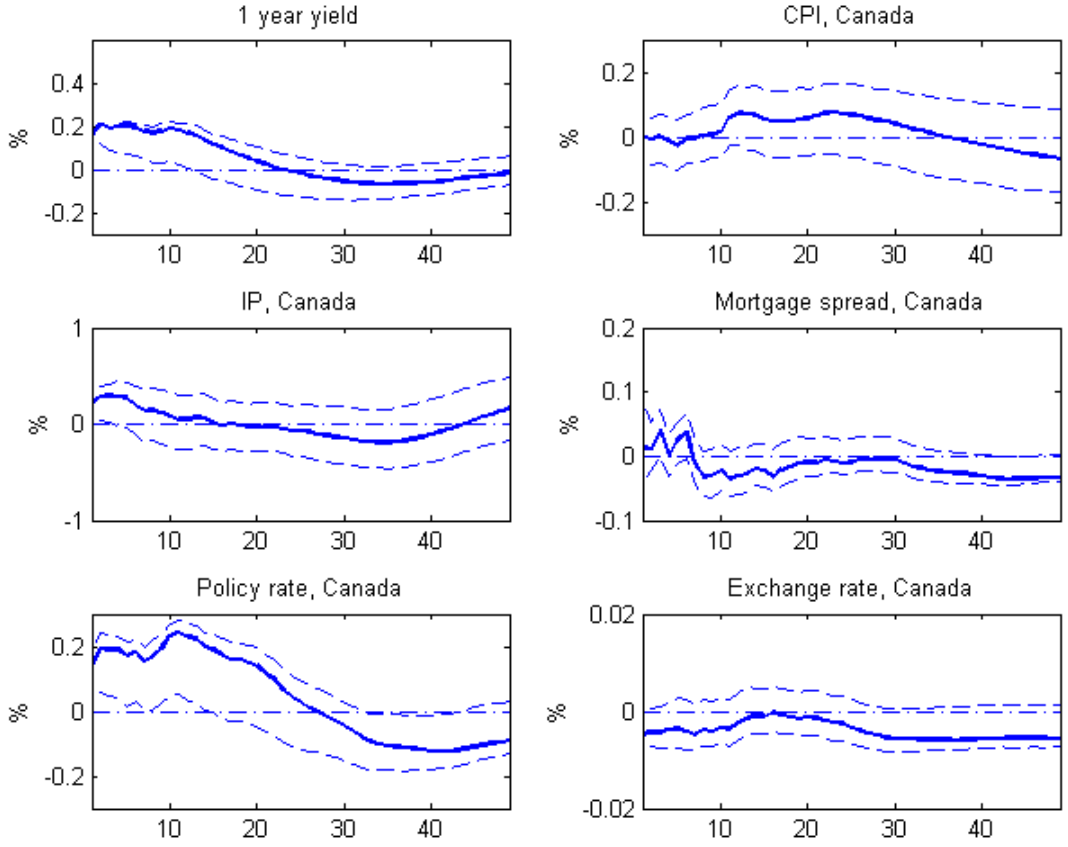
New Zealand

Quarterly data: 1987 Q3 to 2012 Q3 (due to the non avialability of monthly series fro CPI and GDP or IP) . CPI and GDP are seasonally adjusted and from IFS, IMF. The

policy rates come from the Central Banks' website: Overnight interbank cash rate hb2-monthly. Mortgage Spread : difference between the housing lending (floating first mortgage new customer housing rate), column G, spreadsheet hb3 and the 10-year secondary market government bond yield, column S, spreadsheet hb2.

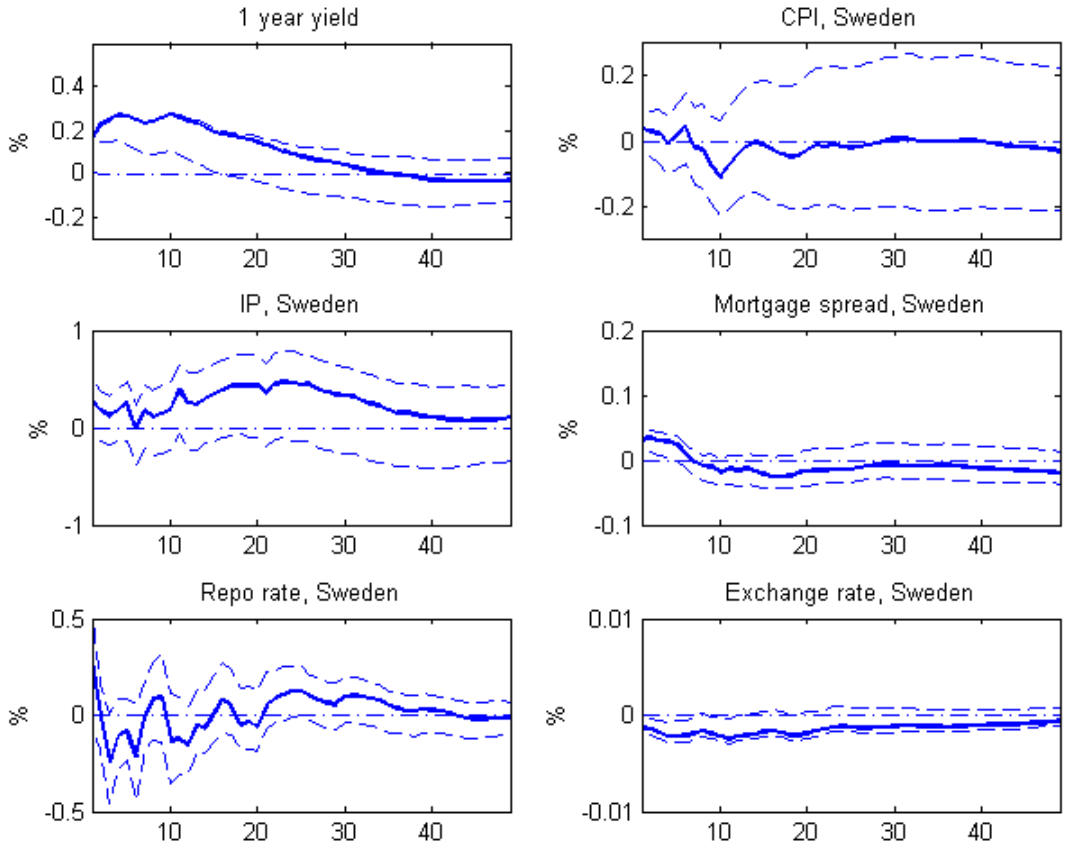
Appendix: US monetary policy spillovers

Figure 9: Effect of US monetary policy shocks on Canada



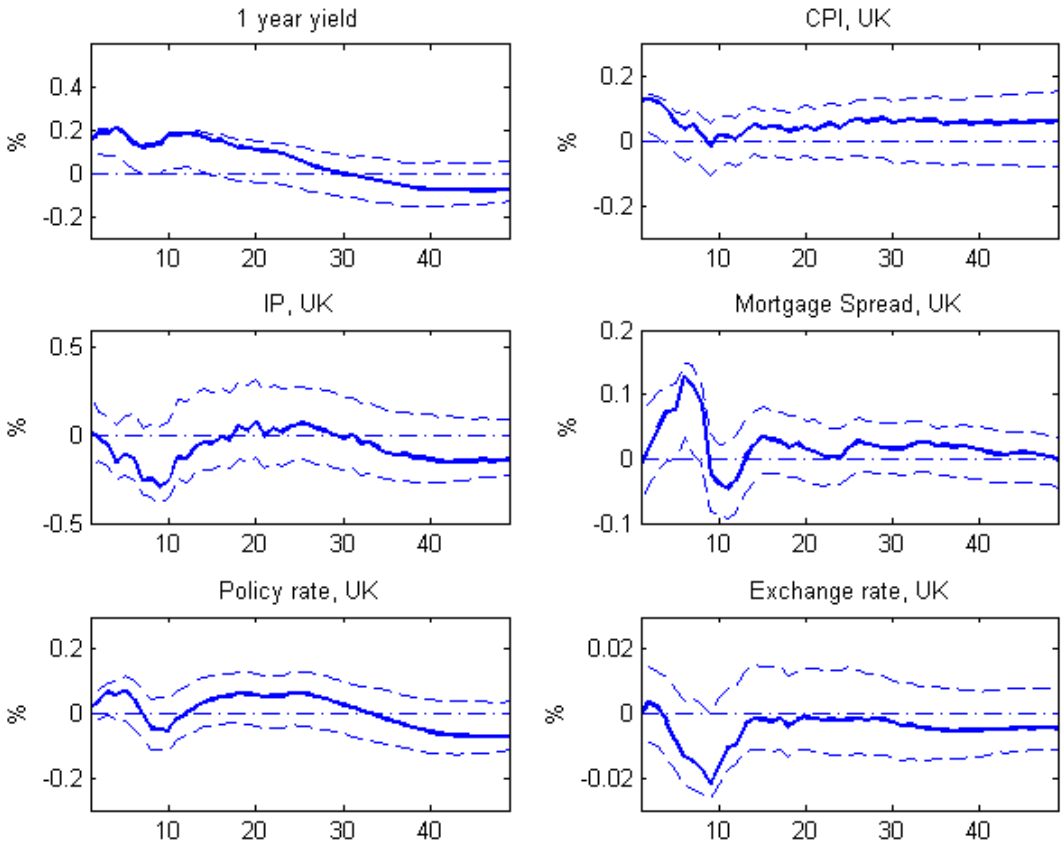
Notes: Monthly data over the period 1985:03 to 2012:06. The instruments (Fed funds futures FF4) are available from the period 1991:01 through 2012:06. The VIX is replaced by the exchange rate. The F-stat is 10.01. I report 90% confidence intervals.

Figure 10: Effect of US monetary policy shocks on Sweden



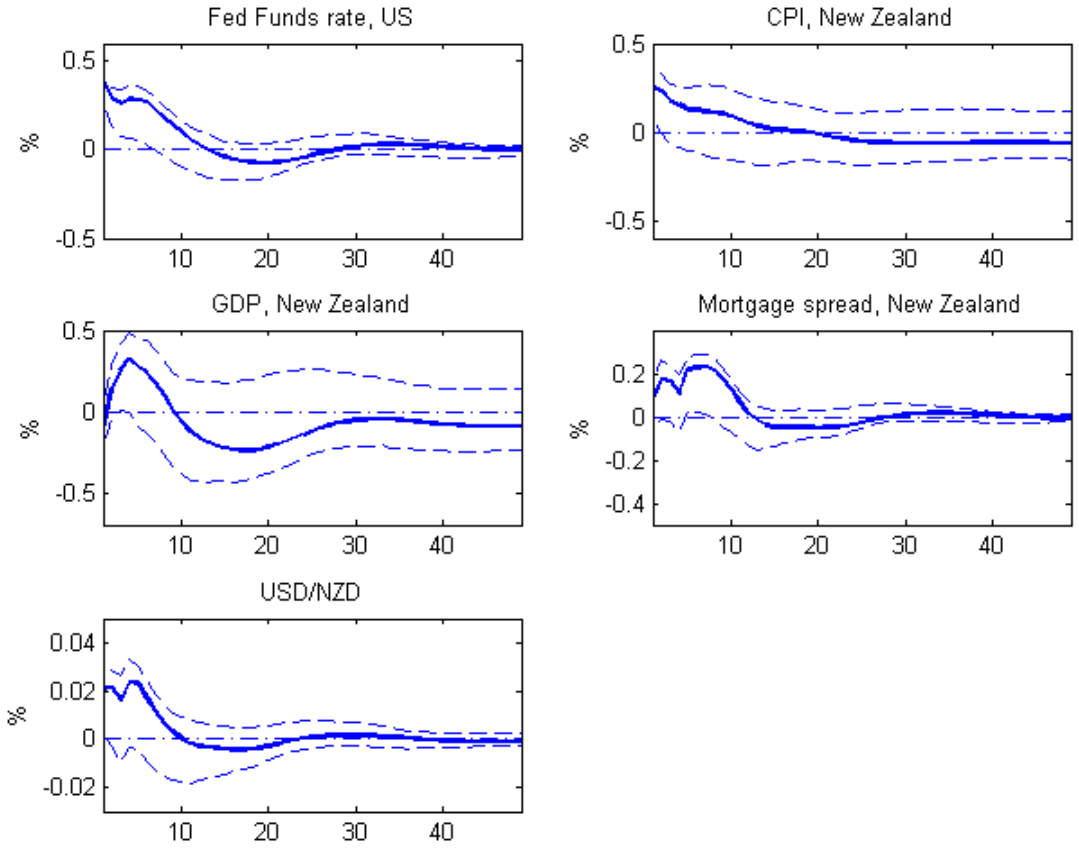
Notes: Monthly data over the period 1987:01 to 2012:06. The instruments (Fed funds futures FF1) are available from the period 1991:01 through 2012:06. The VIX is replaced by the exchange rate. The F-stat is 16.88. I report 90% confidence intervals.

Figure 11: Effect of US monetary policy shocks on the UK



Notes: Monthly data over the period 1995:01-2012:06 (due to lack of mortgage series on a longer sample). The instruments (Fed funds futures FF1) are available from the period 1991:01 through 2012:06. The F-stat is 12.5. I report 90% confidence intervals. The VIX is replaced by the exchange rate.

Figure 12: Effect of US monetary policy shocks on New Zealand



Notes: Quarterly data over the period 1987 Q2 to 2012 Q2 . The instruments (Romer and Romer) are available through 2009:Q1. The F-stat is 10.07. I report 90% confidence intervals. The VIX is replaced by the exchange rate.