# Essays in International Macroeconomics and Monetary Policy

*Inaugural-Dissertation*

*zur Erlangung des Doktorgrades*

*des Fachbereichs Wirtschaftswissenschaften*

*der Johann Wolfgang Goethe-Universität*
*Frankfurt am Main*

vorgelegt von

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aus Hong Kong
October 2010

# List of Original Working Papers

1. **On the Effects of Monetary Policy Shocks on Exchange Rates**

   -Co-authored by Michael Binder and Xuan Zhang,

   in *CESifo Working Paper Series 3162, CESifo Group Munich.*

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   -Co-authored by Stefan Gerlach

# Abstract

This thesis consists of four chapters. Each chapter covers a topic in international macroeconomics and monetary policy. The first chapter investigates the impact of unexpected monetary policy shocks on exchange rates in a multi-country econometric model. The second chapter examines the linkage between macroeconomic fundamentals and exchange rates through the monetary policy expectation channel. The third chapter focuses on the international transmission of bank and corporate distress. The last chapter unfolds the interest rate channel of monetary policy transmission in an emerging economy, China, where regulations and market forces co-exist in this transmission.

# Acknowledgements

I am deeply grateful to Professor Michael Binder, for his invaluable guidance, supervision, and support; and to Professor Thomas Laubach, for his incredible guidance and encouragement. I am specially grateful to Professor Stefan Gerlach, for his advice and comments.

Moreover, I thank specially Alex Ho, Marcel Bluhm, Xuan Zhang, Georgios Georgiadis, Bjőrn Hilberg, for their helpful discussions, and for their support at the final stage of my study. In addition, I thank Bjőrn Kraaz and Pei Kuang for their insightful comments. I would also like to thank Xiaojian Zhao for his influence on my attitude towards life, his help and encouragement through out my graduate study. I also acknowledge the support from Hong Kong institute for monetary research.

Finally, I am gratefully to my parents for their constant support and understanding.

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# Chapter 1

# On the Effects of Monetary Policy Shocks on Exchange Rates

## 1.1 Introduction

It has been a long-standing question in both theoretical and empirical macroeconomics how a change in a country's monetary policy affects the external value of its currency. The recent debate surrounding the International Monetary Fund's recommendation to the Central Bank of Iceland in fall of 2008 to dramatically raise interest rates in an attempt to prevent continued depreciation of the Iceland Krona is just one example highlighting the continued topicality of this question.

From the perspective of macroeconomic theory, a - if not *the* - key contribution towards resolution of this question still is Dornbusch's (1976) exchange rate overshooting model, predicting that in response to a contraction of domestic monetary policy, the real exchange rate - due to a liquidity effect and a no-arbitrage restriction implied by uncovered interest parity - will exhibit an impact appreciation, that is followed by a gradual depreciation. This gradual depreciation continues until the long-run equilibrium - that involves return to the original real exchange rate equilibrium in line with purchasing power parity - is reached. In the recent new open economy macroeconomics literature, the exchange rate overshooting mechanism has been re-examined on the basis of dynamic stochastic general equilibrium models that make reference to the three core components of the overshooting mechanism: a liquidity effect of monetary policy, an interest parity relation, and long-run purchasing power parity. To highlight just two contributions to this literature: Steinsson (2008) argues that in a dynamic stochastic general equilibrium model incorporating *inter alia* staggered price setting, local currency pricing, home biased preferences and heterogeneous factor markets, the real exchange rate exhibits peak overshooting in response to a monetary shock after one or two months, and thereafter decays exponentially, consistent with Dornbusch (1976). Bergin (2006) estimates a dynamic stochastic general equilibrium model *inter alia* including monopolistically competitive firms, sluggish price setting, capital accumulation subject to adjustment costs as well as a risk-premium-augmented interest parity relation, and finds that the real exchange rate exhibits impact overshooting, followed by a gradual return to long-run equilibrium. Benigno (2004) argues that the details of the dynamic adjustment pattern of the real exchange rate after a monetary policy shock depend on the relative degrees of wage/price stickiness in the domestic and foreign economies, as well as the degree of interest rate smoothing of monetary policy domestically and abroad.

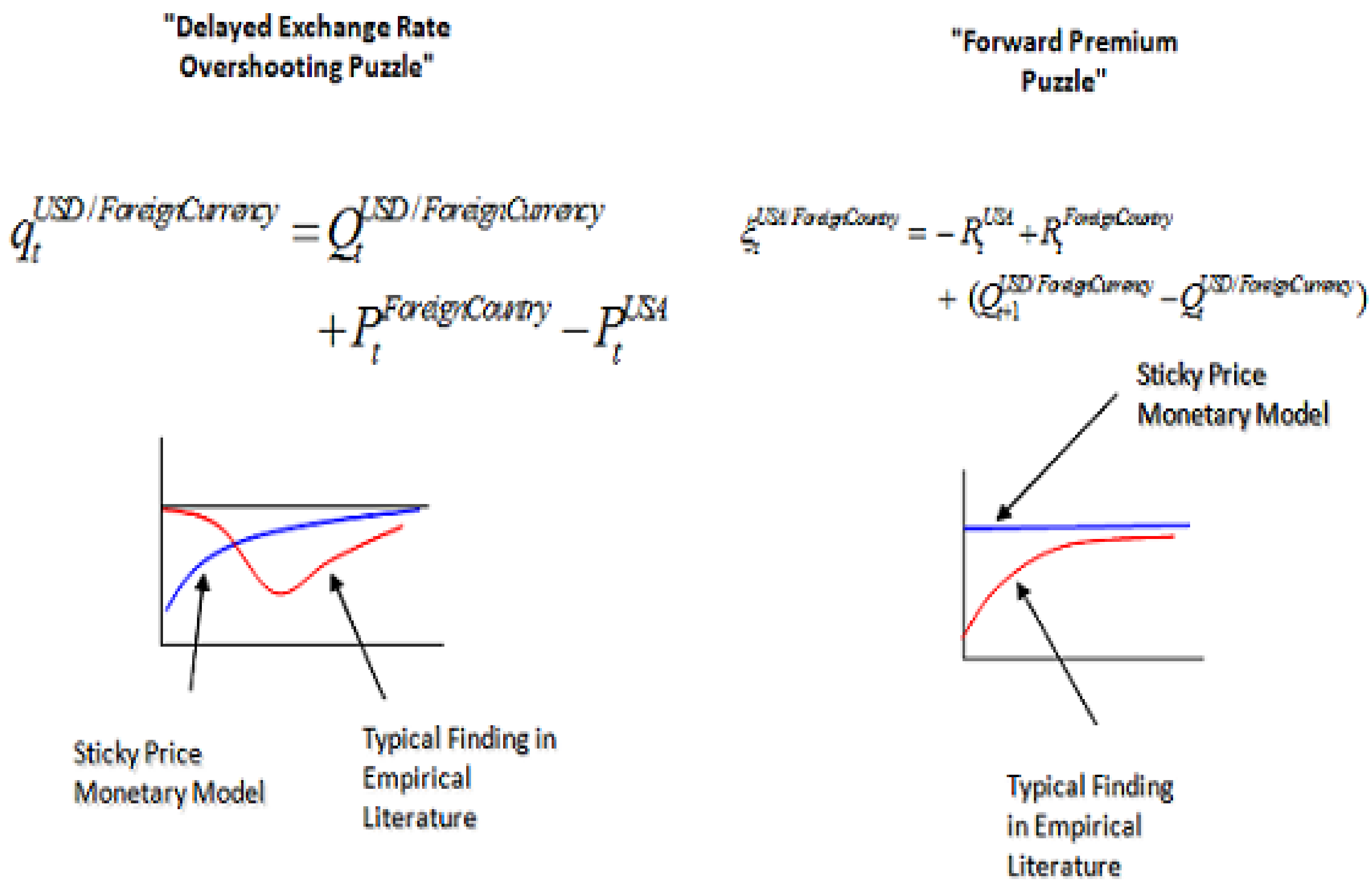
The predominant strand of the empirical literature (including Clarida and Gali, 1994, Eichenbaum and Evans, 1995, Kim, 2005, and Scholl and Uhlig, 2008), on the other hand, has documented that in response to a monetary policy contraction the peak appreciation of the nominal and real exchange rates occurs with sizeable lag only, that is, the impulse response function exhibits a hump-shape pattern, the so-called "delayed exchange rate overshooting puzzle". Furthermore, the empirical evidence appears to contradict *conditional* uncovered interest parity, and suggests sizeable and persistent arbitrage opportunities in favor of U.S. bonds after a contractionary U.S. monetary policy shock, which has been termed the "forward premium/discount puzzle".[1] Figure 1.1 illustrates the "delayed exchange rate overshooting puzzle" as well as the "forward premium puzzle".[2] This empirical evidence has been viewed as so strong that in the open economy macroeconomics literature various mechanisms - such as limited information processing, distortion of beliefs, and state-dependent pricing - have been advanced that can account for the "delayed exchange rate overshooting puzzle" and/or the "forward premium puzzle"; see, for example, Gourinchas and Tornell (2004), Andersen

[1] The "forward premium puzzle" is separate from *unconditional* violations of uncovered interest parity as reviewed, for example, by Engel (1996). It is also worth noting that even papers that have argued that the "delayed exchange rate overshooting puzzle" may be sensitive to the restrictions imposed in identifying monetary policy shocks, argue that the "forward premium puzzle" is robust to identification issues and is empirically prevalent. See, for example, Faust and Rogers (2003).

[2] In Section 1.2, we will also relate our paper to previous papers in the literature, specifically Cushman and Zha (1997), Kim and Roubini (2000), and Bjornland (2009), that have argued that there is no delay of exchange rate overshooting and/or no evidence of deviations from uncovered interest parity in response to monetary policy shocks.

and Beier (2005), Bacchetta and van Wincoop (2006), and Landry (2009).

**Figure 1.1:** The Delayed Exchange Rate Overshooting and Forward Premium Puzzles



The common framework of the empirical literature have been bilateral (two-country) vector autoregressions (VARs) that incorporate key macroeconomic variables for the domestic economy and one foreign economy, and that identify the exchange rate effects of a domestic monetary policy shock primarily on the basis of a Cholesky decomposition involving a Wold recursive ordering of the variables contained in the VAR. Recent empirical work employing weaker short-run identification schemes, namely sign restrictions, argues that the two puzzles are not tied to the identification of VARs using Cholesky decompositions; see, in particular, Scholl and Uhlig (2008).

In this paper, we address the question to what extent previous empirical findings suggesting the presence of a "delayed exchange rate overshooting puzzle" and a "forward premium puzzle" may have been caused by two issues: (i) Working with bilateral VARs neglects to account for multilateral (multi-country) simultaneous adjustments of key macroeconomic variables in response to monetary policy shocks in one given country - even though such multi-country adjustments seem to be an essential feature for groups of economies with sizeable multilateral trade and financial market linkages. (ii) Identifying monetary policy shocks by imposing short-run restrictions of the form of a Cholesky decomposition tends to be difficult to reconcile with macroeconomic theory, and does not take advantage of identification restrictions implied by empirically supported long-run relations between the macroeconomic variables under consideration in the VAR.[3] In this paper, then, we specify a multi-country VAR model for a panel of nine industrial economies (Australia, Canada, France, Germany, Italy, Japan, New Zealand, United Kingdom, and the United States), using monthly data from 1978 to 2006. On the basis of this multi-country specification and exploiting empirically supported long-run relationships for the identification of monetary policy shocks, we find that U.S. Dollar effective and bilateral real exchange rates appreciate on impact after a contractionary U.S. monetary policy shock, and that there is no delay in the overshooting of the U.S. Dollar. Furthermore, after a contractionary monetary policy shock there is no persistent sizeable deviation from uncovered interest parity, and therefore no sizeable forward premium. These results are consistent with the real exchange rate effects of monetary policy shocks in sticky price open economy models, though the results of this paper also suggest that it will be insightful to extend various prominent examples of such models - including

[3] The information content of long-run relations for purposes of model identification has recently been emphasized by Pagan and Pesaran (2008).

those of Benigno (2004), Bergin (2006), and Steinsson (2008) - so as to capture simultaneous multi-country adjustments to shocks.

The remainder of the paper is structured as follows: In Section 1.2, we review the empirical models considered in the previous literature, with particular emphasis on a benchmark model of Eichenbaum and Evans (1995). In Section 1.3, we provide a theoretical motivation for studying multilateral models, and then introduce our empirical multilateral model specification in Section 1.4. We discuss the measurement of monetary policy indicators for the nine economies we consider as well as the identification of monetary policy shocks using empirically supported long-run relations in Section 1.5. We present our empirical results in Section 1.6, and in Section 1.7 provide various comparisons between results from our empirical model specification and those employed in the previous literature. Section 1.8, finally, concludes. Two appendices contain details on the database we have assembled for this paper, as well as some tables of empirical results.

## 1.2 Review of the Literature

### 1.2.1 Methodology of Eichenbaum and Evans (1995)

Almost all of the empirical models considered in the literature to date on the "delayed exchange rate overshooting puzzle" and the "forward premium puzzle" are bilateral (two-country) vector autoregressions (VARs).[4] We take one of the specifications in Eichenbaum and Evans (1995) as a benchmark. Eichenbaum and Evans (1995) use a bilateral VAR to model the bilateral relationships of key macroeconomic variables for five country pairs: the United States versus France, the United States versus Germany, the United States versus Italy, the United States versus Japan, and the United States versus the United Kingdom. For each of these five country pairs, Eichenbaum and Evans (1995) consider a VAR model of the form of

$$\mathbf{z}_t = \mathbf{a}_0 + \mathbf{a}_1 t + \sum_{s=1}^{p} \mathbf{A}_s \mathbf{z}_{t-s} + \mathbf{u}_t, \qquad \mathbf{u}_t \overset{iid}{\sim} (\mathbf{0}, \Omega_{\mathbf{u}}), \tag{1.1}$$

[4]This literature, as noted in the Introduction, includes Clarida and Gali (1994), Eichenbaum and Evans (1995), Cushman and Zha (1997), Kim and Roubini (2000), Faust and Rogers (2003), Kim (2005), Scholl and Uhlig (2008), and Bjornland (2009). Some of these papers also include empirical model specifications for which the "foreign country" variables are specified as weighted averages of variables across a sizeable set of foreign countries, subject to exogeneity restrictions. Such model specifications, unlike the model that we will consider in this paper, still cannot capture simultaneous multi-country adjustments, the hallmark of a genuinely multilateral model.

where

$$\mathbf{z}_t = \left( \begin{array}{ccccccc} y_t & P_t & y_t^* & R_t^* & FFR_t & nbrx_t & q_t \end{array} \right)', \tag{1.2}$$

with $y_t$ denoting U.S. real industrial production, $P_t$ the U.S. consumer price index, $y_t^*$ foreign real industrial production, $R_t^*$ the foreign nominal short-term interest rate (short-term money market rate), $FFR_t$ the federal funds rate, $nbrx_t$ the ratio between U.S. non-borrowed reserves and U.S. total reserves, and $q_t$ the bilateral real exchange rate (in units of U.S. Dollars per one unit of foreign currency). All elements of $\mathbf{z}_t$, except for the interest rates, are in logarithms. Eichenbaum and Evans (1995) choose the VAR lag order, $p$, across all country pairs to be equal to six for the monthly sample from 1974:1 to 1995:5 they are working with. They identify the monetary policy shock using a Cholesky decomposition involving a Wold recursive ordering of the variables (this ordering being as in Equation (1.2)), *inter alia* implying that the Federal Reserve sets the federal funds rate taking into account the lagged values of all the components of $\mathbf{z}_t$ as well as the current values of U.S. industrial production, U.S. prices, foreign industrial production, and the foreign short-term interest rate (but not the real exchange rate).

As has been widely discussed in the literature on monetary policy VARs, monetary policy shocks in VAR models measure the unexpected change in a monetary authority's monetary policy stance relative to the information set to which these shocks are orthogonal, here

$$\Im_t = \left\{ \; y_t, \quad P_t, \quad y_t^*, \quad R_t^*; \quad \mathbf{z}_{t-s}, \, s \geq 1 \; \right\}. \tag{1.3}$$

Such unexpected changes can then be due to, for example, (i) discrepancies between the monetary authority's information set at $t$ and the public's information set at $t$, the latter being given by $\Im_t$, (ii) changes in the target values of the variables entering the monetary authority's monetary policy decisions, and/or (iii) changes in the parameters of the monetary authority's decision rule (for (ii) and (iii) as long as these changes are not reflected in $\Im_t$).

Selecting the United States versus Germany based bilateral VAR of Equation (1.1) as one representative example of the analysis of Eichenbaum and Evans (1995), Figure 1.2 shows the impulse responses for various key variables after a positive federal funds rate shock (that is, a contractionary U.S. monetary policy shock).[5] In regards to exchange rate effects, the

[5] To replicate Eichenbaum and Evans (1995), the U.S. monetary policy shock for Figure 1.2 is set to 50 basis points. All impulse response standard error bands reported in this paper are 95% error bands, which we obtained using a bootstrapping algorithm as described in Kilian (1998).

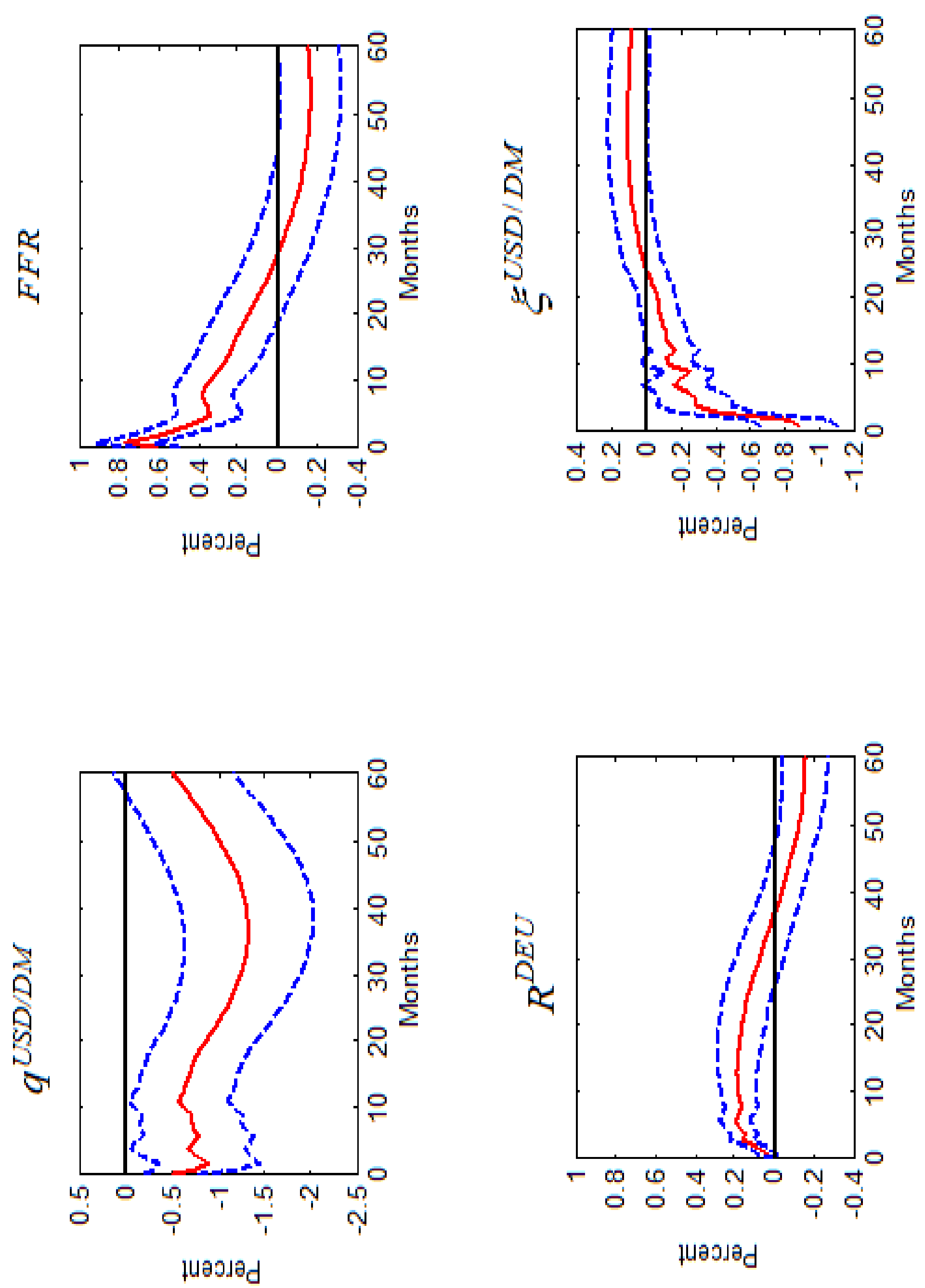
bilateral real exchange rate of the U.S. Dollar relative to the Deutsche Mark ($q^{USD/DM}$) overshoots its long-run level with a delay of about three years, termed the "delayed exchange rate overshooting puzzle" in the literature. The interest rate differential between the federal funds rate ($FFR$) and the German short-term interest rate ($R^{DEU}$) after the positive federal funds rate shock exhibits a positive difference for about 15 months. The forward premium, defined as in Scholl and Uhlig (2008) as

$$\xi_t = -FFR_t + R_t^* + Q_{t+1} - Q_t, \tag{1.4}$$

(the one period ex post excess return after a contractionary U.S. monetary policy shock for a U.S. investor from borrowing U.S. Dollars, exchanging these to foreign currency at the bilateral nominal spot exchange rate, $Q_t$, investing in foreign short-term bonds, and then exchanging the proceeds back to U.S. Dollar after one period),[6] for the United States versus Germany country pair ($\xi_t^{USA/DEU}$) in response to a federal funds rate shock deviates - partially substantially and significantly - from zero for a little more than one year, indicating sizeable arbitrage opportunities in favor of U.S. bonds. As under *conditional* uncovered interest parity in response to a monetary policy shock it would hold that $E_t\left(\xi_{t+s}\right) - E_{t-1}\left(\xi_{t+s}\right) = 0$, $s \geq 0$, with $E_t\left(\cdot\right)$ denoting the conditional expectations operator, this finding is termed the "forward premium puzzle" in the literature. Finally (though not displayed in Figure 1.2), we can also replicate the Eichenbaum and Evans (1995) finding that the impulse responses for U.S. prices display a positive reaction to the positive federal funds rate shock, rather than following the pattern of a typical dynamic stochastic general equilibrium macroeconomic model with price stickiness, namely of initially failing to respond and after a while beginning to fall.

[6] Note that this definition of the forward premium involving the ex post future spot exchange rate differs from that used in other areas of the international macroeconomics literature, which uses the forward exchange rate rather than the ex post future spot exchange rate.

**Figure 1.2:** Key Results of Eichenbaum and Evans (1995)



It should again be emphasized that the "delayed exchange rate overshooting puzzle" and the "forward premium puzzle" of Clarida and Gali (1994) and Eichenbaum and Evans (1995) have recently been re-affirmed in some key contributions to the literature; see, for example, Kim (2005) and Scholl and Uhlig (2008). Also, as noted briefly in the Introduction, this empirical evidence has been viewed as so strong that in the open economy macroeconomics literature various mechanisms - such as limited information processing, distortion of beliefs, and state-dependent pricing - have been advanced that can account for the "delayed exchange rate overshooting puzzle" and/or the "forward premium puzzle"; see, for example, Gourinchas and Tornell (2004), Andersen and Beier (2005), Bacchetta and van Wincoop (2006), and Landry (2009).

### 1.2.2 Further Empirical Work

There is a small number of papers in the literature to date, in particular Cushman and Zha (1997), Kim and Roubini (2000), Faust and Rogers (2003), and Bjornland (2009), that have argued that there is no empirical support for the "delayed exchange rate overshooting puzzle" and/or the "forward premium puzzle".

Cushman and Zha (1997) and Kim and Roubini (2000) consider non-U.S. monetary policy shocks. Exclusively analyzing countries that can arguably be classified as small open economies, they consider short-run monetary policy identification schemes that - unlike the Eichenbaum and Evans (1995) Cholesky decomposition based identification scheme - do allow for monetary policy to contemporaneously respond to changes in the exchange rate. Under such an identification scheme, Cushman and Zha (1997) and Kim and Roubini (2000) find no empirical support for the "delayed exchange rate overshooting puzzle" and/or the "forward premium puzzle". The analyses of Cushman and Zha (1997) and Kim and Roubini (2000) by construction are not applicable to analyzing the effects of U.S. monetary policy shocks, however, and involve short-run identifying restrictions that are rather difficult to justify on the basis of macroeconomic theory.

Faust and Rogers (2003) impose sign restrictions on the impact impulse response, and find that the exchange rate impulse response to contractionary U.S. monetary policy shocks is sensitive to additional - difficult to justify - short-run restrictions required for the identification of U.S. monetary policy shocks, with no robust conclusion about the timing of the appreciation peak after a contractionary U.S. monetary policy shock being possible.[7] As argued by Scholl and Uhlig (2008), however, if one is to impose sign restrictions for the identification of the impact impulse response, one may circumvent having to impose additional - difficult to justify - short-run identifying restrictions by imposing sign restrictions not only on the contemporaneous, but also on the future effects of the shocks. Doing so, Scholl and Uhlig (2008) re-affirm the "delayed exchange rate overshooting puzzle" and the "forward premium puzzle" in response to U.S. monetary policy shocks.

Bjornland (2009), like Cushman and Zha (1997) and Kim and Roubini (2000), constructs a VAR model of a small open economy. For her VAR, Bjornland (2009) imposes the restriction that a monetary policy shock cannot have long-run effects on the level of the real exchange rate. This long-run restriction allows Bjornland (2009) to circumvent having to specify short-run restrictions on the interaction between monetary policy and the real exchange rate of the type considered by Cushman and Zha (1997) and Kim and Roubini (2000). Our approach, as we will detail in Section 1.5, involves using a larger number of long-run identifying restrictions, as is implied by the empirical evidence, and thus indeed uses as few short-run identifying restrictions as possible. In contrast to Bjornland (2009), for each country we link our long-run identifying restrictions to empirical evidence on the number of long-run relations among the variables in our model. Perhaps most important in regards to comparison of our modelling approach to that of Bjornland (2009), our empirical model specification does *not* require a small open economy assumption, and we can therefore also consider U.S. monetary policy shocks.

## 1.3 Multilateral Models: Motivation

In this Section we provide a brief theoretical motivation for working with multilateral rather than bilateral models when analyzing the exchange rate effects of monetary policy shocks. The model we will consider in this Section consider is highly stylized, isolating the instantaneous exchange rate effects of monetary policy shocks in a world of three countries as compared to a world of two countries, rather than providing an elaborate multilateral dynamic stochastic general equilibrium model that would capture the complete set of variables entering our subsequent empirical analysis.

[7] As noted in the Introduction, Faust and Rogers (2003) find the "forward premium puzzle", on the other hand, to be robustly present for the complete set of short-run restrictions they consider.

To keep the exposition in this Section as simple as possible, we suppose that there are at most three countries, labelled as countries "0", "1", and "2". Also for simplicity, we suppose that there are at most three types of financial assets, bonds of maturity one period denominated in the currencies of country 0, of country 1, and of country 2, respectively. As we will consider the exchange rate effects of changes in monetary policy in country 0, only for country 0 we distinguish between private investors and monetary authorities. For countries 1 and 2, we only model private investors.[8]

We will distinguish two model structures: Under model structure "$\mathfrak{M}_2$", we only take into account two of the three countries, namely country 0 as the domestic economy, and the only foreign economy being given by country 1. Under model structure "$\mathfrak{M}_2$", therefore, we drop country 2 from the analysis. Under model structure "$\mathfrak{M}_3$", we model all three countries, with country 0 again being the domestic economy, but now both country 1 and country 2 being foreign economies.

We first describe the two-country world, $\mathfrak{M}_2$. We have the following time $t$ equilibrium conditions for the two bonds in this model structure:

$$B_{i0_pt} + B_{i0_gt} + B_{i1t} = 0, \qquad i = 0, 1, \tag{1.5}$$

where $B_{i0_pt}$ denotes the time $t$ holdings of the bond denominated in the currency of country $i$ by the private investors in country 0, $B_{i0_gt}$ the time $t$ holdings of the bond denominated in the currency of country $i$ by the monetary authorities of country 0, and $B_{i1t}$ the time $t$ holdings of the bond denominated in the currency of country $i$ by the investors in country 1. Suppose that the private investors in country 0 as well as the investors in country 1 use mean-variance analysis to optimize their portfolio holdings. At the time of solving their portfolio optimization problems, the investors know the nominal rates of return on the two bonds (the nominal rate of return for country $i$ from $t$ to $t+1$ being denoted by $R_{it}$), but face uncertainty regarding the one-period-ahead spot exchange rate between country 0 and country 1, and the one-period-ahead prices in both countries. The portfolio optimization

[8] While the magnitude of the exchange rate effects of monetary policy changes in country 0 would be different if we captured that central banks in countries 1 and 2 may respond to the monetary policy changes in country 0, our main point in this Section, namely that the exchange rate effects of monetary policy changes in country 0 will in general be mis-measured when considering a bilateral model, is not dependent on our assumption of there only being private investors in countries 1 and 2.

problem of the private investors in country 0 is then given by:

$$\max_{\omega_{10_p t}|_{\mathfrak{M}_2}} \left\{ E_t \left( \rho_{0_p t}\Big|_{\mathfrak{M}_2} \right) - \frac{1}{2}\gamma_{0_p} Var_t \left( \rho_{0_p t}\Big|_{\mathfrak{M}_2} \right) \right\}, \tag{1.6}$$

$\omega_{10_p t}|_{\mathfrak{M}_2}$ denoting the weight (under model structure $\mathfrak{M}_2$) in the time $t$ portfolio of the private investors in country 0 of the bonds denominated in the currency of country 1, $\rho_{0_p t}\Big|_{\mathfrak{M}_2}$ denoting the real rate of return from $t$ to $t+1$ on the portfolio of the private investors in country 0 (under model structure $\mathfrak{M}_2$), $\gamma_{0_p}$ denoting the coefficient of risk aversion of the private investors in country 0, and $Var_t(\cdot)$ denoting the conditional variance operator at time $t$, with

$$\rho_{0_p t} = \left(1 - \omega_{10_p t}|_{\mathfrak{M}_2}\right)\left(R_{0t} - \pi_{0,t+1}\right) + \omega_{10_p t}|_{\mathfrak{M}_2}\left(R_{1t} + \psi_{01,t+1} - \pi_{0,t+1}\right), \tag{1.7}$$

and with $\pi_{0,t+1}$ denoting the rate of inflation in country 0 at time $t+1$, $\psi_{01,t+1}$ the rate of appreciation of the currency of country 1 against the currency of country 0 from $t$ to $t+1$, and

$$\omega_{10_p t}|_{\mathfrak{M}_2} = \frac{Q_{01t} B_{10_p t}}{B_{00_p t} + Q_{01t} B_{10_p t}}, \tag{1.8}$$

$Q_{01t}$ denoting the time $t$ nominal spot exchange rate between countries 0 and 1 (measured as units of currency of country 0 per one single unit of currency of country 1). Finally, we suppose that

$$E_t\left(\pi_{0,t+1}\right) = \mu_{\pi_0 t}, \qquad Var_t\left(\pi_{0,t+1}\right) = \sigma^2_{\pi_0}, \tag{1.9}$$

$$E_t\left(\psi_{01,t+1}\right) = \mu_{\psi_{01} t}, \qquad Var_t\left(\psi_{01,t+1}\right) = \sigma^2_{\psi_{01}}, \tag{1.10}$$

and

$$Cov_t\left(\pi_{0,t+1}, \psi_{01,t+1}\right) = \sigma_{\pi_0,\psi_{01}}. \tag{1.11}$$

Note that for simplicity of exposition we do not specify the dependence of the first and second moments in (1.9) to (1.11) on underlying macroeconomic and financial market fundamentals. While such specification would be essential for an analysis characterizing the complete time path of the exchange rates, our focus here is on the time $t$ appreciation of the currency of country 0 in response to a contractionary change of the monetary policy stance in country

0 within the two-country model, in contrast to what it would be in a three-country model to be analyzed below. For this purpose, little is to be gained from specifying how the first and second moments in (1.9) to (1.11) depend on macroeconomic and financial market fundamentals.

Solving the optimization problem given by (1.6) to (1.11), it is readily established that the time $t$ optimal portfolio share of the bond denominated in the currency of country 1 by the private investors in country 0 under model structure $\mathfrak{M}_2$ is given by

$$\omega_{10_pt}\big|_{\mathfrak{M}_2} = \frac{R_{1t} + \mu_{\psi_{01}t} - R_{0t}}{\gamma_{0_p}\sigma^2_{\psi_{01}}} + \frac{\sigma_{\pi_0,\psi_{01}}}{\sigma^2_{\psi_{01}}}. \tag{1.12}$$

From (1.12), the optimal portfolio share under model structure $\mathfrak{M}_2$ of the bond denominated in the currency of country 1 for the private investors in country 0 is a function (i) of the risk-adjusted excess rate of return of the bond denominated in the currency of country 1 compared to the bond denominated in the currency of country 0, as well as (ii) the hedge the bond denominated in the currency of country 1 provides against inflation in country 0.

Let us now turn to the three-country world, $\mathfrak{M}_3$. For the three-country world, we extend the time $t$ equilibrium conditions in Equation (1.5) to reflect that the bonds denominated in the currencies of countries 0 and 1 can also be held by the investors in country 2, and to incorporate the time $t$ holdings of the bond denominated in the currency of country 2, $B_{i2t}$:

$$B_{i0_pt} + B_{i0_gt} + B_{i1t} + B_{i2t} = 0, \qquad i = 0, 1, 2. \tag{1.13}$$

We suppose that beyond the private investors in country 0 and the investors in country 1, the investors in country 2 also use mean-variance analysis to optimize their portfolio holdings. Mirroring the set-up of the two-country model, at the time of solving their portfolio optimization problems, the investors know the nominal rates of return on the three bonds, but face uncertainty regarding the set of one-period-ahead spot exchange rates and the one-period-ahead prices in all three countries. The portfolio optimization problem of the private investors in country 0 is now given by:

$$\max_{\omega_{10_pt}|_{\mathfrak{M}_3},\, \omega_{20_pt}|_{\mathfrak{M}_3}} \left\{ E_t\left(\rho_{0_pt}\big|_{\mathfrak{M}_3}\right) - \frac{1}{2}\gamma_{0_p} Var_t\left(\rho_{0_pt}\big|_{\mathfrak{M}_3}\right)\right\}, \tag{1.14}$$

$\omega_{10_p t}\big|_{\mathfrak{M}_3}$ and $\omega_{20_p t}\big|_{\mathfrak{M}_3}$ denoting the weights (under model structure $\mathfrak{M}_3$) in the time $t$ portfolio of the private investors in country 0 of the bonds denominated in the currencies of country 1 and country 2, respectively, $\rho_{0_p t}\Big|_{\mathfrak{M}_3}$ denoting the real rate of return from $t$ to $t+1$ on the portfolio of the private investors in country 0 (under model structure $\mathfrak{M}_3$), with

$$\begin{aligned} \rho_{0_p t}\Big|_{\mathfrak{M}_3} &= \left(1 - \omega_{10_p t}\big|_{\mathfrak{M}_3} - \omega_{20_p t}\big|_{\mathfrak{M}_3}\right)\left(R_{0t} - \pi_{0,t+1}\right) \\ &\quad + \sum_{i=1}^{2} \omega_{i0_p t}\big|_{\mathfrak{M}_3}\left(R_{it} + \psi_{0i,t+1} - \pi_{0,t+1}\right), \end{aligned} \tag{1.15}$$

and with $\psi_{0i,t+1}$ the rate of appreciation of the currency of country $i$ against the currency of country 0 from $t$ to $t+1$, and

$$\omega_{i0_p t}\big|_{\mathfrak{M}_3} = \frac{Q_{0it} B_{i0_p t}}{B_{00_p t} + Q_{01t} B_{10_p t} + Q_{02t} B_{20_p t}}, \qquad i = 1, 2, \tag{1.16}$$

$Q_{0it}$ denoting the time $t$ nominal spot exchange rate between countries 0 and $i$ (measured as units of currency of country 0 per one single unit of currency of country $i$). We suppose in analogy to (1.10) and (1.11) that

$$E_t\left(\psi_{0i,t+1}\right) = \mu_{\psi_{0i} t}, \qquad Var_t\left(\psi_{0i,t+1}\right) = \sigma^2_{\psi_{0i}}, \qquad i = 1, 2, \tag{1.17}$$

and

$$Cov_t\left(\pi_{0,t+1}, \psi_{0i,t+1}\right) = \sigma_{\pi_0, \psi_{0i}}, \qquad i = 1, 2, \qquad Cov_t\left(\psi_{01,t+1}, \psi_{02,t+1}\right) = \sigma_{\psi_{01}, \psi_{02}}. \tag{1.18}$$

Solving the optimization problem given by (1.14) to (1.18), it is readily established that the time $t$ optimal portfolio share of the bond denominated in the currency of country 1 by the private investors in country 0 under model structure $\mathfrak{M}_3$ is given by

$$\begin{aligned} \omega_{10_p t}\big|_{\mathfrak{M}_3} &= \left(\frac{1}{1 - \rho^2_{\psi_{01}, \psi_{02}}}\right)\left[\left(\frac{R_{1t} + \mu_{\psi_{01} t} - R_{0t}}{\gamma_{0_p} \sigma^2_{\psi_{01}}} + \frac{\sigma_{\pi_0, \psi_{01}}}{\sigma^2_{\psi_{01}}}\right)\right. \\ &\quad \left. - \rho^2_{\psi_{01}, \psi_{02}}\left(\frac{R_{2t} + \mu_{\psi_{02} t} - R_{0t}}{\gamma_{0_p} \sigma_{\psi_{01}, \psi_{02}}} + \frac{\sigma_{\pi_0, \psi_{02}}}{\sigma_{\psi_{01}, \psi_{02}}}\right)\right], \end{aligned} \tag{1.19}$$

with

$$\rho^2_{\psi_{01},\psi_{02}} = \frac{\sigma^2_{\psi_{01},\psi_{02}}}{\sigma^2_{\psi_{01}}\sigma^2_{\psi_{02}}}. \tag{1.20}$$

>From (1.19), the optimal portfolio share of the bond denominated in the currency of country 1 for the private investor in country 0 under model structure $\mathfrak{M}_3$ is a function (i) of both the excess rate of return of the bond denominated in the currency of country 1 as well as the excess rate of return of the bond denominated in the currency of country 2, as well as (ii) the hedge both the bond denominated in the currency of country 1 as well as the bond denominated in the currency of country 2 provide against inflation in country 0. The optimal portfolio share of the bond denominated in the currency of country 1 for the private investors in country 0 under model structure $\mathfrak{M}_3$will generally only be the same as it is in the two-country model, model structure $\mathfrak{M}_2$, if

$$\sigma_{\psi_{01},\psi_{02}} = 0. \tag{1.21}$$

Such an orthogonality restriction on the dynamics of different exchange rate pairs is, however, extremely unlikely to hold in empirical practice.

Also solving under model structure $\mathfrak{M}_2$ the optimization problem of the investors in country 1, and under model structure $\mathfrak{M}_3$ the optimization problems of the investors in countries 2 and 3, upon substituting the complete set of optimal portfolio shares into the relevant market clearing condition, (Equation (1.5) under model structure $\mathfrak{M}_2$ and Equation (1.13) under model structure $\mathfrak{M}_3$), and then differentiating the resultant identities under the implicit function theorem with respect to $Q_{01t}$ and $R_{0t}$, it can be shown that[9]

$$\left.\frac{\partial Q_{01t}}{\partial R_{0t}}\right|_{\mathfrak{M}_2} \neq \left.\frac{\partial Q_{01t}}{\partial R_{0t}}\right|_{\mathfrak{M}_3}, \tag{1.22}$$

unless the orthogonality condition of Equation (1.21) holds, which, again, is extremely unlikely to be the case in empirical practice. Thus, a bilateral analysis of monetary policy changes in country 0 that includes only the variables of countries 0 and 1 will generally be subject to an omitted variables problem. The variables for country 2 generally need to be included as well. Through calibration-style exercises, we have established that under reasonable parameterizations of model structures $\mathfrak{M}_2$ and $\mathfrak{M}_3$ the instantaneous bilateral and/or

[9]The algebraic details are described in a note available from the authors upon request.

effective exchange rate appreciations for the currency of country 0 caused by a contractionary monetary policy shock in country 0 may in the three-country model be either weaker or stronger than in the two-country model. The strength of the exchange rate effects of a monetary policy change thus seems to be primarily an empirical question.

Rather than augmenting our simple stylized model to capture frictions that within the model will lead to exchange rate overshooting, in this paper we restrict ourselves to building and estimating an empirical model heeding the main insight of Equation (1.22): The exchange rate and forward premium effects of monetary policy shocks in the presence of more than two countries will generally be mis-measured in a bilateral (two-country) model. A multilateral model is called for, capturing the complete spectrum of the relevant cross-country exchange rate correlations.[10]

## 1.4 An Empirical Multilateral Model

### 1.4.1 A Global Vector Error Correction Model (GVECM)

A common limitation of the empirical models considered in the previous literature on the exchange rate effects of monetary policy is that they omit considering the simultaneous nature of the international spillover effects that a monetary policy shock will cause. To address this problem, we work with a Global VAR (GVAR) model as proposed by Pesaran, Schuermann, and Weiner (2004). Suppose that there are $T$ sample periods, $t = 1, 2, \ldots, T$, and $N + 1$ countries, the countries indexed by $i = 0, 1, 2, \ldots, N$. For each country, we wish to model a vector $\mathbf{x}_{it}$ of $m$ country-specific endogenous variables. Stacking the vectors of country-specific endogenous variables,

$$\mathbf{x}_t = \begin{pmatrix} \mathbf{x}'_{0t}, & \mathbf{x}'_{1t}, & \ldots, & \mathbf{x}'_{Nt} \end{pmatrix}', \tag{1.23}$$

a VAR model in $\mathbf{x}_t$ obviously would contain ways too many parameters to be estimable unless the time dimension, $T$, of each country's data series would by far exceed the cross-sectional dimension, $N + 1$. Therefore, rather than letting $\mathbf{x}_{-i,t}$,

$$\mathbf{x}_{-i,t} = \begin{pmatrix} \mathbf{x}'_{0t}, & \mathbf{x}'_{1t}, & \ldots, & \mathbf{x}'_{i-1t}, & \mathbf{x}'_{i+1,t}, & \mathbf{x}'_{i+2,t}, & \ldots, & \mathbf{x}'_{Nt} \end{pmatrix}', \tag{1.24}$$

[10] We do not address in this paper the question as to the minimum number of countries that is needed to avoid sizeable mis-measurement due to an omitted countries bias. The answer to this question is likely to be sample specific, and in this paper we simply take the approach of working with a panel of major industrial economies spanning Northern America, Europe as well as East Asia and the Pacific.

enter the set of equations for country $i$ in unrestricted form, the GVAR model involves a structural cross-country interdependence restriction, namely relating $\mathbf{x}_{it}$ "only" to an $m^* \times 1$ dimensional vector $\mathbf{x}^*_{it}$,

$$\mathbf{x}^*_{\ell it} = \sum_{j=0}^{N} w_{\ell ij} x_{\ell jt}, \text{ with } w_{\ell ij} = 0 \text{ for } i = j,\ \ell = 1, 2, \dots, m^*, \tag{1.25}$$

and where $\sum_{j=0}^{N} w_{\ell ij} = 1$, for all relevant $\ell$ and all $i$, the weights $w_{\ell ij}$ reflecting the economic importance of country $j$ for country $i$.[11] The GVAR model for country $i$ is then given by

$$\mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1} t + \sum_{s=1}^{p_i} \mathbf{\Phi}_{is} \mathbf{x}_{i,t-s} + \sum_{s=0}^{q_i} \mathbf{\Lambda}_{is} \mathbf{x}^*_{i,t-s} + \sum_{s=0}^{d_i} \mathbf{\Upsilon}_{is} \mathbf{d}_{t-s} + \mathbf{u}_{it}, \qquad \mathbf{u}_{it} \overset{iid\ (\text{for } t)}{\sim} (\mathbf{0},\ \mathbf{\Sigma}_{\mathbf{u}_i}), \tag{1.26}$$

where $\mathbf{d}_t$ is a $q \times 1$ dimensional vector of observed common factors. The vectors of country-specific foreign variables $\mathbf{x}^*_{i,t-s}$ account for direct spillovers across countries and may also proxy the influence of unobserved common factors across countries. The weights $w_{\ell ij}$ entering the construction of $\mathbf{x}^*_{i,t-s}$ capture the differential effects that different foreign countries have on domestic economy variables, and impose the restriction that the magnitude of the spillovers from a foreign economy onto the domestic economy is in proportion to the weighting scheme. The foreign variables and the observed common factors in $\mathbf{d}_t$ in Equation (1.26) are treated as weakly exogenous.

In order to distinguish between temporary and permanent shocks, we re-write Equation (1.26) in error-correction format, rendering the Global Vector Error Correction Model (GVECM):

$$\Delta \mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1} t + \mathbf{\Pi}_i \mathbf{z}_{i,t-1} + \sum_{s=1}^{p-1} \mathbf{\Psi}_{is} \Delta \mathbf{z}_{i,t-s} + \mathbf{\Gamma}_i \Delta \widetilde{\mathbf{z}}_{it} + \mathbf{u}_{it}, \tag{1.27}$$

where

$$\mathbf{\Pi}_i = \left( -\mathbf{I}_m + \textstyle\sum_{s=1}^{p} \mathbf{\Phi}_{is},\ \ \sum_{s=0}^{p} \mathbf{\Lambda}_{is},\ \ \sum_{s=0}^{p} \mathbf{\Upsilon}_{is} \right),\ \mathbf{z}_{it} = \left( \mathbf{x}'_{it},\ \mathbf{x}^{*\prime}_{it},\ \mathbf{d}'_t \right)', \tag{1.28}$$

[11] In this paper, we will use trade weights to construct the $w_{\ell ij}$'s. To capture a separate financial market channel of cross-country spillovers, one might like to (also) consider financial capital flow based weights, in particular for financial market variables. As the necessary broad set of bilateral data on financial capital flow based weights at present are not available, we restrict ourselves to trade weights in this paper.

$$p = \max_i \{p_i, q_i, d_i\}, \;\; \mathbf{\Psi}_{is} = \left( \;-\sum_{q=s+1}^{p} \mathbf{\Phi}_{is}, \quad -\sum_{q=s+1}^{p} \mathbf{\Lambda}_{is}, \quad -\sum_{q=s+1}^{p} \mathbf{\Upsilon}_{is} \;\right), \tag{1.29}$$

$$\widetilde{\mathbf{z}}_{it} = \left( \mathbf{x}_{it}^{*\prime}, \; \mathbf{d}_t^{\prime} \right)^{\prime}, \text{ and } \mathbf{\Gamma}_i = \left( \; \mathbf{\Lambda}_{i0}, \quad \mathbf{\Upsilon}_{i0} \; \right). \tag{1.30}$$

The matrix $\mathbf{\Pi}_i$ may be decomposed as $\mathbf{\Pi}_i = \boldsymbol{\alpha}_i \boldsymbol{\beta}_i^{\prime}$, where $\boldsymbol{\beta}_i$ is the matrix of cointegrating relations.

It would be an enormous task to simultaneously estimate a system in $\Delta \mathbf{x}_t$, with each $\Delta \mathbf{x}_{it}$ generated by Equation (1.27). The GVECM can, however, be readily estimated on a country-by country basis if the degree of cross-country dependence of the idiosyncratic shocks, $\mathbf{u}_{it}$, is sufficiently small, so that

$$\sum_{j=0}^{N} \frac{Cov\left(u_{\ell it}, u_{mjt}\right)}{N} \rightarrow 0 \text{ as } N \rightarrow \infty, \text{ for all } i \neq j, \, \ell \text{ and } m. \tag{1.31}$$

The condition in Equation (1.31), established by Pesaran, Schuermann, and Weiner (2004), may be viewed as weakening one of Zellner's (1962) conditions under which a seemingly unrelated equation system can be estimated on an equation-by-equation basis, namely if the variance-covariance matrix of the system is diagonal. The condition in Equation (1.31) requires that the cross-country interdependencies asymptotically are captured through the foreign variables and the observed common factors in $\mathbf{d}_t$.[12]

Upon country-by-country estimation of the GVECM - which can be accomplished using the methodology of Pesaran, Shin, and Smith (2000) - for an impulse response analysis it is necessary to obtain the implied global solution for $\mathbf{x}_t$.[13] To obtain the global solution in levels form, note that Equation (1.26) can also be re-written as

$$\mathbf{A}_i \mathbf{y}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1} t + \sum_{s=1}^{p} \mathbf{B}_{is} \mathbf{y}_{i,t-s} + \sum_{s=0}^{d_i} \mathbf{\Upsilon}_{is} \mathbf{d}_{t-s} + \mathbf{u}_{it}, \tag{1.32}$$

[12] If the foreign variables and the observed common factors in $\mathbf{d}_t$ in Equation (1.26) cannot be treated as weakly exogenous, the GVECM can still be estimated on a country-by-country basis, but the equation system for country $i$ then will need to include the equations in $\mathbf{x}_{it}^{*\prime}$ and $\mathbf{d}_t^{\prime}$.

[13] Impulse response analysis cannot be carried out on the basis of the GVECM representation in Equation (1.27), as any innovation in $\mathbf{u}_{it}$ in general causes responses of *all* elements of $\mathbf{x}_t$, and thus the foreign variables entering Equation (1.27) cannot be modelled as being unaffected by innovations in $\mathbf{u}_{it}$.

where

$$\mathbf{y}_{it} = \left(\mathbf{x}_{it}^{'},\ \mathbf{x}_{it}^{*'}\right)',\ \mathbf{A}_i = \left(\begin{array}{cc}\mathbf{I}_m, & -\mathbf{\Lambda}_{i0}\end{array}\right),\ \text{and } \mathbf{B}_{is} = \left(\begin{array}{cc}\mathbf{\Phi}_{is}, & \mathbf{\Lambda}_{is}\end{array}\right). \tag{1.33}$$

>From Equation (1.25), it is readily seen that

$$\mathbf{y}_{it} = \mathbf{W}_i \mathbf{x}_t, \tag{1.34}$$

for an appropriately defined weighting and selection matrix $\mathbf{W}_i$. By stacking Equation (1.32) across all $i$, the resultant multilateral ("global") model can be re-written as

$$\mathbf{G}\mathbf{x}_t = \mathbf{a}_0 + \mathbf{a}_1 t + \sum_{s=1}^{p} \mathbf{H}_s \mathbf{x}_{t-s} + \sum_{s=0}^{p} \mathbf{\Upsilon}_s \mathbf{d}_{t-s} + \mathbf{u}_t, \tag{1.35}$$

where

$$\mathbf{G} = \begin{pmatrix} \mathbf{A}_0\mathbf{W}_0 \\ \mathbf{A}_1\mathbf{W}_1 \\ \vdots \\ \mathbf{A}_N\mathbf{W}_N \end{pmatrix},\ \mathbf{a}_0 = \begin{pmatrix} \mathbf{a}_{00} \\ \mathbf{a}_{10} \\ \vdots \\ \mathbf{a}_{N0} \end{pmatrix},\ \mathbf{a}_1 = \begin{pmatrix} \mathbf{a}_{01} \\ \mathbf{a}_{11} \\ \vdots \\ \mathbf{a}_{N1} \end{pmatrix}, \tag{1.36}$$

$$\mathbf{H}_s = \begin{pmatrix} \mathbf{B}_{0s}\mathbf{W}_0 \\ \mathbf{B}_{1s}\mathbf{W}_1 \\ \vdots \\ \mathbf{B}_{Ns}\mathbf{W}_N \end{pmatrix},\ \mathbf{\Upsilon}_s = \begin{pmatrix} \mathbf{\Upsilon}_{0s} \\ \mathbf{\Upsilon}_{1s} \\ \vdots \\ \mathbf{\Upsilon}_{Ns} \end{pmatrix},\ \text{and } \mathbf{u}_t = \begin{pmatrix} \mathbf{u}_{0t} \\ \mathbf{u}_{1t} \\ \vdots \\ \mathbf{u}_{Nt} \end{pmatrix}. \tag{1.37}$$

The matrix $\mathbf{G}$ can in general be expected to be of full rank, in which case the global solution in levels form is given by

$$\mathbf{x}_t = \mathbf{G}^{-1}\mathbf{a}_0 + \mathbf{G}^{-1}\mathbf{a}_1 t + \sum_{s=1}^{p} \mathbf{G}^{-1}\mathbf{H}_s \mathbf{x}_{t-s} + \sum_{s=0}^{p} \mathbf{\Upsilon}_s \mathbf{d}_{t-s} + \mathbf{G}^{-1}\mathbf{u}_t. \tag{1.38}$$

The global solution in Equation (1.38) indeed is a VAR for the union of all countries' sets of domestic variables. The key feature of the GVAR/GVECM framework is that it allows to estimate Equation (1.38) indirectly on a country-by-country basis, allowing for the consideration of a larger number of countries and richer country-specific model formulations than would ever be feasible if it was attempted to estimate Equation (1.38) directly.

### 1.4.2 GVECM Variables and Data

We consider the sample period from January 1978 to December 2006 for nine industrial countries: Australia, Canada, France, Germany, Italy, Japan, New Zealand, the United Kingdom, and the United States. The vector of domestic variables for each country is given by:

$$\mathbf{x}_{it} = \begin{pmatrix} y_{it} & P_{it} & R^m_{it} & R_{it} & Q_{it} \end{pmatrix}', \tag{1.39}$$

where (in all cases for country $i$ at time $t$) $y_{it}$ denotes the logarithm of real industrial production, $P_{it}$ the logarithm of the consumer price index, $R^m_{it}$ the monetary policy indicator (in fractions), $R_{it}$ the short-term nominal interest rate (typically a three-months treasury-bill type rate, in fractions), and $Q_{it}$ the effective nominal exchange rate. The corresponding country-specific foreign variables are given by:

$$\mathbf{x}^*_{it} = \begin{pmatrix} y^*_{it} & P^*_{it} & R^*_{it} & Q^*_{it} \end{pmatrix}', \tag{1.40}$$

each foreign variable defined as in Equation (1.25). Note that we do not construct country-specific foreign variables for the monetary policy indicator, since for each country the indicator reflects different variables (we will discuss our choice of the monetary policy indicators in Section 1.5). Following most of the GVAR literature, the weights we use for the construction of the foreign variables and the effective exchange rates are average trade weights based on a middle period in the sample (namely, from January 1991 to December 1993).

The observed common factor $\mathbf{d}_t$ we specify to be the logarithm of spot world market oil prices and of a commodity price index for agricultural raw materials.

While it would, of course, be of interest to use a real-time database for our empirical analysis, due to lack of the required real-time databases for the majority of the countries in our sample, our data incorporates all data revisions that have been made to date since initial release of the data. This is consistent with all of the previous empirical papers on the exchange rate effects of monetary policy shocks as cited in the Introduction and in Section 2. It should also be noted that the findings of Croushore and Evans (2006) suggest that key results regarding the effects of U.S. monetary policy shocks are the same when real-time data sets are used as when data sets incorporating data revisions are used.

## 1.5 Measuring Monetary Policy Shocks

### 1.5.1 Monetary Policy Indicators

Let us turn to the issue of measuring the monetary policy shock. First, we need to choose the indicators that for each country seem to best measure the monetary policy stance. It has been widely recognized in the literature that monetary aggregates do not represent satisfactory measures of the monetary policy stance, as changes of monetary aggregates involve various non-policy influences and reflect both changes of money demand and money supply.[14] Hence we focus on other variables such as short-term interest rates and reserve ratios. Let us briefly discuss our choices for each country.

For the United States, we consider two alternatives: the federal funds rate ($FFR$) and the ratio between non-borrowed reserves and total reserves ($nbrx$). The $FFR$ has been the Federal Reserve's operating target for most of our sample period; announcing the federal funds target rate has been a major policy signal channel for the Federal Reserve. Thus we believe that the $FFR$ closely reflects the Federal Reserve's policy stance. This is also supported by empirical evidence. Bernanke and Mihov (1998), for example, conclude that it seems best to measure the Federal Reserve's monetary policy stance using the $FFR$ prior to 1979 and $nbrx$ from 1979 to 1982, and either $FFR$ or $nbrx$ for more recent periods. Therefore, we choose the $FFR$ for our default analysis, and augment our analysis with $nbrx$ for robustness checks.

For Canada, it appears that the Bank of Canada's overnight rate contains much of the relevant information about the Bank of Canada's monetary policy stance. The Bank of Canada announces the target rate for the overnight rate to send policy signals (Armour, Engert, and Fung, 1996). According to the analysis of Armour, Engert, and Fung (1996), the path of the overnight rate is consistent with the policy record of the Bank of Canada from the 1970s, and is preferable compared to use of other alternatives such as the 90-days paper rate term spread (the 90-days paper rate minus the yield on ten-years or longer maturity Canadian government bonds). Therefore, we choose the overnight rate as the indicator of Canadian monetary policy.

For the European countries France, Germany, and Italy, as first candidates for measures of the monetary policy stance we consider money market rates as the target rates steered by their respective central banks. Before 1999, unlike the Federal Reserve and the Bank of Canada

[14] See, for example, Bernanke and Mihov (1998).

that sent signals mainly through announcements of target rates, these European countries' central banks used various strategies to signal their monetary policy stance, including tender rates in open market operations, quantity signals, and standing facilities. The Bank of France used repurchases of government and private claims as its major operation; important signals were sent via various repurchase rates. Even among the tender rates, no single rate seems to have adequately captured the complete monetary policy stance of the Bank of France, though. The Deutsche Bundesbank's lombard rate, constituting an upper bound for German money market rates, was an important signal for German monetary policy for many years. The lombard rate and the overnight call rate are identified as useful measures of the Bundesbank's monetary policy stance in Bernanke and Mihov (1997) using data before 1990. From the 1990s on, standing facilities have accounted for less and less of the re-financing, and the day-to-day call money market rate seems to be a more appropriate measure of the Deutsche Bundesbank's monetary policy stance (Brueggemann, 2003). For Italy, in addition to the repurchase rates, the discount window has been conveying the long-term monetary policy stance of the Bank of Italy. De Arcangelis and Di Giorgio (1999) argue that the repurchase agreement rate and the overnight rate have been strong substitutes, and that the Bank of Italy has been targeting the overnight interbank loan rate. Given these considerations, instead of using for France, Germany, and Italy variables that likely reflect only a limited amount of information about monetary policy operations, we prefer to use for the time period prior to the establishment of the European Central Bank country-specific overnight money market rates. For the time period following the introduction of a common monetary policy for the Euro area in January 1999, we use the European Overnight Index Average (EONIA) as the monetary policy indicator for France, Germany, and Italy, as the European Central Bank appears to have a strong interest in steering it.

For the United Kingdom, our choice is the "official bank rate". The "official bank rate" includes all the rates that the Bank of England has sequentially used since 1978.[15]

For Japan, we consider the overnight call rate as our primary candidate for the monetary policy indicator for the Bank of Japan, as it was the operating target before 2001 and then again after 2006. Between 2001 and 2006, the Bank of Japan primarily targeted the quantity of bank reserves (for example, McCallum, 2003). Using the overnight call rate as the monetary

[15]The precise measurement of the official bank rate has changed several times. For further details, see http://www.bankofengland.co.uk/mfsd/iadb/notesiadb/Wholesale_discount.htm#BANK%20 RATE

policy indicator, Miyao (2002) finds plausible effects for apparent changes in the Bank of Japan's monetary policy stance.

For Australia, we use the official cash rate; the target for the official cash rate appears to be a reasonable measure of the Reserve Bank of Australia's monetary policy intentions.[16] The Reserve Bank of New Zealand targeted settlement cash balances until 1999, and there were no officially set or targeted interest rates during that time period. In March 1999, the official cash rate was introduced to help meet the inflation target.[17] We therefore use a combination of the discount rate prior to 1999 and the official cash rate thereafter as our monetary policy indicator for the Reserve Bank of New Zealand.

### 1.5.2 Identification of Monetary Policy Shocks in the Global Vector Error Correction Model

The structural form of the Global Vector Error Correction Model (GVECM) for country $i$ from Equation (1.27) can be represented as

$$\begin{aligned}\mathbf{A}_{\mathbf{xx},i}\Delta\mathbf{x}_{it} &= \mathbf{A}_{\mathbf{xx},i}\mathbf{a}_{i0} + \mathbf{A}_{\mathbf{xx},i}\mathbf{a}_{i1}t + \mathbf{A}_{\mathbf{xx},i}\mathbf{\Pi}_i\mathbf{z}_{i,t-1} + \mathbf{A}_{\mathbf{xx},i}\sum_{s=1}^{p-1}\mathbf{\Psi}_{is}\Delta\mathbf{z}_{i,t-s} \\ &\quad + \mathbf{A}_{\mathbf{xx},i}\mathbf{\Gamma}_i\Delta\widetilde{\mathbf{z}}_{it} + \boldsymbol{\varepsilon}_{\mathbf{x}it}, \qquad \boldsymbol{\varepsilon}_{\mathbf{x}it} \overset{iid.\ (\text{for } t)}{\sim} (\mathbf{0},\ \mathbf{\Sigma}_{\boldsymbol{\varepsilon}_{\mathbf{x}i}}), \end{aligned} \tag{1.41}$$

with the reduced form shocks in $\mathbf{u}_{it}$ are related to the structural shocks in $\boldsymbol{\varepsilon}_{\mathbf{x}it}$ as $\mathbf{u}_{it} = \mathbf{A}^{-1}_{\mathbf{xx},i}\boldsymbol{\varepsilon}_{\mathbf{x}it}$. Let us suppose that the processes for the foreign variables in $\mathbf{x}^*_{it}$ and the common factors in $\mathbf{d}_t$ are given by

$$\Delta\widetilde{\mathbf{z}}_{it} = \mathbf{b}_{i0} + \sum_{s=1}^{p-1}\mathbf{\Theta}_{is}\Delta\widetilde{\mathbf{z}}_{i,t-s} + \boldsymbol{\varepsilon}_{\widetilde{\mathbf{z}}it}, \qquad \boldsymbol{\varepsilon}_{\widetilde{\mathbf{z}}it} \overset{i.i.d.\ (\text{for } t)}{\sim} (\mathbf{0},\ \mathbf{\Sigma}_{\boldsymbol{\varepsilon}_{\widetilde{\mathbf{z}}i}}). \tag{1.42}$$

with, as before, $\widetilde{\mathbf{z}}_{it} = \begin{pmatrix} \mathbf{x}^{*\prime}_{it} & \mathbf{d}'_t \end{pmatrix}'$. We need to identify the $m^2$ elements in $\mathbf{A}_{\mathbf{xx},i}$. As is standard in the literature, we normalize $E(\boldsymbol{\varepsilon}_{\mathbf{x}it}\boldsymbol{\varepsilon}'_{\mathbf{x}it}) = \mathbf{I}_m$, that is $E\left(\mathbf{A}_{\mathbf{xx},i}\mathbf{u}_{it}\mathbf{u}'_{it}\mathbf{A}'_{\mathbf{xx},i}\right) = \mathbf{I}_m$, implying that $\sum_{\mathbf{u}_i} = \mathbf{A}^{-1}_{\mathbf{xx},i}\mathbf{A}^{-1\prime}_{\mathbf{xx},i}$. This orthogonality condition provides $m(m+1)/2$ restrictions for identification. We thus still need an additional $m(m-1)/2$ restrictions to just-identify $\mathbf{A}_{0,\mathbf{xx},i}$.

Typical restrictions considered in the VAR literature are to impose $m(m-1)/2$ short-run

[16] http://www.rba.gov.au/MonetaryPolicy/about_monetary_policy.html
[17] http://www.rbnz.govt.nz/monpol/about/0047041.html

(contemporaneous) restrictions, such as by restricting the $\mathbf{A}_{\mathbf{xx},i}$ matrix to be lower triangular, as in Eichenbaum and Evans (1995). In this case, a strong causal ordering assumption for the model variables is made, rendering the contemporaneous variable interaction structure recursive. Such a recursive structure from the perspective of macroeconomic theory seems unlikely to hold. Impulse responses from such a recursive structure based identification scheme, known as orthogonalized impulse responses, also often are sensitive to the ordering of the variables.

In our GVECM, the cointegrating relationships provide us with useful information for the identification of the structural shocks, enabling us to work with identifying assumptions that from the perspective of macroeconomic theory are considerably weaker than those underlying orthogonalized impulse responses.[18] We stack Equations (1.41) and (1.42) to obtain

$$\mathbf{A}_i \Delta \mathbf{z}_{it} = \mathbf{c}_{i0} + \mathbf{c}_{i1} t + \widetilde{\mathbf{\Pi}}_i \mathbf{z}_{i,t-1} + \sum_{s=1}^{p-1} \mathbf{\Xi}_{is} \Delta \mathbf{z}_{i,t-s} + \boldsymbol{\varepsilon}_{it}, \tag{1.43}$$

where

$$\mathbf{A}_i = \begin{pmatrix} \mathbf{A}_{\mathbf{xx},i} & -\mathbf{A}_{\mathbf{xx},i}\Gamma_i \\ \mathbf{0}_{(m^*+q)\times m} & \mathbf{I}_{m^*+q} \end{pmatrix}, \ \mathbf{c}_{i0} = \begin{pmatrix} \mathbf{A}_{\mathbf{xx},i}\mathbf{a}_{i0} \\ \mathbf{b}_{i0} \end{pmatrix}, \ \mathbf{c}_{i1} = \begin{pmatrix} \mathbf{A}_{\mathbf{xx},i}\mathbf{a}_{i1} \\ \mathbf{0}_{(m^*+q)\times 1} \end{pmatrix}, \tag{1.44}$$

$$\widetilde{\mathbf{\Pi}}_i = \begin{pmatrix} \mathbf{A}_{\mathbf{xx},i}\mathbf{\Pi}_i \\ \mathbf{0}_{(m^*+q)\times n} \end{pmatrix}, \ \mathbf{\Xi}_{is} = \begin{pmatrix} \mathbf{A}_{\mathbf{xx},i}\mathbf{\Psi}_{is} \\ \mathbf{\Theta}_{is} \end{pmatrix}, \ \boldsymbol{\varepsilon}_{it} = \begin{pmatrix} \boldsymbol{\varepsilon}_{\mathbf{x}it} \\ \boldsymbol{\varepsilon}_{\tilde{\mathbf{z}}it} \end{pmatrix}, \tag{1.45}$$

and $k = m + m^* + q$. Suppose that we have $r$ cointegrating relationships among the total of $k$ variables in $\mathbf{z}_{it}$. We can then represent $\{\mathbf{z}_{it}\}$ as

$$\mathbf{z}_{it} = \mathbf{z}_{i0} + \mathbf{C}_i \sum_{s=1}^{t} \mathbf{u}_{is} + \sum_{s=1}^{\infty} \mathbf{C}^*_{is} \mathbf{u}_{i,t-s}, \tag{1.46}$$

where $\mathbf{C}_i = \boldsymbol{\beta}_{i\perp}[\widetilde{\boldsymbol{\alpha}}'_{i\perp}(\mathbf{I} - \sum_{s=1}^{p-1} \mathbf{\Xi}_{is})\boldsymbol{\beta}_{i\perp}]^{-1}\widetilde{\boldsymbol{\alpha}}'_{i\perp}$, with $\widetilde{\boldsymbol{\alpha}}'_{i\perp}\widetilde{\boldsymbol{\alpha}}_i = \mathbf{0}$ and $\boldsymbol{\beta}'_i\boldsymbol{\beta}_{i\perp} = \mathbf{0}$, so that

[18] Faust and Leeper (1997) in the context of a bivariate VAR argue against a long-run identification scheme with one transitory and one permanent shock, as such a scheme may lead to misidentification when the true empirical model features a larger number of shocks than the estimated model. In line with the arguments in Pagan and Pesaran (2008), we view long-run identifying restrictions not just as weaker than corresponding short-run restrictions from the perspective of macroeconomic theory, but also as recognizing existing properties of a dynamic model with cointegrating relations. Furthermore, there is a wealth of econometric evidence (much of it reviewed, for example, in Luetkepohl, 2007), that for the type of data sample we are working with in this paper, such models can be estimated with a satisfactory degree of reliability.

$\mathbf{C}_i\widetilde{\boldsymbol{\alpha}}_i = \mathbf{0}_{k\times r}$ and $\boldsymbol{\beta}_i^{'}\mathbf{C}_i = \mathbf{0}_{r\times k}$; $\mathbf{z}_{i0}$ is an initialization of $\{\mathbf{z}_{it}\}$. It is well known (for a review, see, for example, Pesaran, Shin, and Smith, 2000) that $\sum_{s=1}^{t}\mathbf{u}_{is}$ is a vector of random walks, and that $\mathbf{C}_{is}^{*}$ is absolutely summable, with $\mathbf{C}_{is}^{*}$ converging to the zero matrix as $s \to \infty$. Therefore, the long-run effects of innovations to $\mathbf{u}_{it}$ are fully captured through common trend component $\mathbf{C}_i\sum_{s=1}^{t}\mathbf{u}_{is}$. As $\mathbf{C}_i$ has rank $k-r$, there are $k-r$ stochastic trends that are driving the system in $\mathbf{z}_{it}$. Moving from a representation involving the reduced form disturbances in $\mathbf{u}_{it}$ to one involving the structural disturbances in $\boldsymbol{\varepsilon}_{it}$, Equation (1.46) can be re-written as

$$\mathbf{z}_{it} = \mathbf{z}_{i0} + \mathbf{C}_i\mathbf{A}_i^{-1}\sum_{s=1}^{t}\boldsymbol{\varepsilon}_{is} + \sum_{s=1}^{\infty}\mathbf{C}_{is}^{*}\mathbf{A}_i^{-1}\boldsymbol{\varepsilon}_{i,t-s}, \tag{1.47}$$

with

$$\begin{aligned}\mathbf{C}_i\mathbf{A}_i^{-1} &= \begin{pmatrix}\mathbf{C}_{\mathbf{xx},i} & \mathbf{C}_{\mathbf{x}\widetilde{\mathbf{z}},i}\\ \mathbf{C}_{\widetilde{\mathbf{z}}\mathbf{x},i} & \mathbf{C}_{\widetilde{\mathbf{z}}\widetilde{\mathbf{z}},i}\end{pmatrix}\begin{pmatrix}\mathbf{A}_{\mathbf{xx},i}^{-1} & -\left(\mathbf{A}_{\mathbf{xx},i}\Gamma_i\right)^{-1}\\ \mathbf{0}_{(m^*+q)\times m} & \mathbf{I}_{m^*+q}\end{pmatrix}\\ &= \begin{pmatrix}\mathbf{C}_{\mathbf{xx},i}\mathbf{A}_{\mathbf{xx},i}^{-1} & -\mathbf{C}_{\mathbf{xx},i}\left(\mathbf{A}_{\mathbf{xx},i}\Gamma_i\right)^{-1} + \mathbf{C}_{\mathbf{x}\widetilde{\mathbf{z}},i}\\ \mathbf{C}_{\widetilde{\mathbf{z}}\mathbf{x},i}\mathbf{A}_{\mathbf{xx},i}^{-1} & -\mathbf{C}_{\widetilde{\mathbf{z}}\mathbf{x},i}\left(\mathbf{A}_{\mathbf{xx},i}\Gamma_i\right)^{-1} + \mathbf{C}_{\widetilde{\mathbf{z}}\widetilde{\mathbf{z}},i}\end{pmatrix}.\end{aligned} \tag{1.48}$$

Clearly, $\mathbf{A}_i$ is non-singular, and thus $\mathbf{C}_i\mathbf{A}_i^{-1}$ is of rank $k-r$, that is, only $k-r$ structural shocks have long-run effects on the total of $k$ variables in $\mathbf{z}_{it}$. If the foreign variables in $\mathbf{x}_{it}^{*}$ and the common factors in $\mathbf{d}_t$ are weakly exogenous $I(1)$ processes, and there are no cointegrating relations among these, then the shocks to these variables will be among those having long-run effects.

For most of the empirical analysis of this paper, we will focus on the effects of U.S. monetary policy shocks. For the U.S., we find that there are three cointegrating relations. Let us thus discuss the case of $r = 3$ in more detail. It would seem a strong restriction to impose that the structural shocks to industrial production and to prices have no long-run effects. It seems very reasonable, however, to impose that the structural shocks to the monetary policy indicator, to the short-term interest rate, and to the effective nominal exchange rate have no long-run effects. This assumption renders the columns of $\mathbf{C}_{\mathbf{xx},i}\mathbf{A}_{\mathbf{xx},i}^{-1}$ that measure the long-run effects of these shocks equal to zero vectors, reflecting that these shocks only have transitory effects. Placing the structural shocks to the monetary policy indicator, the short-term interest rate, and the effective nominal exchange rate last in the disturbance vector $\boldsymbol{\varepsilon}_{\mathbf{x}it}$, we have:

$$\mathbf{C}_{\mathbf{xx},i}\mathbf{A}_{\mathbf{xx},i}^{-1} = \begin{pmatrix} & \varepsilon_y & \varepsilon_P & \varepsilon_{R^m} & \varepsilon_R & \varepsilon_Q \\ y & * & * & 0 & 0 & 0 \\ P & * & * & 0 & 0 & 0 \\ R^m & * & * & 0 & 0 & 0 \\ R & * & * & 0 & 0 & 0 \\ Q & * & * & 0 & 0 & 0 \end{pmatrix}. \tag{1.49}$$

The zeros in the last three columns of $\mathbf{C}_{\mathbf{xx},i}\mathbf{A}_{\mathbf{xx},i}^{-1}$ reflect that we have six (in general $r(m-r)$) linearly independent long-run restrictions for structural shock identification. Therefore, we now only need four (in general $m(m-1)/2 - r(m-r)$) additional restrictions for a just-identified $\mathbf{A}_{\mathbf{xx},i}$ matrix. As the first additional restriction, we assume that the shocks to consumer prices do not have long-run effects on real industrial production, so that now

$$\mathbf{C}_{\mathbf{xx},i}\mathbf{A}_{\mathbf{xx},i}^{-1} = \begin{pmatrix} & \varepsilon_y & \varepsilon_P & \varepsilon_{R^m} & \varepsilon_R & \varepsilon_Q \\ y & * & 0 & 0 & 0 & 0 \\ P & * & * & 0 & 0 & 0 \\ R^m & * & * & 0 & 0 & 0 \\ R & * & * & 0 & 0 & 0 \\ Q & * & * & 0 & 0 & 0 \end{pmatrix}. \tag{1.50}$$

Observing the local uniqueness condition when solving for $\mathbf{A}_{\mathbf{xx},i}$,[19] we are left with having to impose three short-run restrictions to complete just-identification of $\mathbf{A}_{\mathbf{xx},i}$. It appears reasonable to impose that (i) real industrial production does not contemporaneously respond to monetary policy indicator and short-term interest rate shocks, and that (ii) consumer

[19] See, for example, Luetkepohl (2007) for a discussion of the local uniqueness condition.

prices do not contemporaneously respond to short-term interest rate shocks:

$$\mathbf{A}_{\mathbf{xx},i} = \begin{pmatrix} & \varepsilon_y & \varepsilon_P & \varepsilon_{R^m} & \varepsilon_R & \varepsilon_Q \\ y & * & * & 0 & 0 & * \\ P & * & * & * & 0 & * \\ R^m & * & * & * & * & * \\ R & * & * & * & * & * \\ Q & * & * & * & * & * \end{pmatrix}. \tag{1.51}$$

Having identified the U.S. structural monetary policy shock, we can move to the global solution and the impulse response functions. Recalling the global solution given by Equation (1.38), we first stack it in companion form,

$$\mathbf{X}_t = \widetilde{\mathbf{a}}_0 + \widetilde{\mathbf{a}}_1 t + \widetilde{\mathbf{H}}\mathbf{X}_{t-1} + \mathbf{D}_t + \mathbf{U}_t, \tag{1.52}$$

where

$$\mathbf{X}_t = \begin{pmatrix} \mathbf{x}_t \\ \mathbf{x}_{t-1} \\ \mathbf{x}_{t-2} \\ \vdots \\ \mathbf{x}_{t-p+1} \end{pmatrix}, \ \widetilde{\mathbf{a}}_0 = \begin{pmatrix} \mathbf{G}^{-1}\mathbf{a}_0 \\ \mathbf{0}_{(N+1)m\times 1} \\ \mathbf{0}_{(N+1)m\times 1} \\ \vdots \\ \mathbf{0}_{(N+1)m\times 1} \end{pmatrix}, \ \widetilde{\mathbf{a}}_1 = \begin{pmatrix} \mathbf{G}^{-1}\mathbf{a}_1 \\ \mathbf{0}_{(N+1)m\times 1} \\ \mathbf{0}_{(N+1)m\times 1} \\ \vdots \\ \mathbf{0}_{(N+1)m\times 1} \end{pmatrix}, \tag{1.53}$$

$$\widetilde{\mathbf{H}} = \begin{pmatrix} \mathbf{G}^{-1}\mathbf{H}_1 & \mathbf{G}^{-1}\mathbf{H}_2 & \cdots & \mathbf{G}^{-1}\mathbf{H}_{p-1} & \mathbf{G}^{-1}\mathbf{H}_p \\ \mathbf{I}_{(N+1)m} & \mathbf{0}_{(N+1)m} & \cdots & \mathbf{0}_{(N+1)m} & \mathbf{0}_{(N+1)m} \\ \mathbf{0}_{(N+1)m} & \mathbf{I}_{(N+1)m} & \cdots & \mathbf{0}_{(N+1)m} & \mathbf{0}_{(N+1)m} \\ \vdots & \vdots & \ddots & & \vdots \\ \mathbf{0}_{(N+1)m} & \mathbf{0}_{(N+1)m} & \cdots & \mathbf{I}_{(N+1)m} & \mathbf{0}_{(N+1)m} \end{pmatrix} \tag{1.54}$$

$$, \mathbf{D}_t = \begin{pmatrix} \mathbf{G}^{-1}\sum_{s=0}^{r}\boldsymbol{\Upsilon}_s\mathbf{d}_{t-s} \\ \mathbf{0}_{(N+1)m\times 1} \\ \mathbf{0}_{(N+1)m\times 1} \\ \vdots \\ \mathbf{0}_{(N+1)m\times 1} \end{pmatrix}, \tag{1.55}$$

and

$$\mathbf{U}_t = \begin{pmatrix} \mathbf{G}^{-1}\mathbf{A}_0\boldsymbol{\varepsilon}_t \\ \mathbf{0}_{(N+1)m\times 1} \\ \mathbf{0}_{(N+1)m\times 1} \\ \vdots \\ \mathbf{0}_{(N+1)m\times 1} \end{pmatrix}, \tag{1.56}$$

where we take the shock vector $\boldsymbol{\varepsilon}_t$ to be composed of the U.S. structural shocks and reduced form shocks for all other countries:

$$\boldsymbol{\varepsilon}_t = \begin{pmatrix} \boldsymbol{\varepsilon}'_{USA,t}, & \mathbf{u}'_{1t}, & \mathbf{u}'_{2t}, & \ldots, & \mathbf{u}'_{Nt} \end{pmatrix}', \tag{1.57}$$

and

$$\mathbf{A}_0 = \begin{pmatrix} \mathbf{A}^{-1}_{\mathbf{xx},i} & \mathbf{0}_m & \mathbf{0}_m & \cdots & \mathbf{0}_m \\ \mathbf{0}_m & \mathbf{I}_m & \mathbf{0}_m & \cdots & \mathbf{0}_m \\ \mathbf{0}_m & \mathbf{0}_m & \mathbf{I}_m & \ddots & \mathbf{0}_m \\ \vdots & \vdots & \vdots & & \vdots \\ \mathbf{0}_m & \mathbf{0}_m & \mathbf{0}_m & \cdots & \mathbf{I}_m \end{pmatrix}. \tag{1.58}$$

We should note that identifying the complete set of structural shocks across all countries would result in us having to impose more than 2,000 parameter restrictions on the global solution. We therefore choose to restrict structural identification to the U.S. component of the GVECM, including in particular the U.S. monetary policy shock. Doing so, we actually can also allow for the U.S. structural monetary policy shock to be correlated with any of the reduced form shocks in any of the other countries, and do not need to impose zero contemporaneous impact restrictions for any of the U.S. structural shocks on other countries' variables. On this count, we let the data speak freely.[20] The $s$-period ahead global impulse response for a U.S. structural monetary policy shock can now be computed as

$$IR\left(\mathbf{X}_{t+s}\right) = \widetilde{\mathbf{H}}^s E\left(\mathbf{U}_t \,\middle|\, \varepsilon_{R^m_{USA,t}} = \kappa\right), \tag{1.59}$$

[20] In Section 7, we will nevertheless also document the robustness of our main empirical findings to imposing orthogonality on the monetary policy shocks across all countries.

where

$$E(\mathbf{U}_t \Big| \varepsilon_{R^m_{USA,t}} = \kappa) = \begin{pmatrix} \mathbf{G}^{-1}\mathbf{A}_0 \frac{Var(\boldsymbol{\varepsilon}_t)\ \mathbf{e}_i}{Var(\varepsilon_{R^m_{US},t})}\kappa \\ \mathbf{0}_{(N+1)m\times 1} \\ \mathbf{0}_{(N+1)m\times 1} \\ \vdots \\ \mathbf{0}_{(N+1)m\times 1} \end{pmatrix}, \tag{1.60}$$

with $\mathbf{e}_i$ being the selection vector detailing the location of the U.S. monetary policy shock in the vector $\boldsymbol{\varepsilon}_t$.

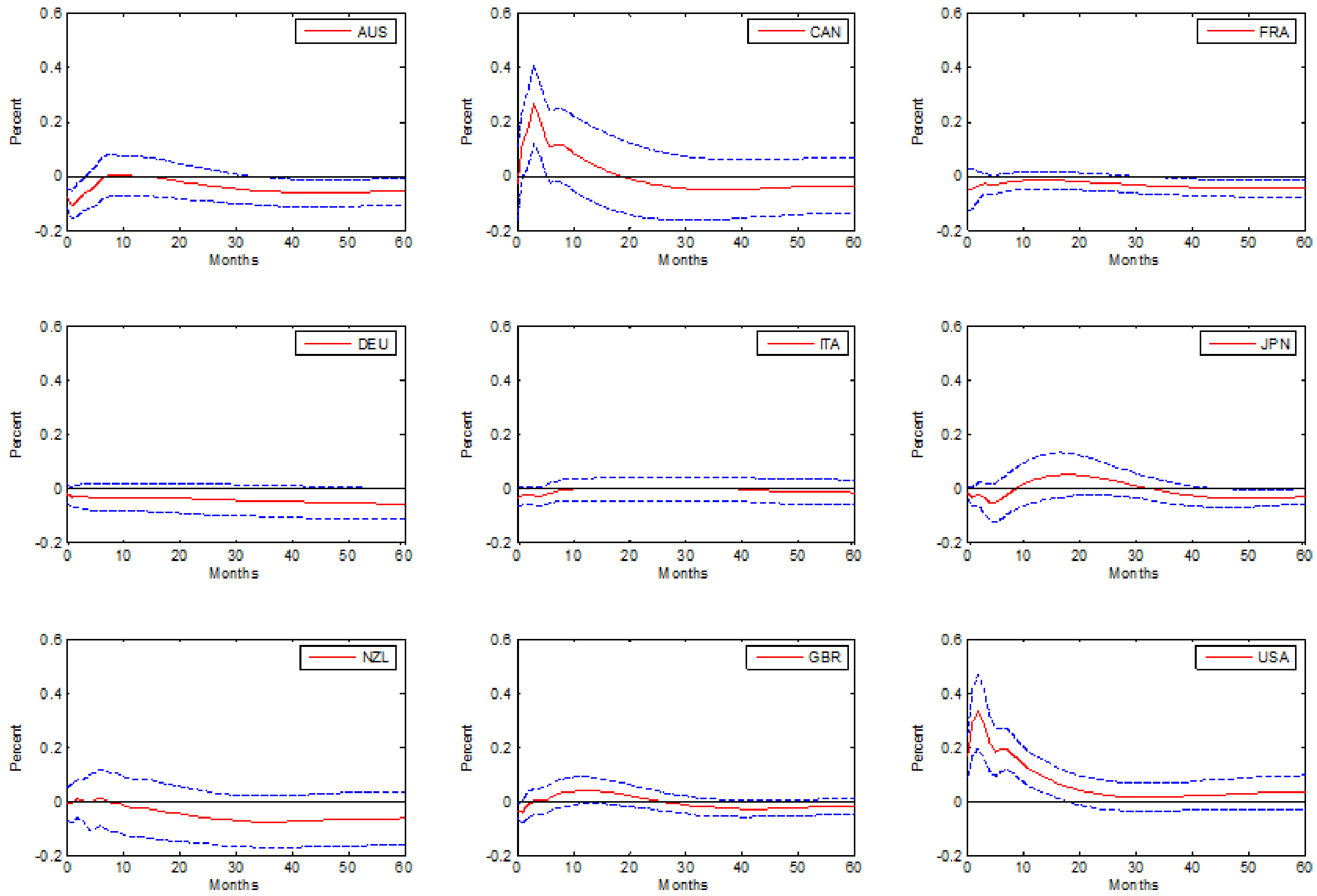
## 1.6 Empirical Results

We consider the effects of a contractionary U.S. monetary policy shock, defined in this Section as a one-standard deviation positive innovation of the federal funds rate, and identified as discussed in Section 1.5. All results in this Section are based on allowing for three cointegrating relations among the domestic and foreign variables for the United States block of the GVECM, as is empirically supported by unit root and cointegration rank tests.[21]

A one-standard deviation positive shock to the federal funds rate represents an almost immediate increase of the federal funds rate of about 30 basis points, before the federal funds rate falls gradually back to its steady state level within about two years (see Figure 1.3). The other countries' monetary policy indicators do barely respond to the U.S. shock, except for Canada, which features a positive increase in the overnight rate for the first 18 months. This is in contrast to previous empirical studies using bilateral settings, which have found positive and significant responses for foreign countries' monetary policy indicators in response to U.S. monetary policy shocks.

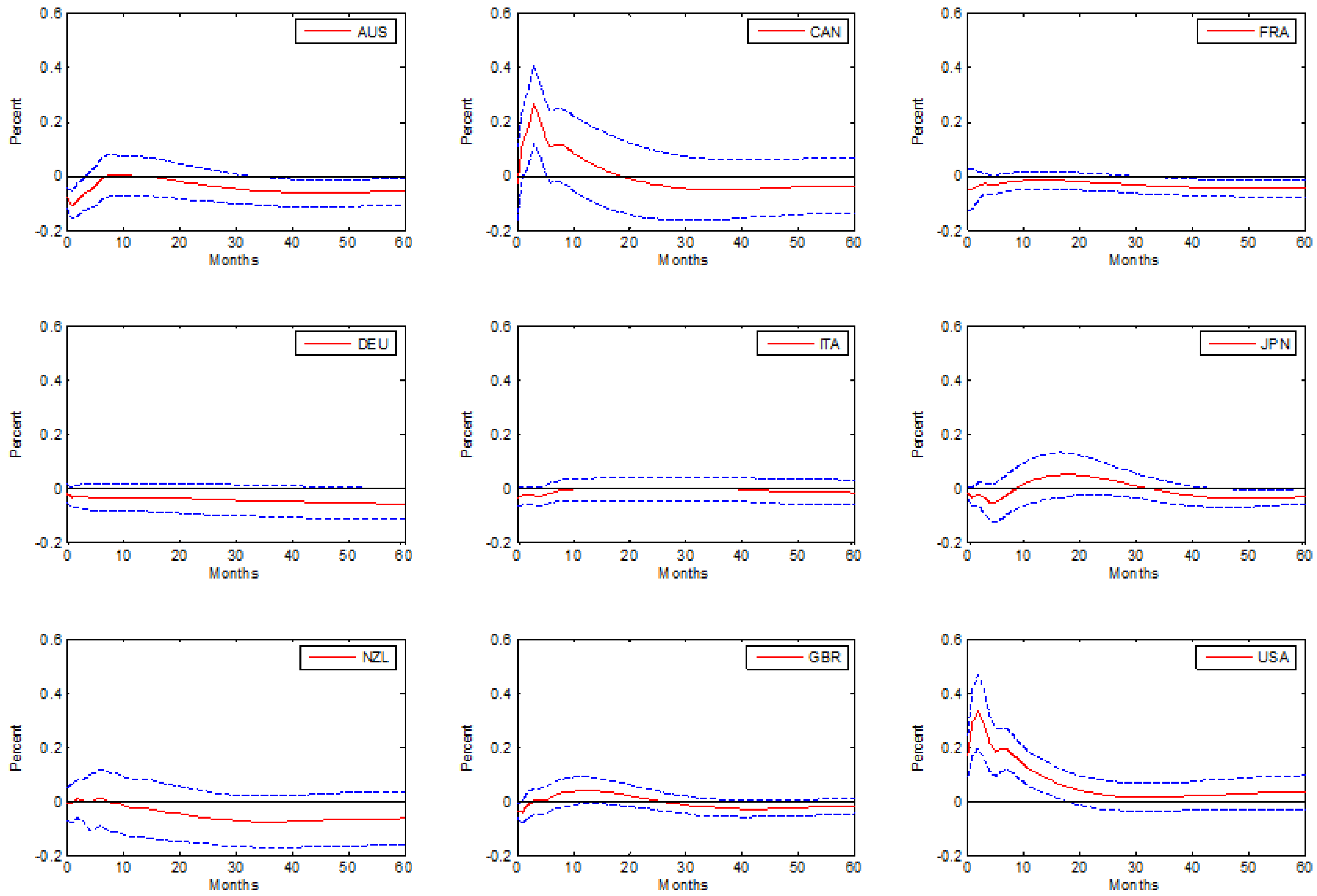
[21] The unit root and cointegration test results (as well as test results for weak exogeneity) are documented in an appendix available from the authors upon request.

**Figure 1.3:** Impulse Response Functions for Monetary Policy Indicator in Response to One-Standard Error U.S. Monetary Policy Shock



The effects for a consistent cross-country measure of short-term interest rates, three-month bond returns, are by and large similar to those for the monetary policy indicator, with the exception of Canada: The response of Canadian short-term interest rates to a U.S. monetary policy shock is insignificant. Therefore, the U.S. monetary policy shock for the majority of countries in our panel leads to a significant and relatively persistent increase in the spread between U.S. and foreign interest rates. (Figure 1.4.)

**Figure 1.4:** Impulse Response Functions for Short-Term Interest Rate Differential in Response to One-Standard Deviation U.S. Monetary Policy Shock



Turning to the nominal and real effective exchange rates, we find that the contractionary U.S. monetary policy shock leads to immediate overshooting of the U.S. Dollar nominal and real effective exchange rates (Figures 1.5,1.6 and 1.7,1.8). Namely, the peak of the exchange rate appreciation occurs in the second month after the federal funds rate shock, before the U.S. Dollar gradually depreciates back to its long-run PPP level within about two and half years. This is in line with standard overshooting theory and in contrast to most of the previous empirical findings. There is no delayed overshooting puzzle for the U.S. Dollar effective exchange rate after a domestic contractionary monetary policy shock. The appreciation at the peak is about 0.9 percent for both the nominal and real U.S. Dollar effective exchange rates. The majority of the other countries' nominal effective exchange rates respond to the contractionary U.S. monetary policy shock with a small, often insignificant depreciation (the depreciation is statistically significant for the Canadian Dollar for about six months, the Japanese Yen for about 18 months, and for the Pound Sterling for about three months. The real effective exchange rates behave very similar to the nominal ones.

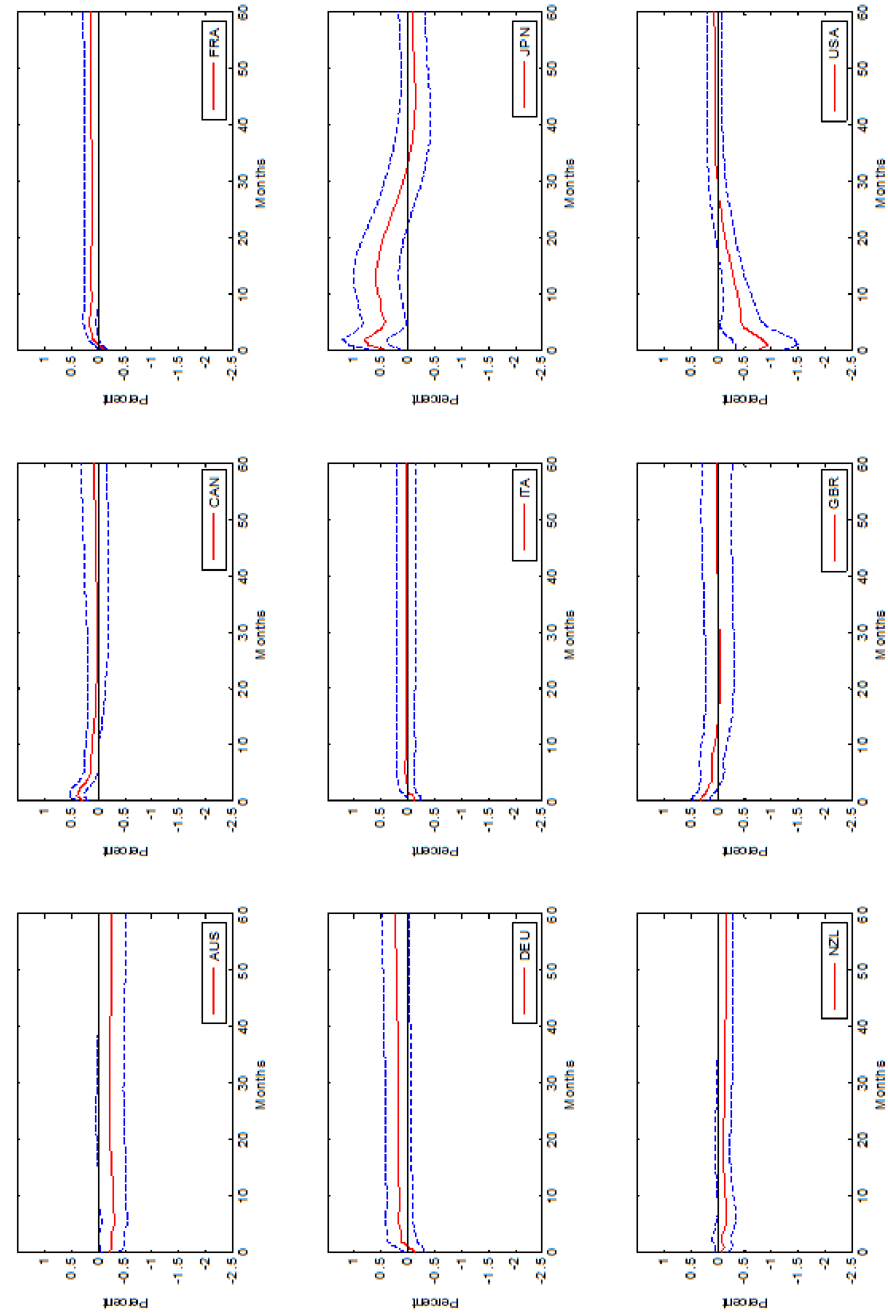



**Figure 1.5:** Impulse Response Functions for Nominal Effective Exchange Rates in Response to One-Standard Deviation U.S. Monetary Policy Shock

**Figure 1.6:** Impulse Response Function for U.S. Dollar Nominal Effective Exchange Rate in Response to One-Standard Deviation U.S. Monetary Policy Shock

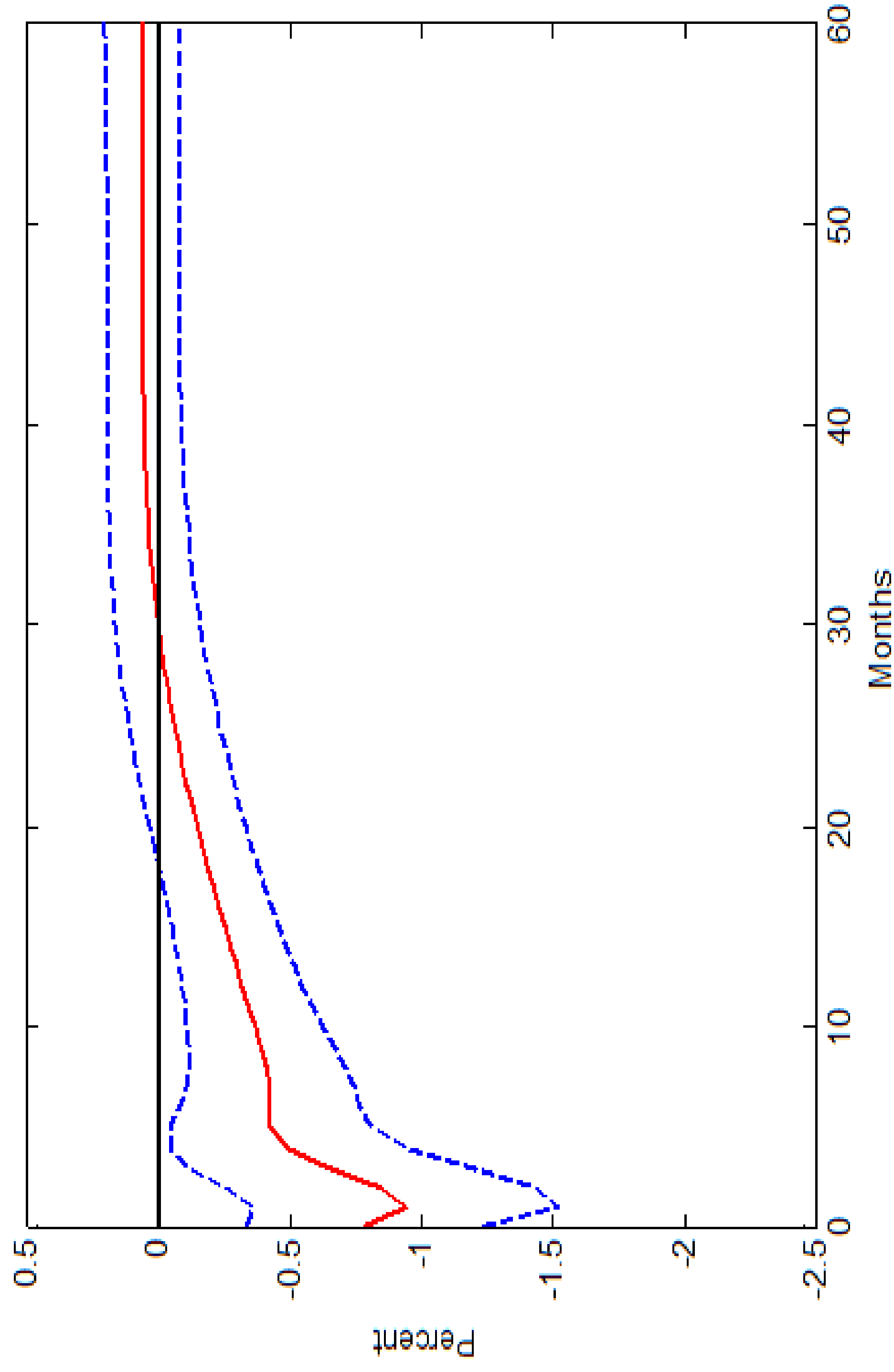


**Figure 1.7:** Impulse Response Functions for Real Effective Exchange Rates in Response to One-Standard Deviation U.S. Monetary Policy Shock

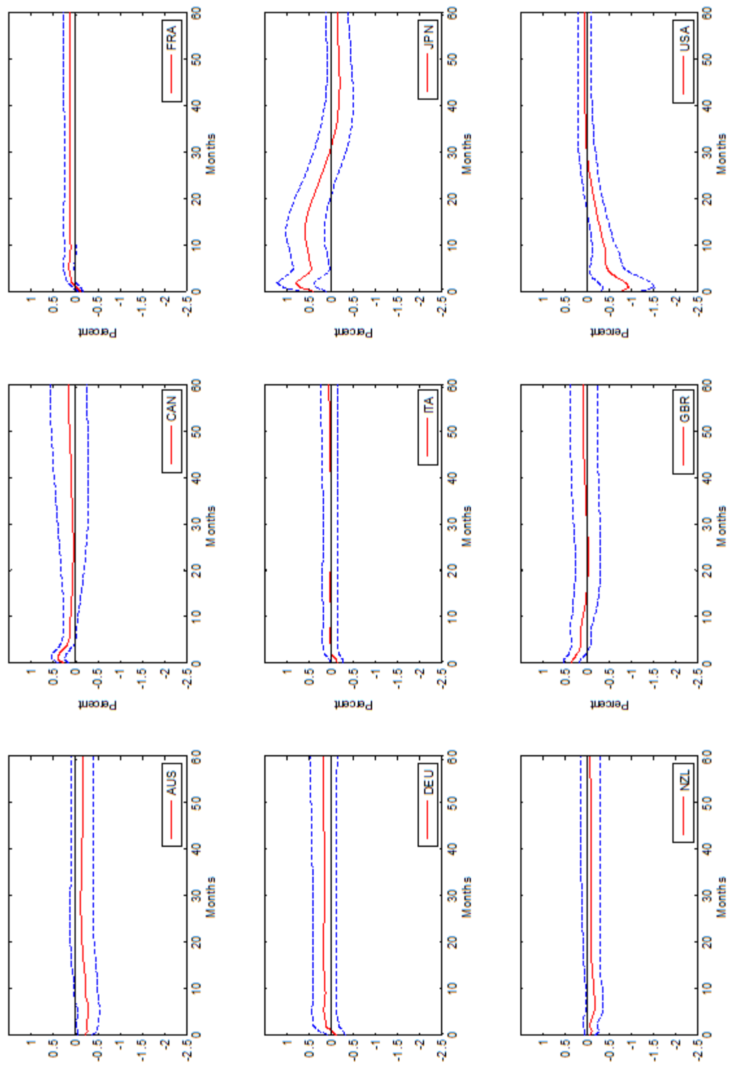
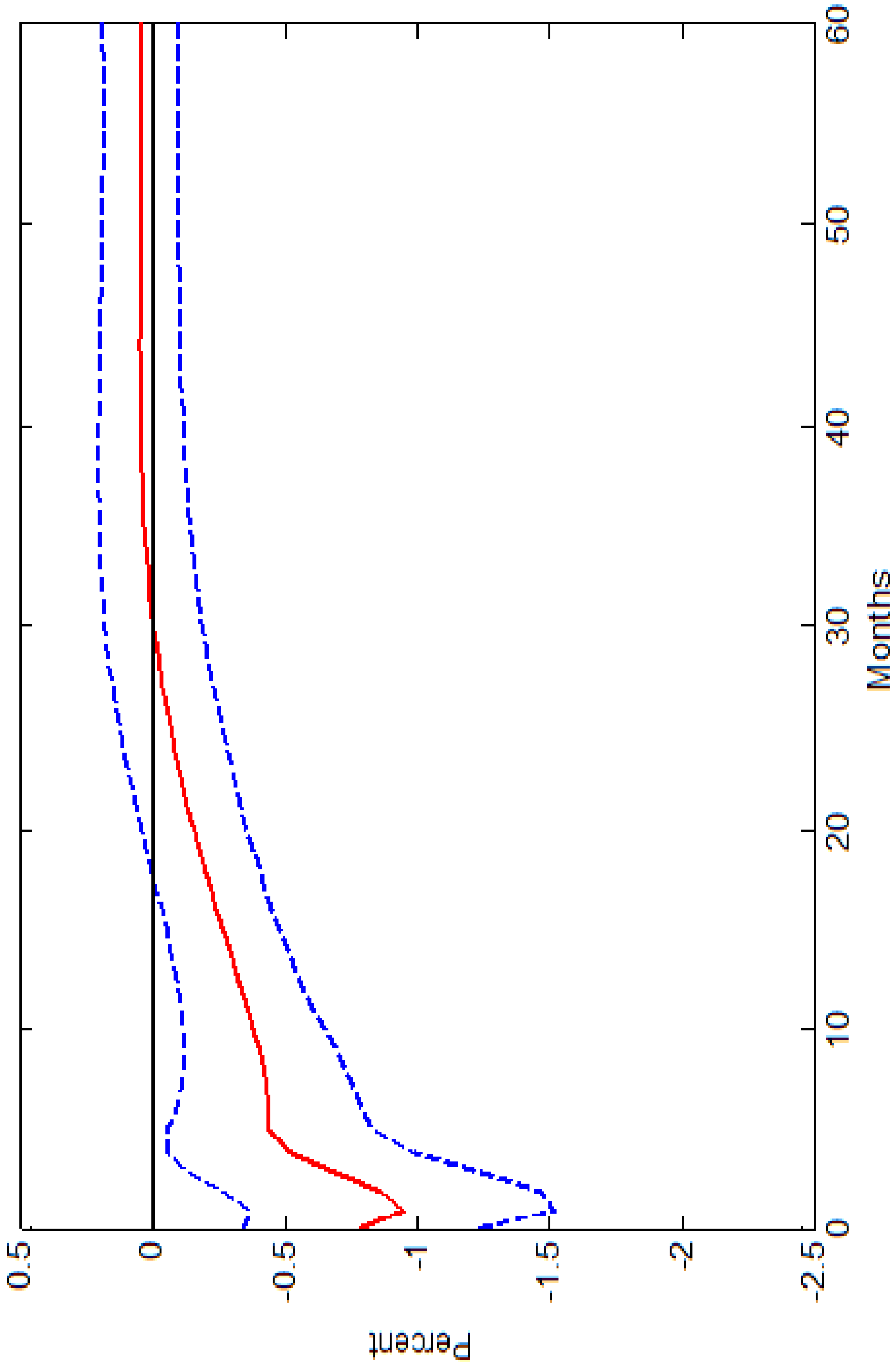


**Figure 1.8:** Impulse Response Function for U.S. Dollar Real Effective Exchange Rate in Response to One-Standard Deviation U.S. Monetary Policy Shock



With regards to the forward premium's response to a contractionary U.S. monetary policy shock, Figure 1.9 provides these impulse responses. For the U.S. forward premium, except for the first two months, we do not observe a significant *conditional* short-run deviation from uncovered interest parity. Our finding that there is no significant *conditional* deviation from uncovered interest parity again is in contrast to most of the previous empirical work. For the other countries in our panel, these do not feature persistently significant short-run forward premia either. Only for the first three to six months there are small but significant forward premia (of the opposite sign as for the United States) for France, Germany, Italy, and Japan.

**Figure 1.9:** Impulse Response Functions for Effective Forward Premia in Response to One-Standard Deviation U.S. Monetary Policy Shock

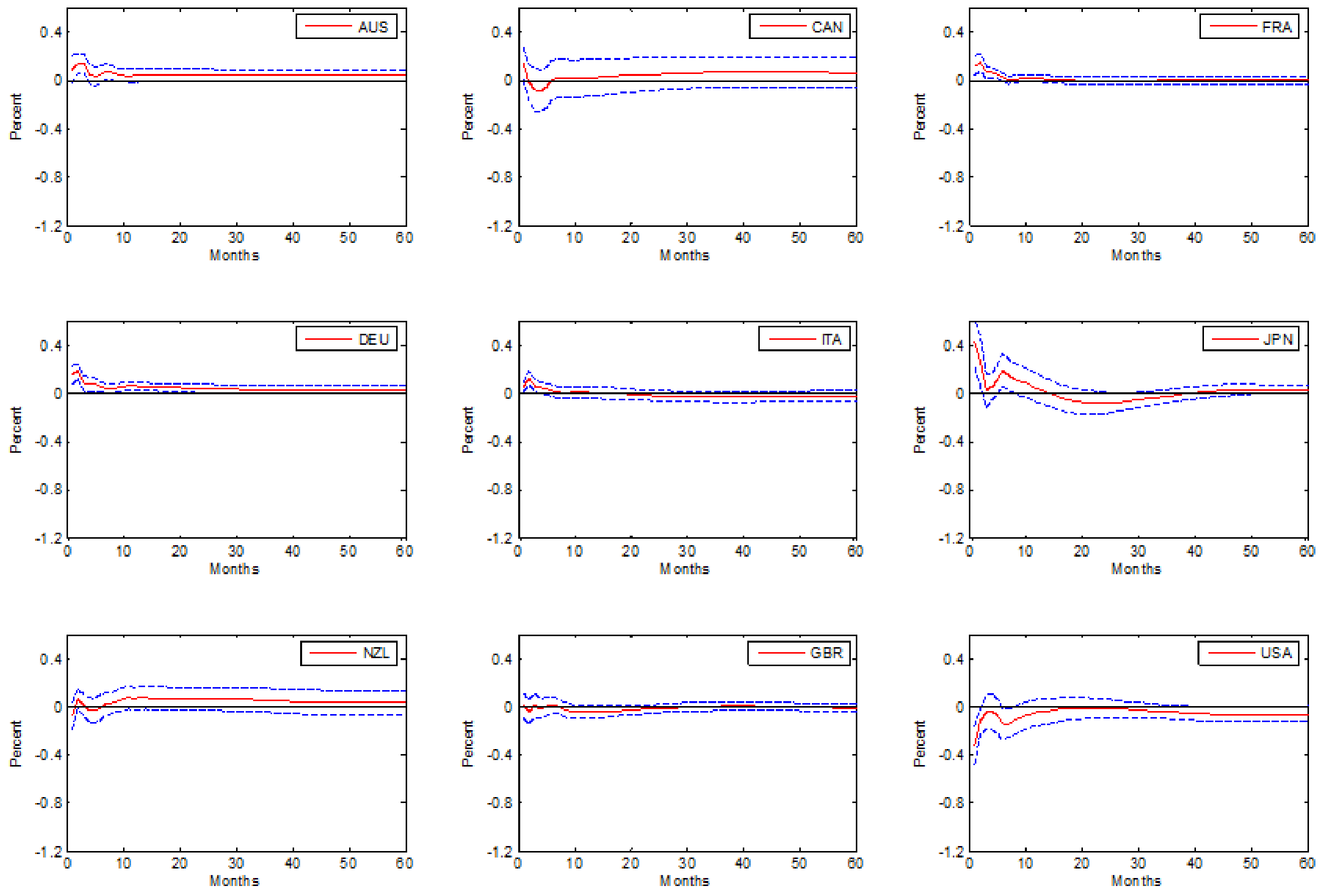


**Figure 1.10:** Impulse Response Function for U.S. Effective Forward Premium in Response to One-Standard Deviation U.S. Monetary Policy Shock

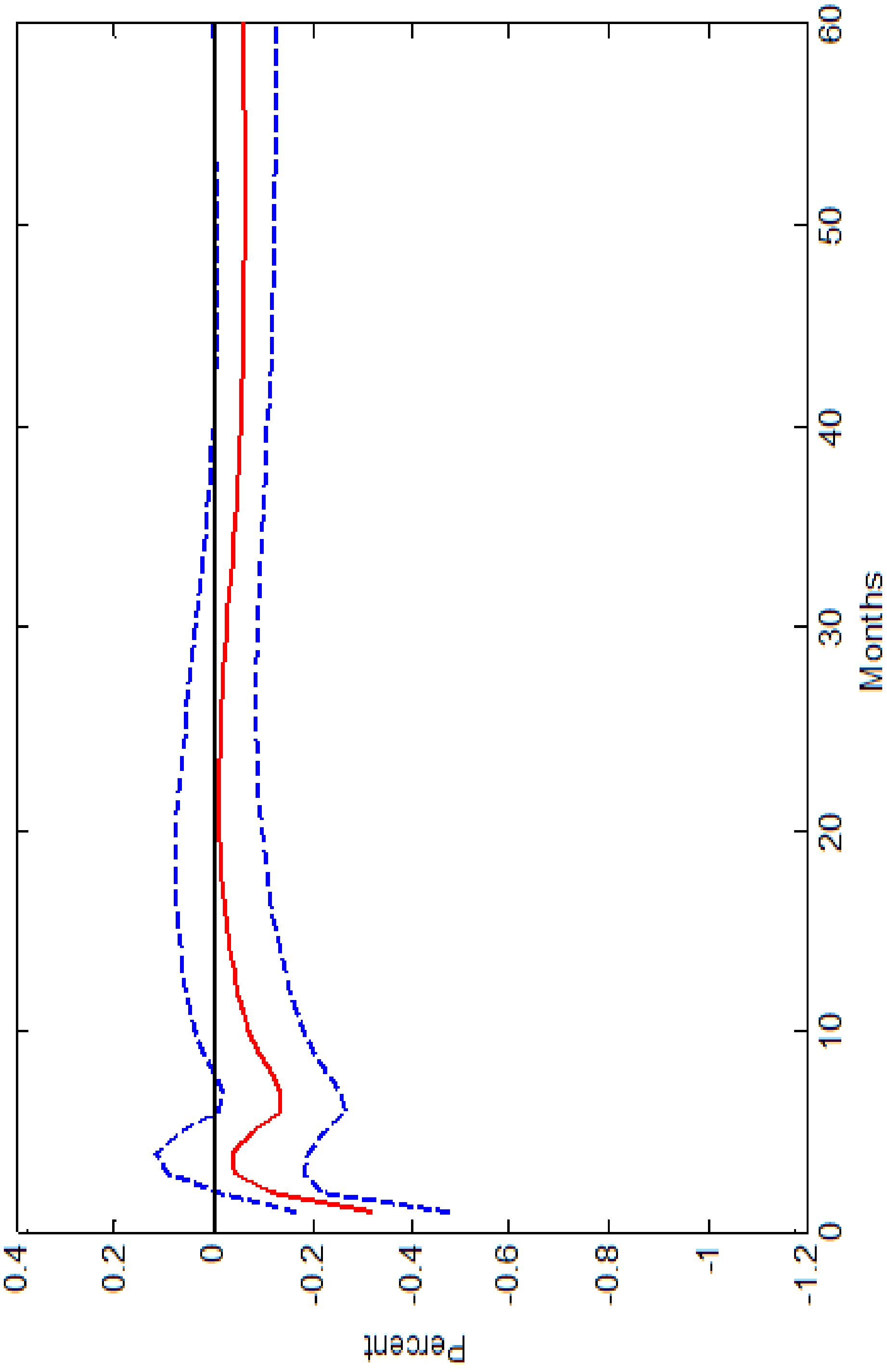


Figure 1.11 graphs the impulse responses for the consumer price indices. After a contractionary U.S. monetary policy shock, the consumer price index in the U.S. responds with an increase of about 0.025 percent, which is followed by a gradual fall, until it reaches the long-run response of about $-0.1$ percent. Only the long-run response is significant. For the other countries, we do not find significant short-run increases of the consumer price indices, though over longer horizons the impulse responses for these price indices fall as well, typically by rather small magnitudes.

**Figure 1.11:** Impulse Response Functions for Prices in Response to One-Standard Deviation U.S. Monetary Policy Shock

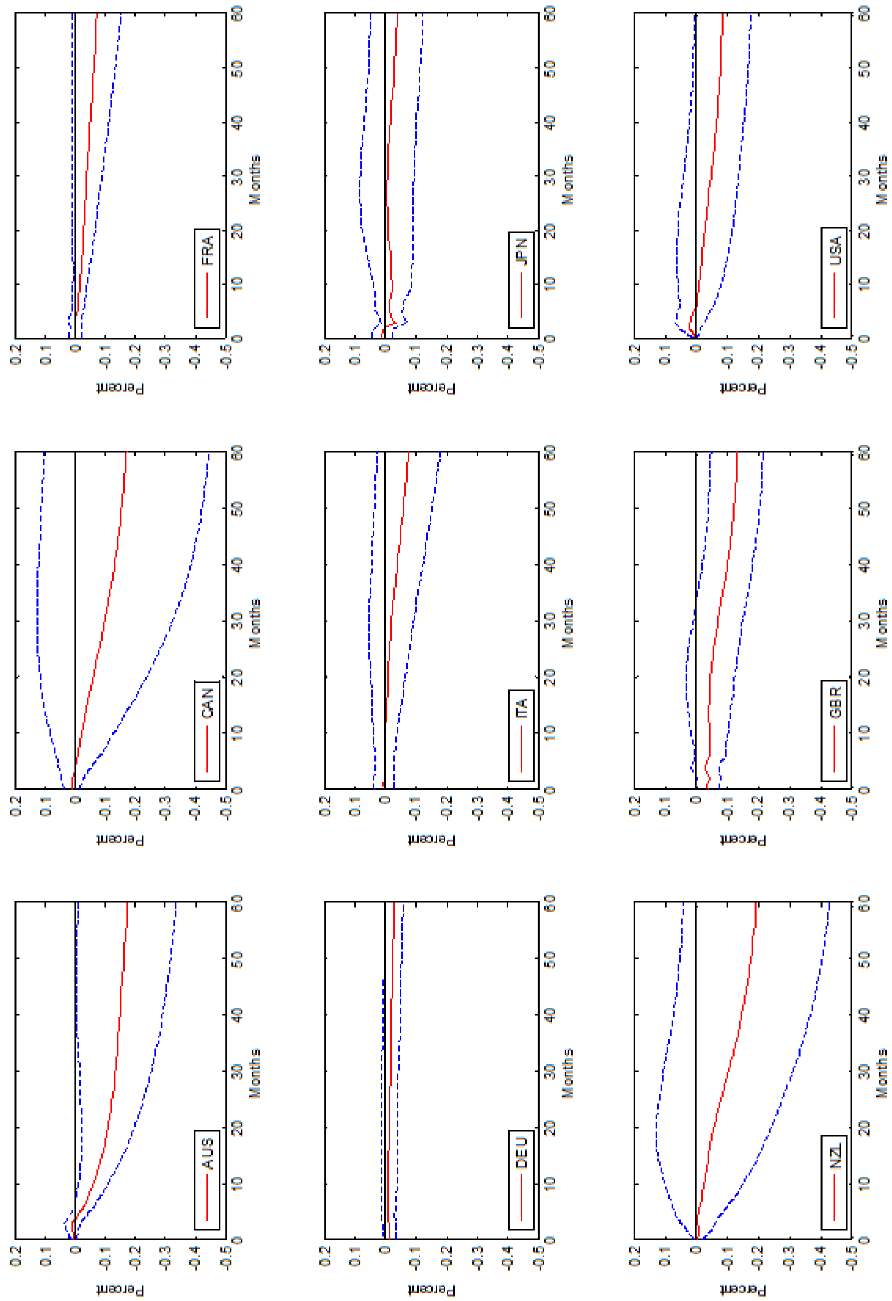
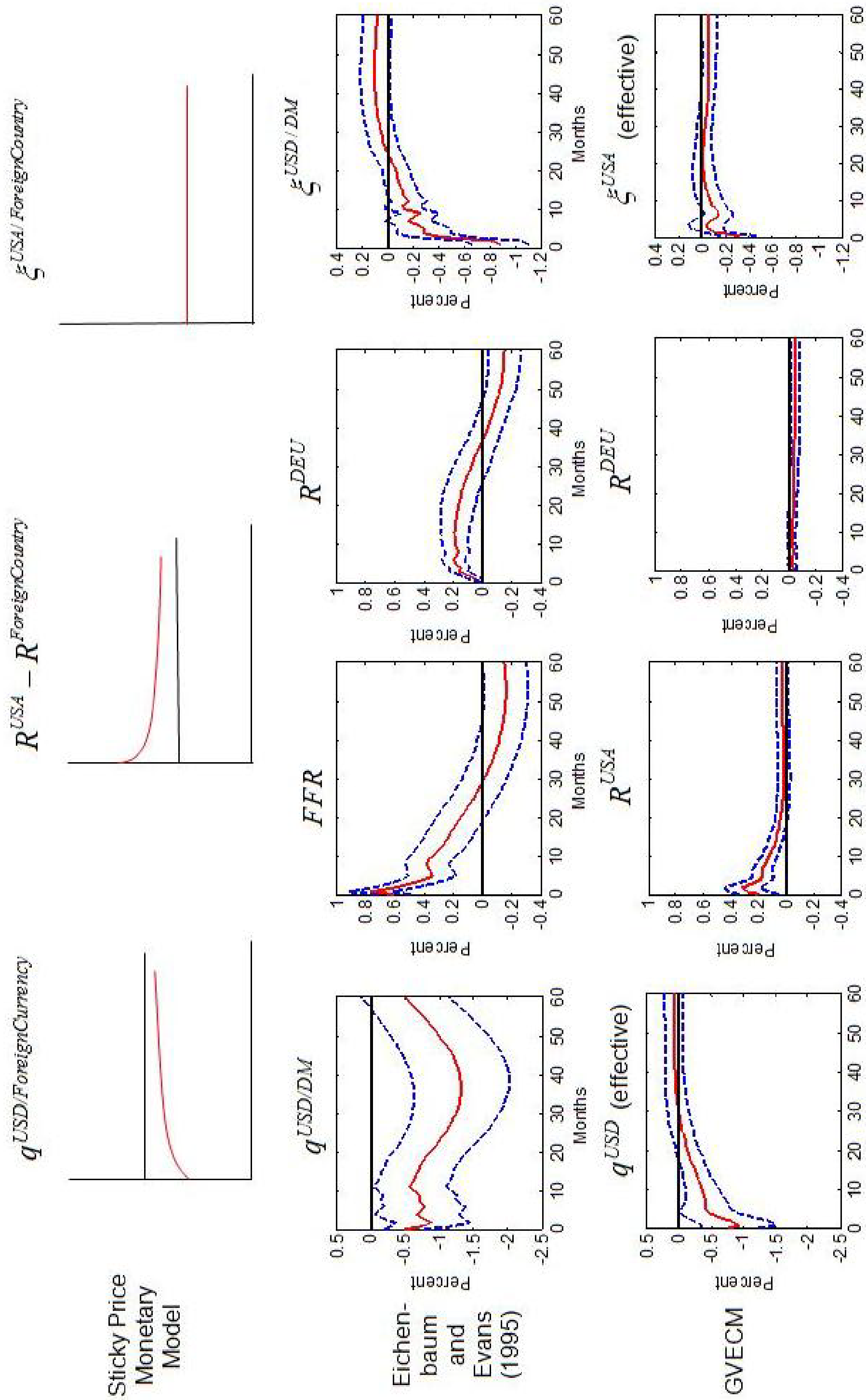


Figure 1.12 summarizes the main findings conveyed by the impulse responses presented so far: For our GVECM, unlike the Eichenbaum and Evans (1995) results as an example of the typical previous empirical findings, there is no delayed exchange rate overshooting puzzle (but rather an almost immediate peak appreciation in response to a U.S. contractionary monetary policy shock that is in line with sticky price macroeconomic models), and there is (except for the first two months after the shock) no significant *conditional* deviation from uncovered interest parity, again consistent with sticky price macroeconomic models.

**Figure 1.12:** Comparison of Some Key Results



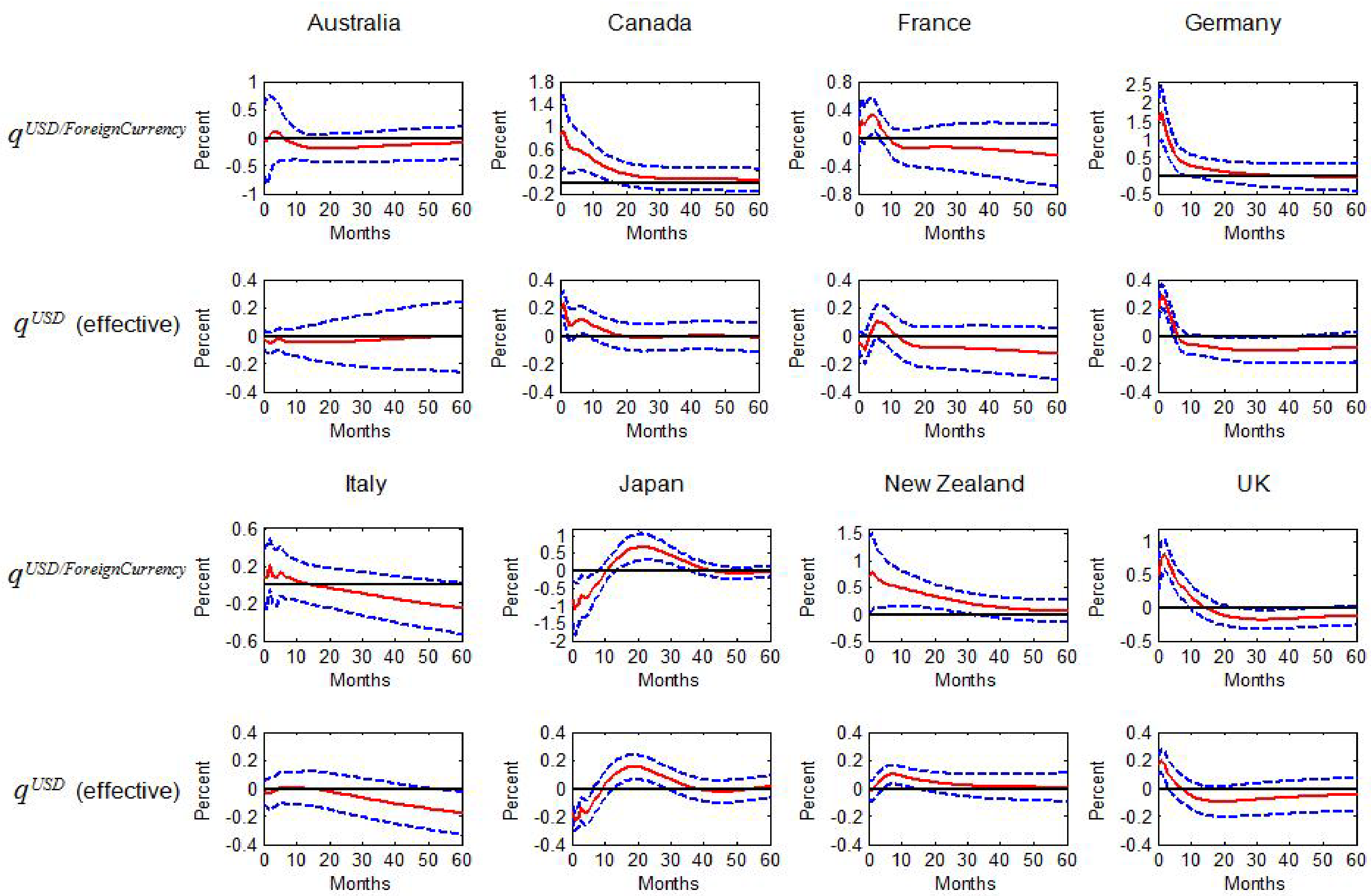
It is important to note that our findings of exchange rate and forward premium adjustment paths consistent with *conditional* uncovered interest parity and a long-run return to purchasing power parity equilibrium in response to a contractionary U.S. monetary policy shock are not implied by findings in favor of uncovered interest parity and/or purchasing power parity as *unconditional* long-run relationships. Table 1 provides the three U.S. cointegration relations. Table 2 provides tests for uncovered interest parity and purchasing power parity as long-run relationships within our GVECM. Note that the joint validity of the uncovered interest parity and purchasing power parity hypotheses is rejected for all nine countries in our sample, and that uncovered interest parity and purchasing power parity individually also are rejected for almost all countries. It is therefore critical to distinguish between different sources of shocks, a finding that again is consistent with the predictions of the new open economy macroeconomics literature, for example Bergin (2006).

While for space reasons we do not document so in elaborate detail, these results are robust to considerations such as modification of our lag length selection criteria (our default results are based on Schwarz Bayesian Criterion based lag orders) as well as the addition of dummy variables to account for the monetary policy change for some of the European countries in 1999, and to account for German re-unification in 1990. The results are furthermore robust to using a broader commodity price index (rather than spot oil prices) as a common factor in the GVECM.

Finally, as can be seen from Figure 1.13, the GVAR/GVECM based results indicate that in response to a contractionary monetary policy shock in the countries other than the United States,[22] in virtually all cases either the bilateral and effective real U.S. Dollar exchange rates either depreciate significantly for a period of between three and 18 months (Canada, Germany, New Zealand, and the United Kingdom), or exhibit no significant reaction.

[22] A note describing our identification procedure for monetary policy shocks in countries for which the number of cointegrating relations is, unlike for the U.S., not equal to three, is available from the authors upon request.

**Figure 1.13:** Impulse Response Function for U.S. Dollar Real Effective and Bilateral Exchange Rates in Response to One-Standard Deviation Foreign Monetary Policy Shocks



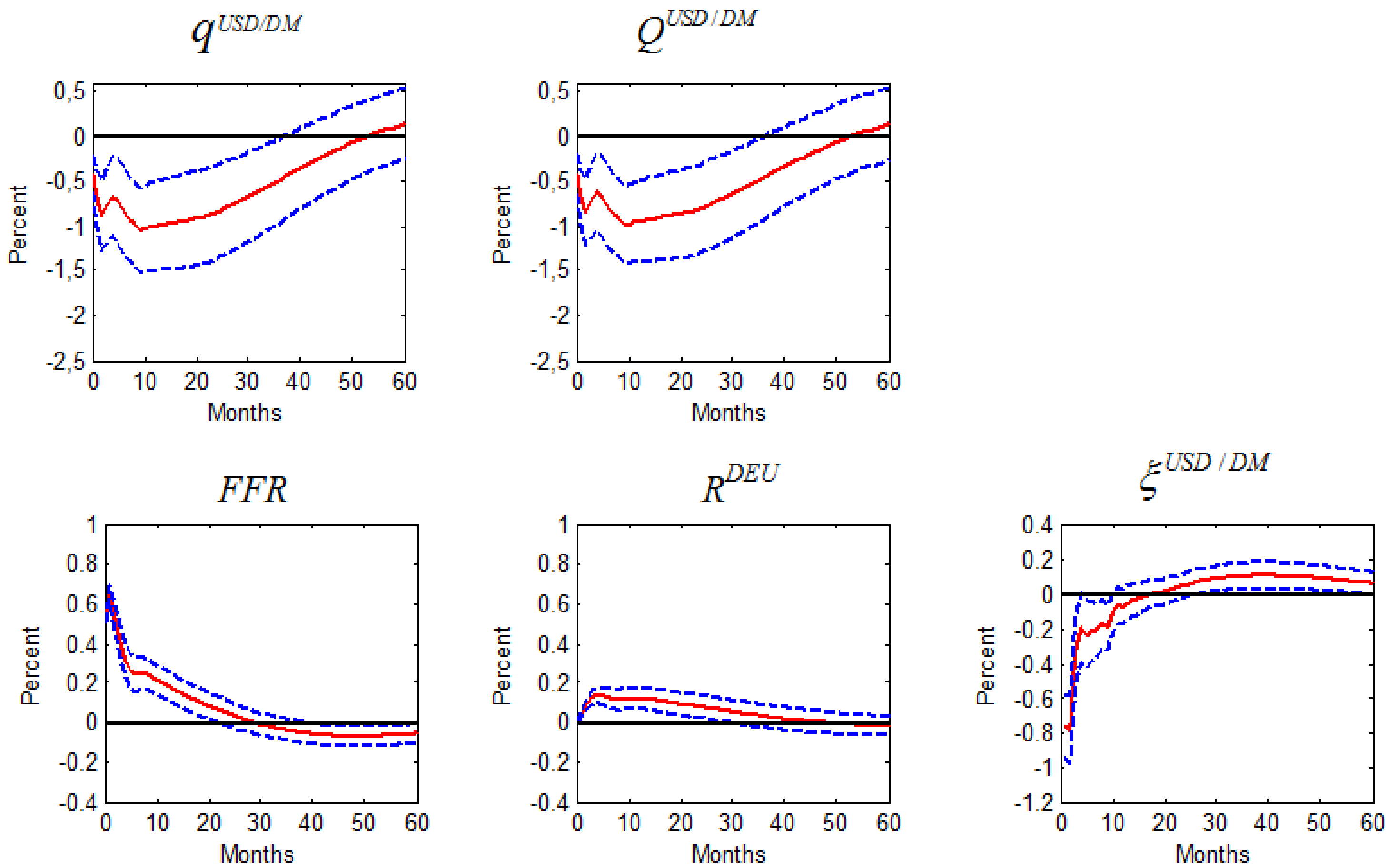
## 1.7 Model Comparisons and Counterfactual Analysis

Clearly, the Eichenbaum and Evans (1995) specification and our GVECM specification differ beyond considering bilateral (two-country) versus multilateral (multi-country) settings in several other aspects also:
(i) data sets: relative to Eichenbaum and Evans (1995), we have an extended data set available;
(ii) variable specification: our GVECM includes a larger number of foreign variables than accounted for by Eichenbaum and Evans (1995);
(iii) cointegrating relations: Eichenbaum and Evans (1995) use a level VAR, while our GVECM imposes restrictions implied by empirically supported cointegrating relations;
(iv) monetary policy shock identification: our GVECM exploits a combination of long- and short-run restrictions for identification purposes, whereas Eichenbaum and Evans (1995) identify monetary policy shocks based on short-run restrictions imposing a recursive ordering of the model variables (the Cholesky decomposition).

Therefore, in order to explore the reasons underlying the remarkable differences between our empirical findings of Section 6 and those of Eichenbaum and Evans (1995), we conduct a step-by-step "counterfactual analysis".

In the first step of this counterfactual analysis, we use our sample from January 1978 to December 2006 to replicate Eichenbaum and Evans (1995), namely, we estimate a bilateral VAR for the U.S. versus Germany, containing seven variables, $\begin{pmatrix} y_t & P_t & y_t^* & R_t^* & FFR_t & nbrx_t & q_t \end{pmatrix}$, where $y_t$ denotes U.S. real industrial production, $P_t$ the U.S. consumer price index, $y_t^*$ German real industrial production, $R_t^*$ German short-term interest rates, $FFR_t$ the federal funds rate as the U.S. monetary policy indicator, $nbrx_t$ the ratio between U.S. non-borrowed reserves and U.S. total reserves, and $q_t$ the bilateral real exchange rate between the U.S. Dollar and the Deutsche Mark. The lag order is chosen to be six in order to be consistent with Eichenbaum and Evans (1995). The U.S. monetary policy shock is identified using the Cholesky decomposition of the variables (ordered as above), which implies that the Federal Reserve sets the federal funds rate taking into account the lagged values of all variables as well as the current value of U.S. industrial production, the U.S. consumer prices, German industrial production, and German short-term interest rates. To facilitate comparison with Eichenbaum and Evans (1995), the U.S. monetary policy shock throughout our counterfactual analysis in this Section is set to 50 basis points, rather than to one standard deviation, as it was for Figures 1.3 to 1.11, Figure 1.12 (iii) and Figure 1.13. Figure 1.14 shows that when incorporating more recent data than Eichenbaum and Evans (1995) could, the peak of the real U.S. Dollar/Deutsche Mark exchange rate impulse response occurs about 10 months after the shock, and thus the delay of overshooting is shorter than found by Eichenbaum and Evans (1995). The federal funds rate and German short-term interest rates behave similarly as in Eichenbaum and Evans (1995), and a significant instantaneous deviation of about 0.8 percent from uncovered interest parity is observed, with significance of this conditional uncovered interest parity deviation holding for up to nine months. Overall, therefore, while the results in the extended sample suggest a less pronounced delayed exchange rate overshooting puzzle than in the original Eichenbaum and Evans (1995) sample, both the delayed exchange rate overshooting puzzle and the forward premium puzzle are not addressed by updating of the Eichenbaum and Evans (1995) sample.

**Figure 1.14:** Comparison of Results through "Counterfactual Analysis" Step 1: Eichenbaum and Evans (1995) Specification for Extended Data Set

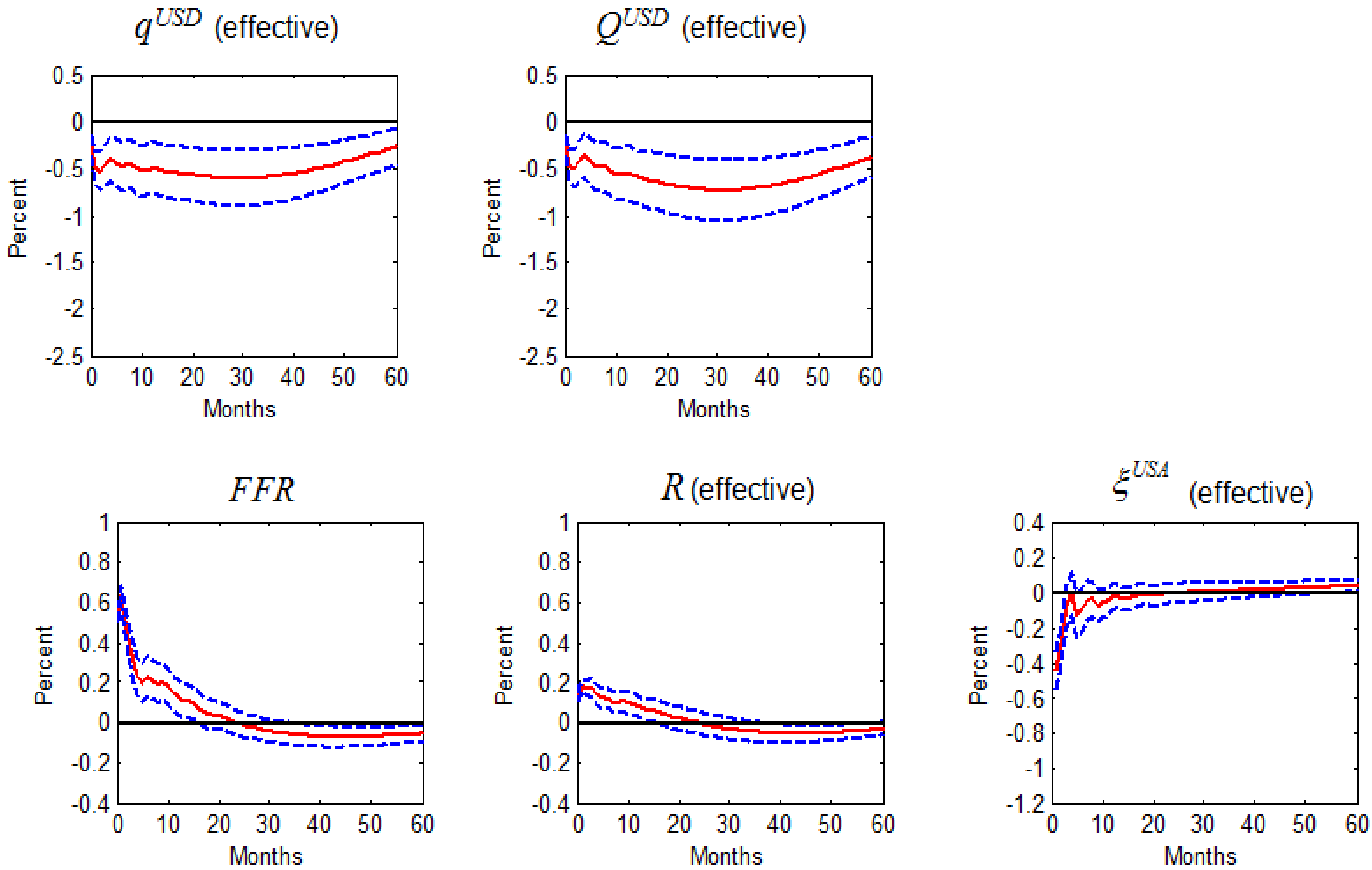


Our next step is to investigate how the key empirical results would change if rather than using German variables we used weighted foreign variables for the U.S. (as well as the full sample of data), within the VAR framework of Eichenbaum and Evans (1995). Therefore, we adapt the Eichenbaum and Evans (1995) VAR specification to contain the same domestic and foreign variables as we use in the U.S. portion of our GVAR: We consider a VAR with the endogenous variables vector

$$\begin{pmatrix} y_t & P_t & y_t^* & P_t^* & FFR_t & R_t & R_t^* & Q_t^* \end{pmatrix}. \tag{1.61}$$

(Note that the starred variables now again denote the weighted sums of the corresponding U.S. variables across all eight countries in our panel foreign to the U.S., instead of referring to one specific foreign country (Germany in the previous step of our counterfactual analysis).) Compared to Eichenbaum and Evans (1995), we add the foreign consumer price index and the U.S. short-term interest rate $R_t$, replace the real bilateral U.S. Dollar versus Deutsche Mark exchange rate with the nominal effective U.S. Dollar exchange rate ($Q_t^*$ rather than $q_t$), and drop the ratio between U.S. non-borrowed reserves and U.S. total reserves, $nbrx_t$. We continue to keep the Cholesky decomposition based identification scheme of Eichenbaum and Evans (1995), with the variable ordering as noted in Equation (1.61)). While this is not a truly multilateral specification yet, it captures a larger number of foreign variables than the original Eichenbaum and Evans (1995) specification, and may address issues of potentially peculiar results for specific country pairs. Figure 1.15 provides the impulse responses. The nominal and real effective U.S. Dollar exchange rates still display delayed overshooting, with the peak of the appreciation of the U.S. Dollar occurring approximately 24 to 30 months after the federal funds rate shock. The forward premium exhibits an approximately 0.4 percent deviation from uncovered interest parity right after the U.S. monetary policy shock, before the forward premium returns to zero within about 12 months. Augmenting the bilateral VAR of Eichenbaum and Evans (1995) to capture all variables entering the United States component of our GVECM thus still resolves neither the delayed exchange rate overshooting puzzle nor the forward premium puzzle.

**Figure 1.15:** Comparison of Results through "Counterfactual Analysis" Step 2: Augmenting Eichenbaum and Evans (1995) Specification to Capture this Paper's Specification of Domestic and Foreign Variables



The third step of our counterfactual analysis is to move from the VAR setting to the truly multilateral GVAR setting, specifying separate models for all nine countries in our panel. For each country we consider the five domestic variables ($y_{it}$ $P_{it}$ $R^m_{it}$ $R_{it}$ $Q_{it}$), and the four weighted foreign variables ($y^*_{it}$ $P^*_{it}$ $R^*_{it}$ $Q^*_{it}$). The U.S. monetary policy shock is identified in the United States portion of the GVAR using a Wold ordering, and is then incorporated into the global solution. In this analysis, only the order of the domestic variables matters, and we order these as $y_{it}$, $P_{it}$, $R^m_{it}$, $R_{it}$, and $Q_{it}$. A major difference in empirical results that we obtain for the Cholesky decomposition-based GVAR as compared to the models considered in the first two steps of our counterfactual analysis is that after a U.S. monetary policy shock, the German short-term interest rate displays no significant response (see Figure 1.16). The non-GVAR setting appears to overstate the response of German interest rates to U.S. monetary policy shocks. In addition, the federal funds rate falls back to its original levels within 14 months, a shorter adjustment phase than in the bilateral models. The peak responses of the U.S. Dollar nominal and real effective exchange rates occur in the second month after the U.S. monetary policy shock, but except for the first two months these responses are insignificant, and for all months of very small magnitude. The contemporaneous effective forward premium's response is about $-0.3$ percent, the deviations from uncovered interest parity now being smaller and less persistent than for the bilateral models, with significant responses occurring only for the first four or so months. Figure 1.17 reports results for the impulse responses implied by this set-up for bilateral U.S. Dollar versus Deutsche Mark nominal and real exchange rates, as well as bilateral forward premia between the United States and Germany. The peak of the overshooting for the bilateral rates occurs with a significant delay of about 12 months only. The forward premium is significant in favor of U.S. bonds for about nine months. Overall, therefore, working with a multilateral GVAR model without considering long-run cointegration based monetary policy shock identification, there still is evidence for the delayed exchange rate overshooting and forward premium puzzles. The lack of significance of the U.S. Dollar nominal and real effective exchange rate impulse responses cast, however, doubt on the set-up of a GVAR with the U.S. monetary policy shock being identified on the basis of a Cholesky decomposition.

**Figure 1.16:** Comparison of Results through "Counterfactual Analysis" Step 3: Considering a GVAR Specification (Same Variables as in GVECM, Cholesky Decomposition Based Shock Identification) – Effective Exchange Rates and Forward Premium

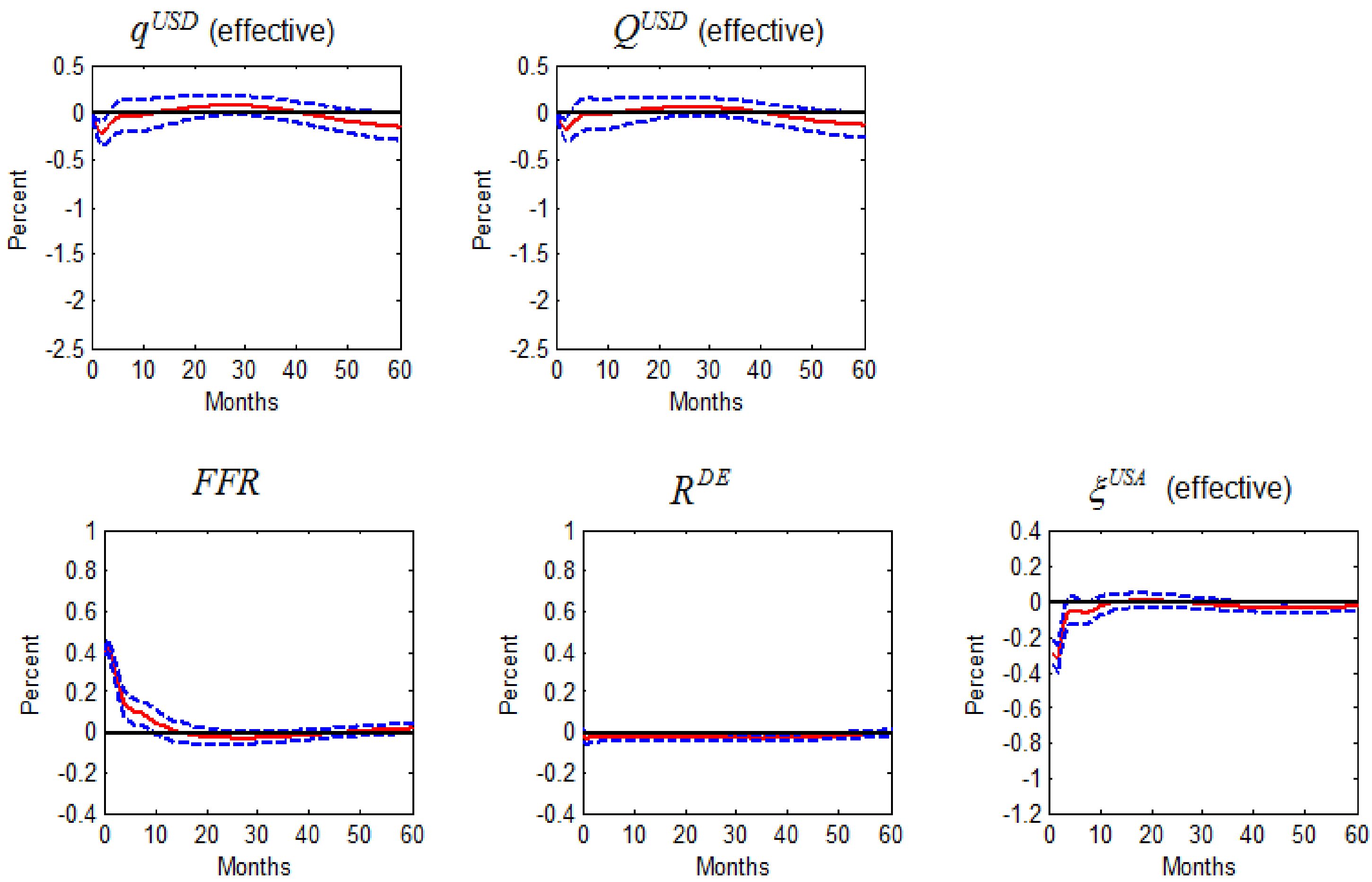
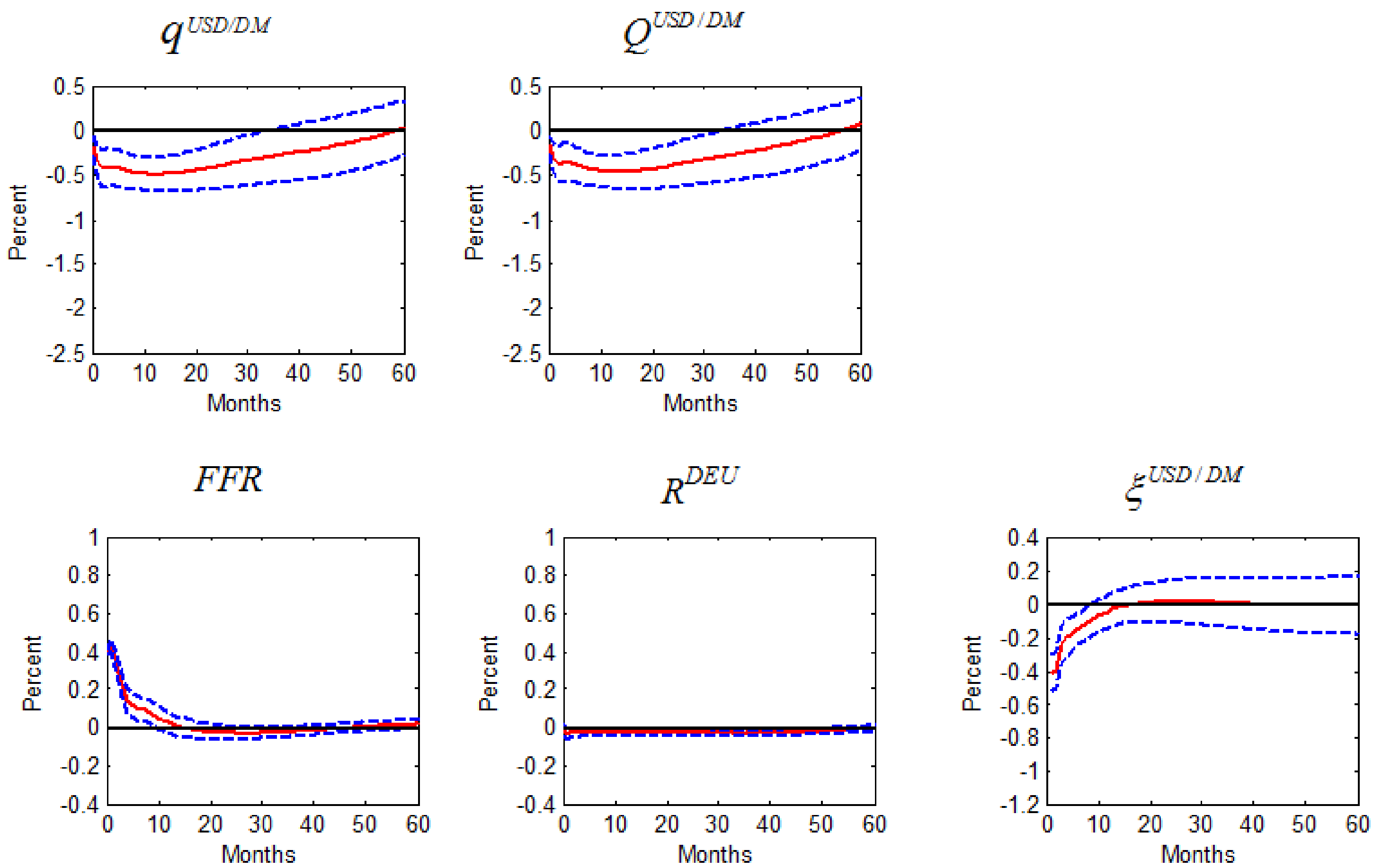


**Figure 1.17:** Comparison of Results through "Counterfactual Analysis" Step 3: Considering a GVAR Specification (Same Variables as in GVECM, Cholesky Decomposition Based Shock Identification) – Bilateral Exchange Rates and Forward Premiu



In the fourth step of our counterfactual analysis, we capture the long-run cointegrating relations of our GVECM set-up, but still use the Cholesky decomposition based monetary policy shock identification of the previous steps of our counterfactual analysis. The results are displayed in Figures 1.18 and 1.19. As for the GVAR results, the German short-term interest rate does not display a significant reaction to the U.S. monetary policy shock. The U.S. Dollar effective nominal and real exchange rates show small short-term appreciation, and then depreciate. For the U.S. Dollar versus Deutsche Mark bilateral nominal and real exchange rates implied by this set-up, we observe a similar small short-run appreciation. The forward premium impulse responses, both measured as effective forward premia for the United States and as bilateral forward premia for the United States relative to Germany, indicate forward premia in favor of U.S. bonds for about four months. The mostly insignificant nominal and real depreciation of the U.S. Dollar in response to a contractionary U.S. monetary policy shock obtained in the GVECM setting of this step suggests that the Cholesky decomposition based shock identification is rather problematic when applied to a model containing long-run restrictions.

**Figure 1.18:** Comparison of Results through "Counterfactual Analysis" Step 4: GVECM Specification (Cholesky Decomposition Based Shock Identification) – Effective Exchange Rates and Forward Premium

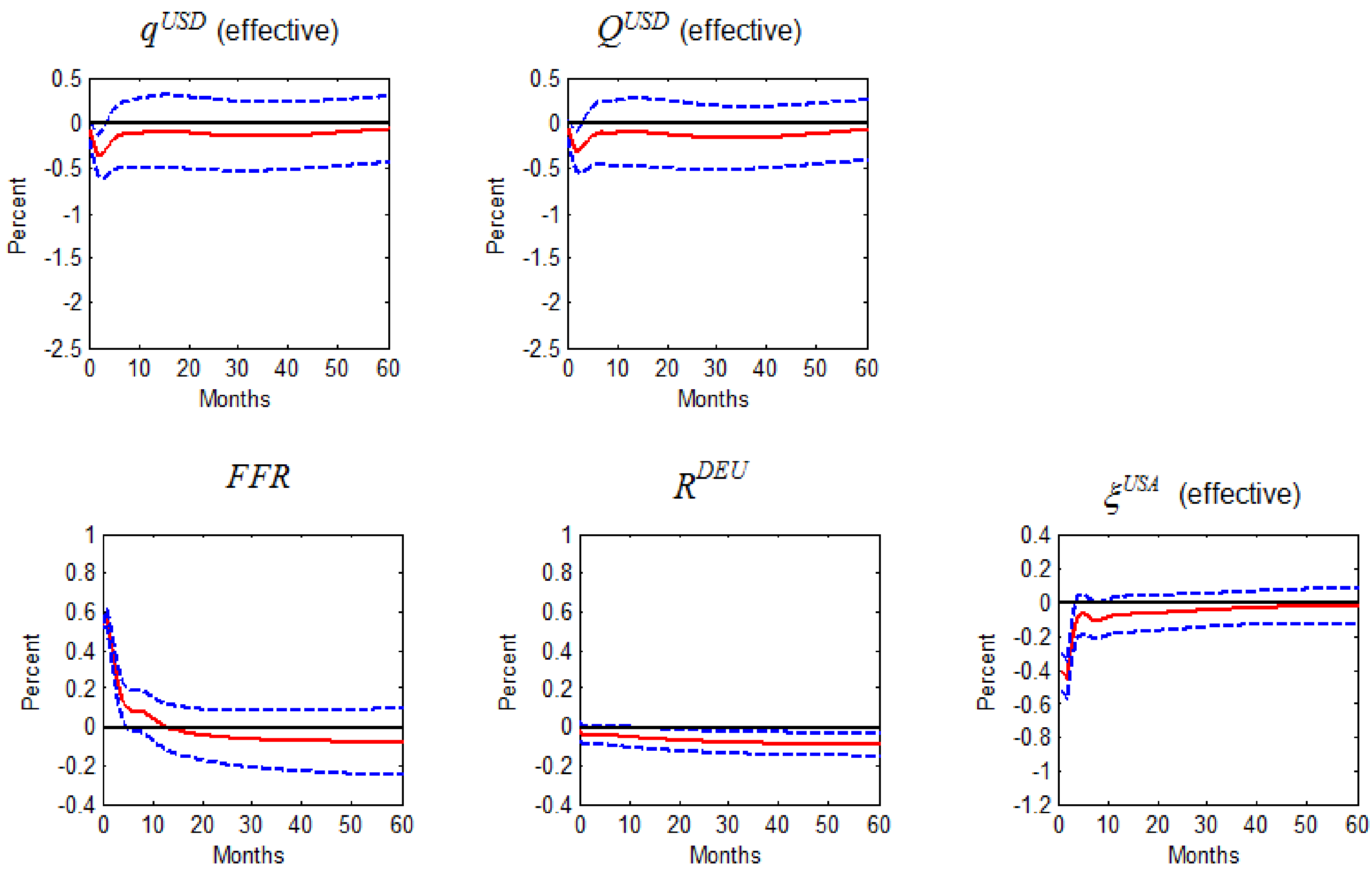
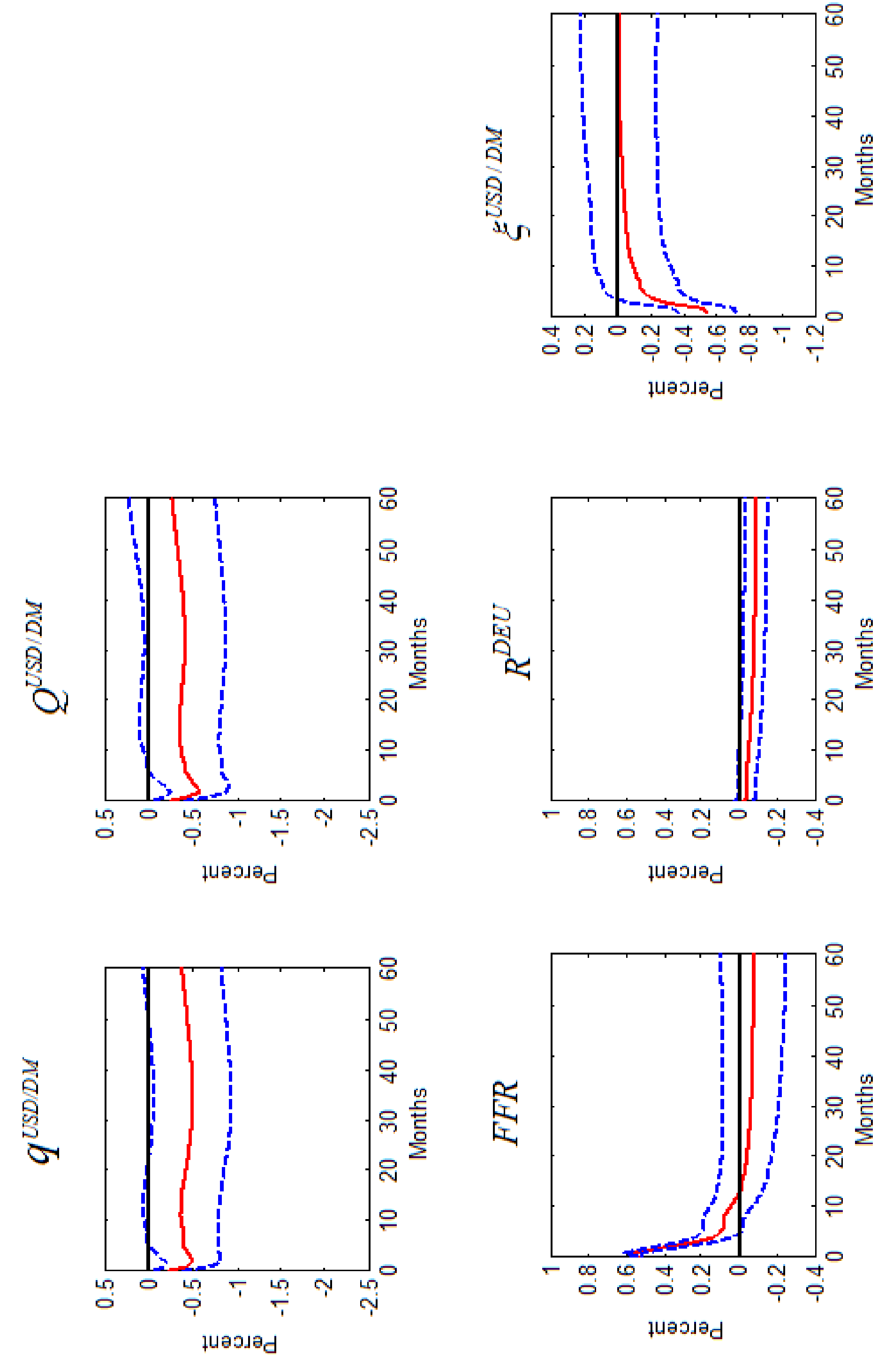
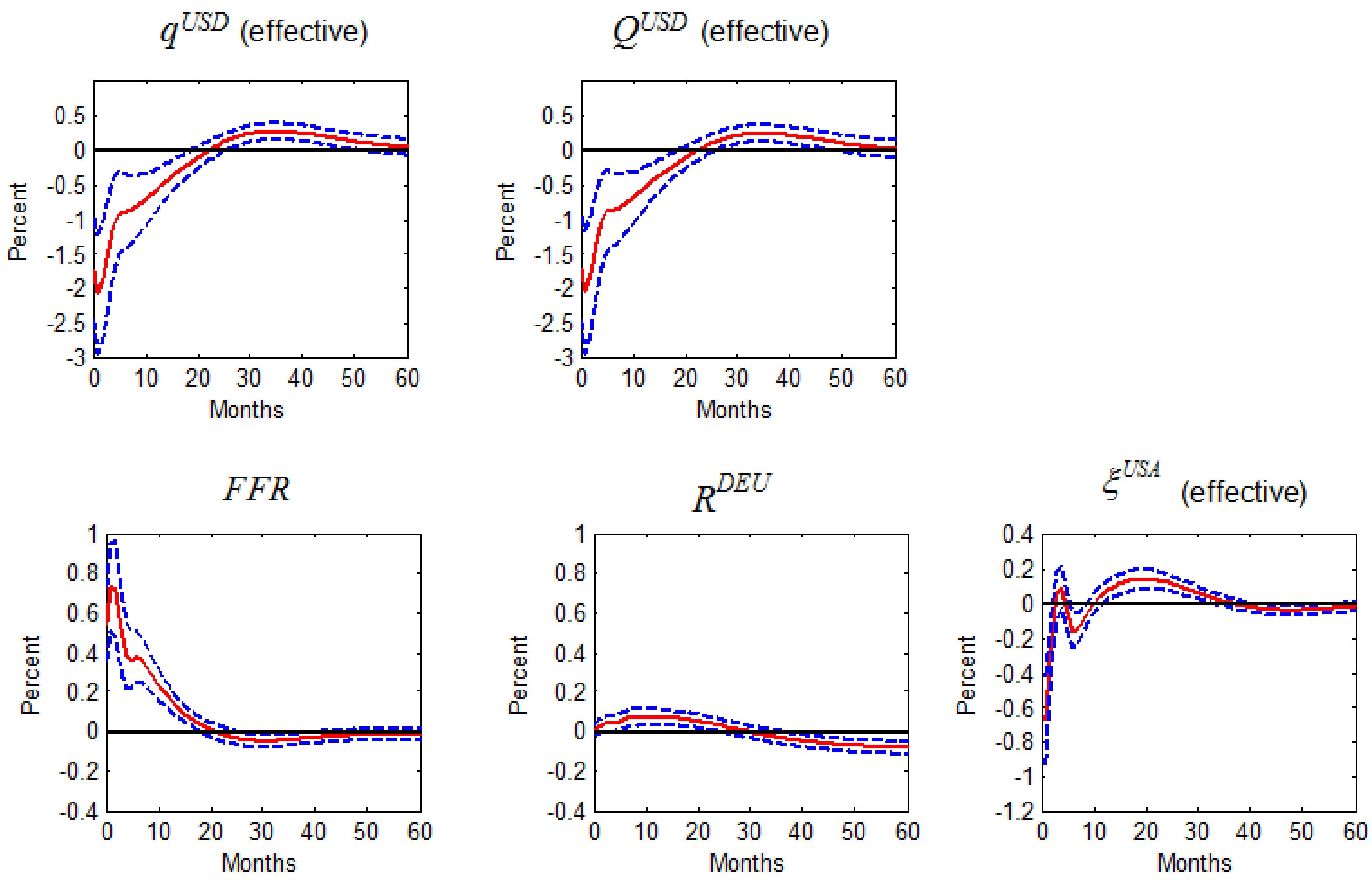


**Figure 1.19:** Comparison of Results through "Counterfactual Analysis" Step 4: GVECM Specification (Cholesky Decomposition Based Shock Identification) – Bilateral Exchange Rates and Forward Premium



For the fifth step of our counterfactual analysis, we then move to our GVECM set-up with identification restrictions similar to those in Sections 5 and 6, namely cointegration-based long-run restrictions augmented by as few short-run identification restrictions as necessary, but now - unlike in Sections 5 and 6 - we impose cross-country orthogonality of the monetary policy shocks. As Figure 1.20 shows, for the impulse responses for the nominal and real effective U.S. Dollar exchange rates this yields very similar results as we had obtained in Section 6. (The impulse responses in Figures 1.22 and 1.23 are obtained using our methodology of Sections 5 and 6, except that they are plotted for a U.S. contractionary monetary policy shock of 50 basis points, as in the previous steps of the counterfactual analysis in this Section.) Also, the impulse response for the effective U.S. forward premium is very similar to the one we had obtained in Section 6. While there are quantitative differences for the bilateral exchange rate and forward premium responses across the two settings of cross-country orthogonality of the monetary policy shocks being imposed/not imposed, and the results are stronger when cross-country orthogonality of the monetary policy shocks is not imposed (which also is our preferred specification), for the analysis involving effective rates assumptions regarding the presence of cross-country correlation of shocks abroad with U.S. monetary policy shocks clearly are not a factor for the results.

**Figure 1.20:** Comparison of Results through "Counterfactual Analysis" Step 5: GVECM Specification (Cross-Country Orthogonality of U.S. Monetary Policy Shocks) – Effective Exchange Rates and Forward Premium



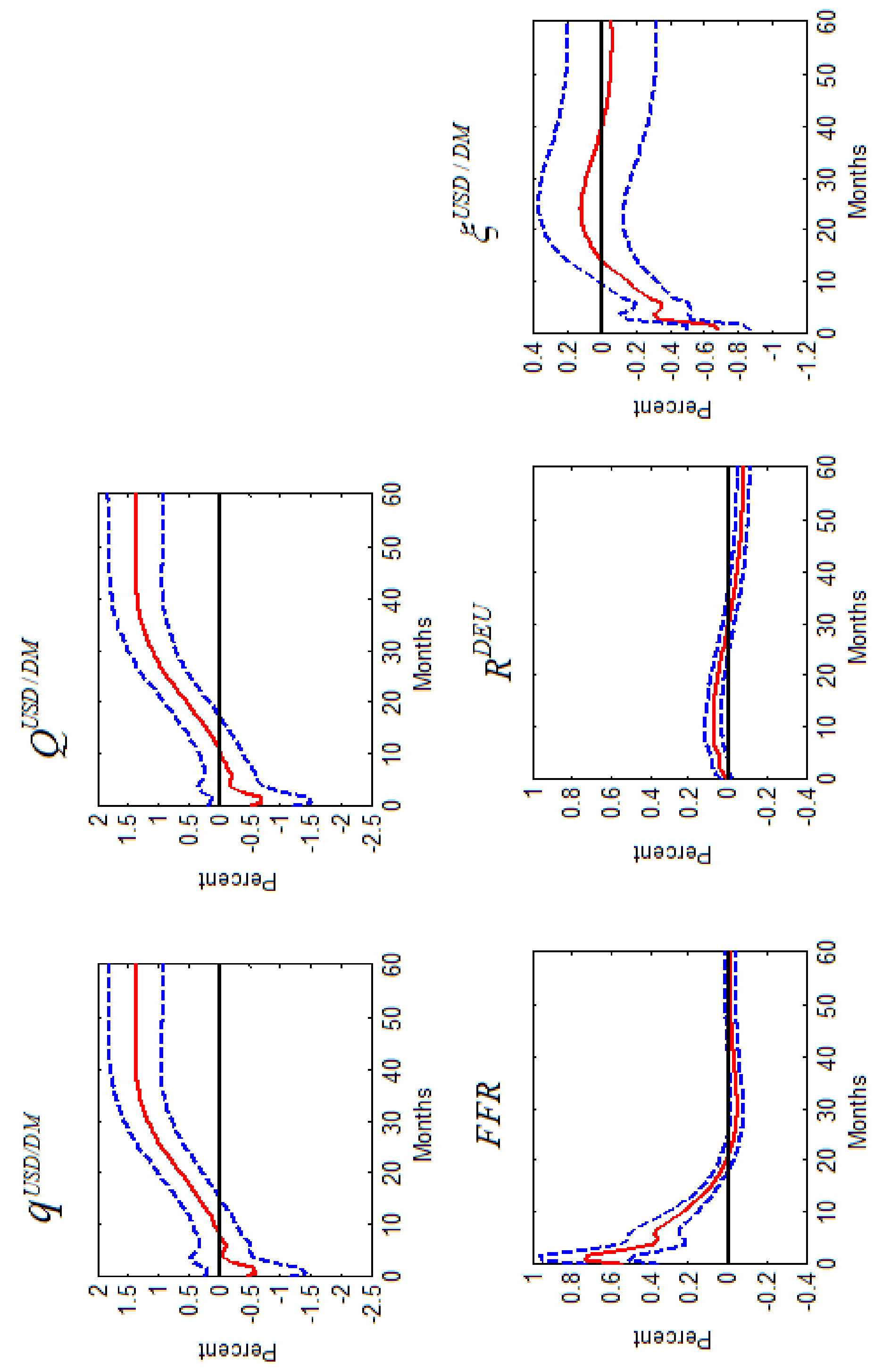



**Figure 1.21:** Comparison of Results through "Counterfactual Analysis" Step 5: GVECM Specification (Cross-Country Orthogonality of U.S. Monetary Policy Shocks) – Bilateral Exchange Rates and Forward Premium

**Figure 1.22:** Comparison of Results through "Counterfactual Analysis" Step 6: GVECM Specification – Effective Exchange Rates and Forward Premium

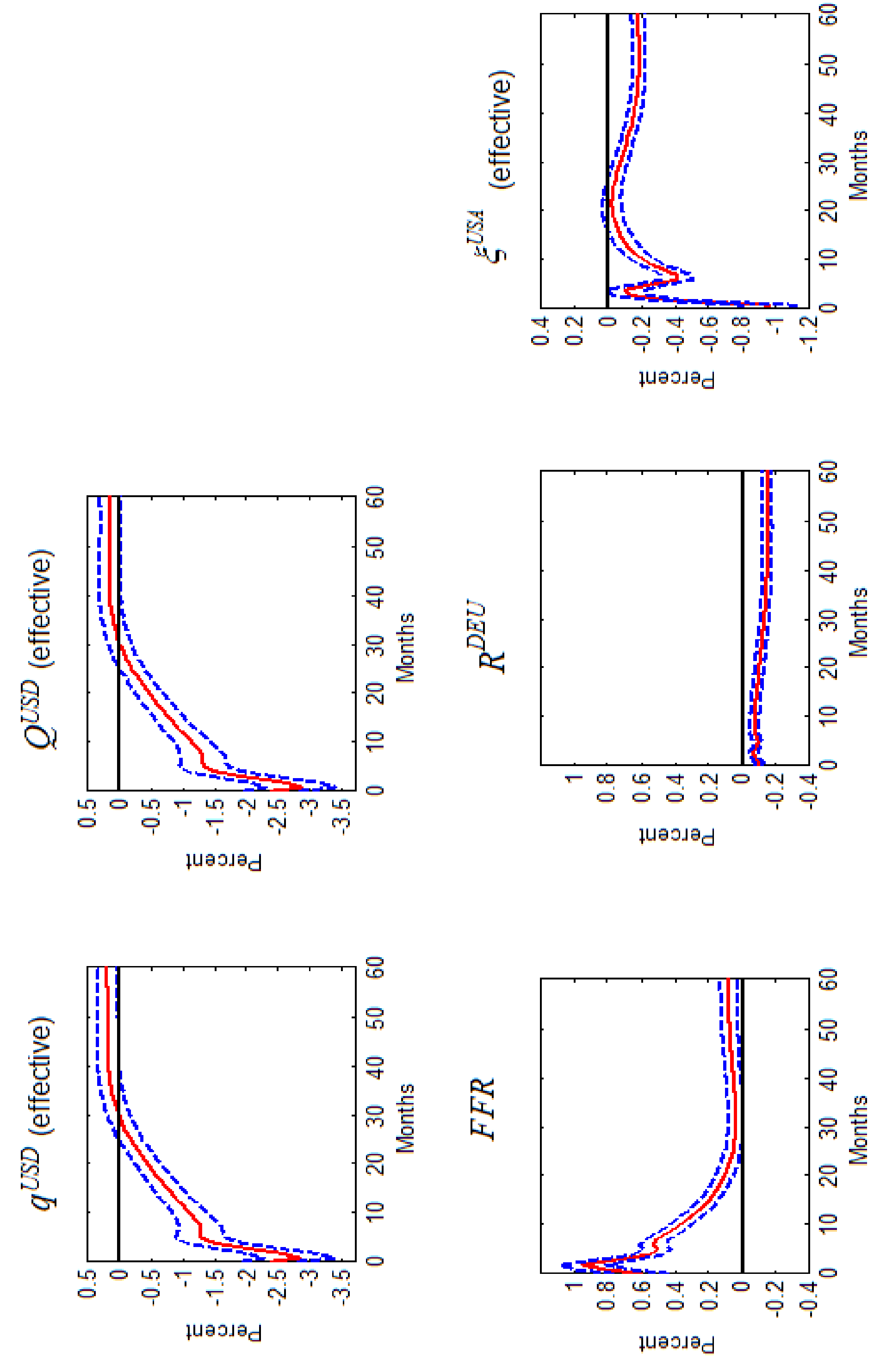
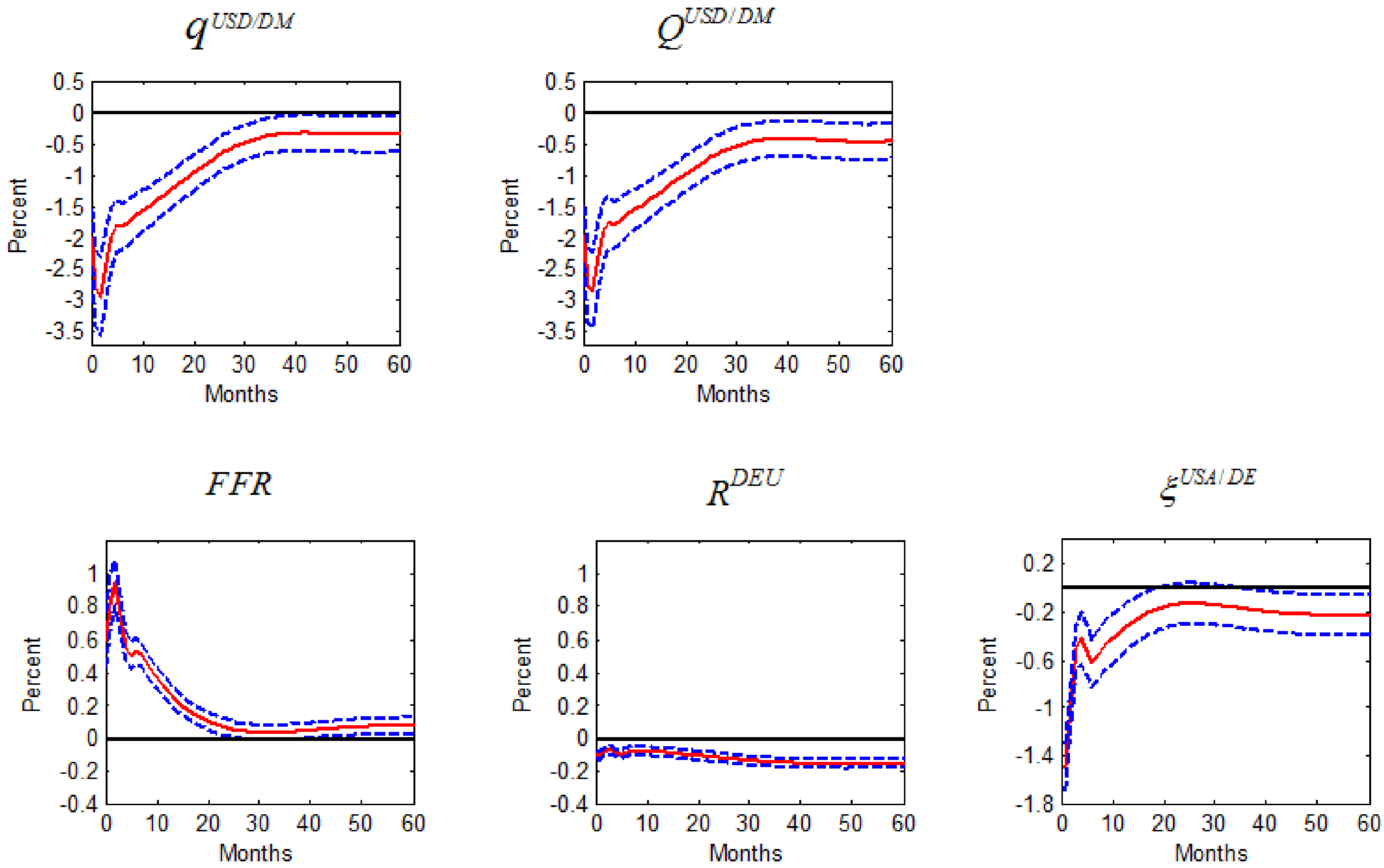


**Figure 1.23:** Comparison of Results through "Counterfactual Analysis" Step 6: GVECM Specification – Effective Exchange Rates and Forward Premium



Overall, the findings of our counterfactual analysis strongly suggest that both (i) our accounting for multilateral (rather than just bilateral) cross-country adjustment in response to monetary policy shocks, and (ii) our taking advantage of the identifying restrictions for monetary policy shocks implied by long-run relations between the macroeconomic variables under consideration, are of critical relevance in us being able to provide evidence that there is neither a delayed exchange rate overshooting puzzle nor a forward premium puzzle in the adjustment of U.S. Dollar nominal and real exchange rates and forward premia in response to U.S. monetary policy shocks.

## 1.8 Conclusion

In this paper we have re-considered the effects of monetary policy shocks on exchange rates and forward premia. In the recent empirical literature these effects have been described as puzzling, in that they would include delayed overshooting of the exchange rate as well as persistent deviations from uncovered interest parity. We have constructed an empirical model that in particular (i) allows for simultaneous *multi*-country adjustments in response to monetary policy shocks, and (ii) takes advantage of the identifying restrictions for monetary policy shocks implied by long-run relations between the macroeconomic variables under consideration. Using monthly data from 1978 to 2006 for a panel of nine industrial economies (Australia, Canada, France, Germany, Italy, Japan, New Zealand, United Kingdom, and the United States), we have found that U.S. Dollar effective and bilateral real exchange rates appreciate almost on impact after a contractionary U.S. monetary policy shock, and that there is no delay in the overshooting of the U.S. Dollar. Furthermore, there is no persistent significant forward premium and the price puzzle is at most weakly present. These results are consistent with the real exchange rate effects of monetary policy shocks in sticky price open economy macroeconomic models, though the results of this paper also suggest that the latter models should be specified so as to capture simultaneous multi-country adjustments to shocks.

## 1.9 Appendix 1.1 : Data Definitions and Sources

The following are the data definitions and sources for the variables used in the empirical analysis of the paper

| Variable | Description | Source | Notes |
|---|---|---|---|
| $y$ | Index of real industrial production | International Financial Statistics (IFS) | The series for Australia, France, the United Kingdom and the United States were not available in seasonally adjusted form from the IFS, and were seasonally adjusted by the authors. |
| $P$ | Index of consumer prices | IFS | The price series for Australia and New Zealand involve authors' interpolation from quarterly series. |
| $Q$ | Trade-weighted effective nominal exchange rates | IFS and OECD | The effective exchange rates were computed by the authors combining bilateral nominal exchange rates from the IFS with bilateral import and export data for the sample of nine countries from the OECD. The effective exchange rates are not the multilateral effective nominal exchange rates reported in the IFS. |
| $Po$ | Spot world market oil price | Federal Reserve Bank of St. Louis | |
| $Pc$ | Commodity price index (agricultural raw materials) | International Monetary Fund | |

| **Variable: Rm** | **Description** | **Source** |
|---|---|---|
| Australia | Official cash rate | Australian Reserve Bank |
| Canada | Bank of Canada overnight rate | IFS |
| France | Until December 1998: overnight money market rate; from January 1999: EONIA | IFS |
| Germany | Until December 1998: overnight money market rate; from January 1999: EONIA | IFS |
| Italy | Until December 1998: overnight money market rate; from January 1999: EONIA | IFS |
| Japan | Overnight call rate | IFS |
| New Zealand | Until December 1998: discount rate; from January 1999: official cash rate | IFS |
| United Kingdom | Official bank rate | Bank of England |
| United States | Federal funds rate | IFS |

| **Variable: Rs** | **Description** | **Source** | **Notes** |
|---|---|---|---|
| Australia | Treasury bill rate / 90 days bank bill rate | IFS | Until May 2002: treasury bill rate; from June 2002: 90 days bank bill rate (no observations on treasury bill rate). |
| Canada | Treasury bill rate | IFS | |
| France | Treasury bill rate / EU refinancing rate | IFS | Until September 2004: treasury bill rate; from October 2004: EU refinancing rate (no observations on treasury bill rate). |
| Germany | Treasury bill rate | IFS | |
| Italy | Treasury bill rate | IFS | |
| Japan | 2 months treasury bill rate / 89-90 days domestic certificate rate | Bank of Japan | Until December 1995: 2 months treasury bill rate; from January 1996: 89-90 days domestic certificate rate. |
| New Zealand | New issue 3 months bill rate / 90 days bank bill rate | IFS / Reserve Bank of New Zealand | Until December 1984: new issue 3 months bill rate; from January 1985: 90 days bank bill rate (no observations on 3 months bill rate). |
| United Kingdom | 3 months treasury bill rate | Bank of England | |
| United States | Treasury bill rate | IFS | |

## 1.10 Appendix 1.2: Cointegrating Relations for the United States, and Tests for Long-Run Uncovered Interest and Purchasing Power Parity for All Countries

Cointegration #1

$$\begin{aligned} & 0.01t + 1.00y_{t-1} + 0.00P_{t-1} + 0.00R^{m}_{t-1} - 2.79R_{t-1} - 1.89Q_{t-1} + 0.53y^{*}_{t-1} \\ - \quad & 3.92P^{*}_{t-1} + 9.18R^{s^{*}}_{t-1} - 1.13Q^{*}_{t-1} + 0.45P^{o}_{t-1} + 0.18P^{o}_{t-1} \backsim I(0) \end{aligned} \tag{1.62}$$

Cointegration #2

$$\begin{aligned} & -0.01t + 0.00y_{t-1} + 1.00P_{t-1} + 0.00R^{m}_{t-1} - 0.56R_{t-1} + 0.81Q_{t-1} - 0.22y^{*}_{t-1} \\ + \quad & 0.76P^{*}_{t-1} - 3.12R^{s^{*}}_{t-1} + 0.41Q^{*}_{t-1} - 0.12P^{o}_{t-1} - 0.05P^{o}_{t-1} \backsim I(0) \end{aligned} \tag{1.63}$$

Cointegration #3

$$\begin{aligned} & 0.00t + 0.00y_{t-1} + 0.00P_{t-1} + 1.00R^{m}_{t-1} - 1.20R_{t-1} + 0.21Q_{t-1} - 0.11y^{*}_{t-1} \\ + \quad & 0.40P^{*}_{t-1} - 0.73R^{s^{*}}_{t-1} + 0.11Q^{*}_{t-1} - 0.02P^{o}_{t-1} - 0.01P^{o}_{t-1} \backsim I(0) \end{aligned} \tag{1.64}$$

**Tests for Long-Run Uncovered Interest and Purchasing Power Parity**

| | **Australia** | **Canada** | **France** |
|---|---|---|---|
| Uncovered Interest Parity | 0.20 | 0.00 | 0.00 |
| Purchasing Power Parity | 0.00 | 0.00 | 0.00 |
| Uncovered Interest and Purchasing Power Parity | 0.00 | 0.00 | 0.00 |

| | **Germany** | **Italy** | **Japan** |
|---|---|---|---|
| Uncovered Interest Parity | 0.00 | 0.00 | 0.00 |
| Purchasing Power Parity | 0.00 | 0.00 | 0.07 |
| Uncovered Interest and Purchasing Power Parity | 0.00 | 0.00 | 0.00 |

| | **New Zealand** | **United Kingdom** | **United States** |
|---|---|---|---|
| Uncovered Interest Parity | 0.00 | 0.00 | 0.00 |
| Purchasing Power Parity | 1.00 | 0.00 | 0.00 |
| Uncovered Interest and Purchasing Power Parity | 0.00 | 0.00 | 0.00 |

The reported p-values are for likelihood ratio tests of the overidentifying restrictions on the cointegrating relations implied by Uncovered Interest and Purchasing Power Parity.

# Chapter 2

# Exchange Rate Dynamics, Expectations, and Monetary Policy Fundamentals

## 2.1 Introduction

Since the study by Meese and Rogoff (1983), the literature has favored the view that exchange rate dynamics are unrelated to macroeconomic fundamentals. Macroeconomic models with an exogenous money supply and rational expectations cannot outperform the random walk model in terms of exchange rate return forecasts over a short to medium horizon, although they gain empirical support in the case of long-horizon forecasts.[1] Recent studies, such as those by Taylor (1993) and Clarida, Gali and Gertler (1998) have found that central banks set interest rates in reaction to macroeconomic fundamental changes. The implication is that macroeconomic fundamentals could influence the exchange rates by inducing changes in monetary policy expectations. Furthermore, fundamentals to which the central banks react (monetary policy fundamentals) should be considered as one set of determinants of exchange rate movements.

Recent studies such as Andersen et al. (2003), Faust et al. (2007), and Clarida and Waldman (2007) show that exchange rates react to macroeconomic news, suggesting that market participants expect future monetary policy to change in reaction to macroeconomic

[1] See Mark (1995), Mark and Sul (2001).

conditions. Furthermore, subsequent changes in anticipation of the interest rate differential influence their demand for currencies and thus influence the exchange rates. These findings highlight the importance of the channel of monetary policy expectation through which macroeconomic variables influence exchange rate dynamics.

Recent papers on exchange rates model monetary policy as a function of macroeconomic fundamentals and evaluate the explanatory and predictive power of the fundamentals of monetary policy, with mixed results. Molodtsova and Papell (2009) find that econometric models with Taylor rule fundamentals beat the random walk for some currency pairs in terms of one-month exchange rate return forecasts. Chen and Tsang (2010) find that models with Taylor rule fundamentals and yield curve factors embedding financial market expectations outperform the random walk model for forecasting the price of the yen and pound relative to the U.S. dollar. Engel and West (2006) and Mark (2009) find that the price of the deutsche mark and euro relative to the U.S. dollar generated from a UIP model with Taylor rule fundamentals is moderately correlated with the actual exchange rate. However, the same correlations for the exchange rate returns are rather mild over the short to medium horizon. Binici and Cheung (2010) find the explanatory power of monetary policy rule fundamentals varies across different assumptions of policy rules. Therefore, it is difficult to conclude whether the monetary policy expectation channel can improve the explanatory and predictive power of macroeconomic fundamentals.

The importance of modeling the market expectations of macroeconomic fundamentals are highlighted in the above models. However, their treatments of market expectations regarding future monetary policy are relatively simple. Typically, the expectations are assumed to be based on a constant-parameter Taylor rule (Engel and West 2006 and Engel, Mark and West 2007) or an adaptive learning mechanism (Mark 2009), which is not guaranteed to be consistent with market expectations. Because the movement of current and future monetary policy fundamentals influence the exchange rate through an induced change in market expectations of monetary policy, a correct model of these expectations is crucial to reach a conclusion on this question. In addition, the findings of Binici and Cheung (2010) suggest the need for a systematic way to model monetary policy expectations.

This paper investigates the linkage between monetary policy fundamentals and exchange rate returns through the channel of monetary policy expectations. In particular, we decompose the exchange return into three components: market expectations of short-term interest rates, market expectations of currency risk premia and the exchange rate forecast error. We focus on the determination of monetary policy fundamentals on the exchange rate through the first component. We first examine whether the monetary policy fundamentals are part of the process by which market participants form expectations of future interest rates and how they determine these expectations. We then explore whether the expected future interest rates determine the exchange rate dynamics. In particular, we model this expectation formation process based on consensus forecasts, which come from forecasts collected from surveyed market participants. Specifically, we generate interest rate forecasts from a large number of VAR models that represent the alternatives of learning processes of the agents. We use the model that generates the interest rate forecast closest to the consensus forecast based on a set of criteria and we consider this the formation process for market expectations. We therefore obtain the expected interest rates from this model. This avoids misspecification from arbitrary assumptions about expectations.

Our analysis of the deutsche mark and euro price of U.S. dollar from 1979 to 2008 confirms that the fundamentals of monetary policy influence exchange rate returns through the monetary policy expectation channel. Modeling market expectations of monetary policy based on consensus forecasts considerably improves the explanatory and predictive power of the monetary policy fundamentals over the existing literature. Specifically, we present the following findings and contributions.

First, Taylor rule fundamentals play a central role in the process of forming monetary policy expectations among German and U.S. market participants. However, the functional forms of the formation processes change over time and differ across countries; the evidence for the former property is stronger for the U.S. than it is for Germany and the euro area. This implies that market expectations of short-term interest rates in Germany and the U.S. cannot be represented by a single learning mechanism. This provides a reference for future research that considers market expectations of monetary policy.

Second, in the pre-euro era, the expected short-term interest rate differentials are moderately correlated with exchange rate returns over short horizons of up to one year and strongly correlated over medium to longer horizons of up to four years. In the euro era, they are strongly correlated with the exchange rate returns, even for the short to medium horizon. These correlations are much larger than those found in previous studies. The volatility of expected interest rates accounts for a large part of exchange rate return volatility over longer horizons. These findings imply that Taylor rule fundamentals have considerable explanatory power for exchange rate returns once the monetary policy expectation is modeled to be consistent with the market's expectation.

Third, the correlation between the expected interest rate and the exchange rate return changes its sign from positive in the pre-euro era to negative in the euro era. The negative sign implies that the UIP does not hold in the euro era and that the higher expected future interest rate is associated with stronger currency, which is in line with the "interest parity puzzle" in the international finance literature.

Furthermore, the expected sum of future interest rate differentials is a good candidate for the out-of-sample forecasting of exchange rate return, which outperforms the random walk model for most of the forecast horizons in all sample periods in our exercise. This may imply that macroeconomic fundamentals such as the output gap and inflation rate have high predictive power. Previous papers' failure to beat the random walk model may result from using the incorrect functional form instead of the wrong set of fundamentals. This is worth considering before seeking other factors for forecasting exchange rates.

The remainder of the paper is as follows: Section 2.2 presents the conventional model linking the monetary policy and the exchange rate, and the exchange rate return decomposition derived from it. We also present the treatment in the previous literature and the motivation of this paper. Section 2.3 discusses the modeling of the process of forming market expectations of monetary policy. Section 2.4 evaluates the explanatory power of the monetary policy expectations. Section 2.5 further evaluates the predictive power of monetary policy expectations and section 2.6 concludes.

## 2.2 The Exchange Rate Model

### 2.2.1 Decomposition

In this section, we use a model to demonstrate how macroeconomic fundamentals influence exchange rate movements by inducing changes in monetary policy expectations. Following the model, a summary of treatment for this problem in the existing literature is discussed.

We start from an uncovered interest parity (UIP) model with deviation from UIP, which is the major link between exchange rate movement and macroeconomic variables in the existing literature:

$$E_t \Delta s_{t,t+h} = E_t s_{t+h} - s_t = \left(i_t^h - i_t^{h*}\right) + \rho_{t,t+h} \tag{2.1}$$

where $s_t$ is the logarithm of the nominal bilateral exchange rate at period $t$, defined as the domestic price of the foreign currency. Furthermore, $i_t^h$ is the interest rate at $t$ with maturity $h$, $i_t^{h*}$ is the corresponding foreign interest rate, and $\rho_{t,t+h}$ indicates the currency risk premium between $t$ and $t+h$. Since the exchange rate return over $k$ maturity horizons can be written as the sum exchange rate changes over each maturity horizon of $h$ periods:

$$E_t \Delta s_{t,t+kh} = E_t s_{t+kh} - s_t = E_t \Delta s_{t,t+h} + E_t \Delta s_{t+h,t+2h} + \ldots + E_t s_{t+(k-1)h,t+kh} \tag{2.2}$$

by combining equation 2.1 and 2.2, the $kh$-period ahead exchange rate change is expressed as

$$E_t s_{t+kh} - s_t = E_t \sum_{i=0}^{k-1} \left(i_{t+ih}^h - i_{t+ih}^{h*}\right) + E_t \sum_{i=0}^{k-1} \rho_{t+ih,t+(i+1)h}. \tag{2.3}$$

If $\epsilon_{t,t+kh}$ represents the forecast error, that is $s_{t+kh} = E_t s_{t+kh} + \epsilon_{t,t+kh}$, the actual exchange rate over $kh$-period horizon becomes:

$$\Delta s_{t,t+kh} = E_t \sum_{i=0}^{k-1} \left(i_{t+ih}^h - i_{t+ih}^{h*}\right) + E_t \sum_{i=0}^{k-1} \rho_{t+ih,t+(i+1)h} + \epsilon_{t,t+kh}. \tag{2.4}$$

Therefore, the exchange rate change is decomposed into three parts: the expected sum of current and future interest rate differentials between the domestic and foreign country (which are indicators for monetary policies in many advanced economies), the expected sum of current and future currency risk premia, and the forecast error.[2]

An example of this relationship is as follows: if we have monthly data and the interest rate maturity is 3 months ($k = 3$), then the 5-year (60-month) ahead change of exchange rate is written

$$s_{t+60} - s_t = E_t \sum_{i=0}^{19} \left(i_{t+3i}^3 - i_{t+3i}^{3*}\right) + E_t \sum_{i=0}^{19} \rho_{t+3i,t+3(i+1)} + \epsilon_{t,t+60}. \tag{2.5}$$

[2] I do not decompose the level of exchange rate here because, since as the infinite forward interation requires a stationarity assumption for the exchange rate. See Engel and West (2010). I do not impose this assumption in the model.

The actual change in exchange rates over the horizon of five years equals the expected sum of current and future 3-month interest rates spanning 19 maturity periods, the expected sum of corresponding future risk premium, and the forecast error.

Based on this decomposition, any impact of the macroeconomic fundamentals on exchange rate return must go through these three channels:

(i) (i) Changing the expectations of domestic and foreign monetary policies, that is, the first term on the right-hand side of Equation 2.4 can be written as a function of the fundamentals:

$$E_t \sum_{i=0}^{k-1} \left( i^h_{t+ih} - i^{h*}_{t+ih} \right) = f\left(X_t, X^*_t\right), \tag{2.6}$$

with $\mathbf{X}_t = \begin{pmatrix} \mathbf{x}'_{t,} & \mathbf{x}'_{t-1,} & \dots & \mathbf{x}'_{t-p} \end{pmatrix}'$ and $\mathbf{X}^*_t = \begin{pmatrix} \mathbf{x}^{*'}_{t,} & \mathbf{x}^{*'}_{t-1,} & \dots & \mathbf{x}^{*'}_{t-q} \end{pmatrix}'$. $\mathbf{x}_t$ denotes the vector of macroeconomic fundamentals at period $t$ in the home and foreign country and $\mathbf{x}^*_t$denotes the foreign counterpart.[3] $p$ and $q$ are the lags chosen by market participants. These fundamentals are the ones to which the market participants perceive that the central banks will react by adjusting the short-term interest rates. Therefore, $f$ indicates how the monetary policy fundamentals determine the expected sum of future interest rates.

(ii) Changing the expectation of risk premium, that is,

$$E_t \sum_{i=0}^{k-1} \rho_{t+ih,t+(i+1)h} = g\left(X_t, X^*_t\right) + \widetilde{g}\left(n_t\right). \tag{2.7}$$

Here $n_t$ represents a vector containing variables other than the monetary policy fundamentals that determine the expected future currency risk premia. $g$ and $\widetilde{g}$ are the functions mapping fundamentals and other factors to expected premia respectively.

(iii) Changing the forecast error:

$$\epsilon_{t,t+3k} = l\left(X_t, X^*_t\right) + \widetilde{l}\left(m_t\right), \tag{2.8}$$

where, analogously, $m_t$ is a vector of variables determining the forecast error in addition to these fundamentals, $l$ and $\widetilde{l}$ are corresponding functions.

The research question that asks whether and how monetary policy fundamentals determine exchange rate change by inducing changes in monetary policy expectations requires

[3] $X_t$ and $X^*_t$ include lag interest rates.

a focus on channel (i). Specifically, we need to identify $f$ and to evaluate the explanatory power of $f$ for $s_{t+kh} - s_t$. Only if there is evidence that $f$ is determined by monetary policy fundamentals and $f\left(X_t, X_t^*\right)$ can explain $s_{t+kh} - s_t$, can the above question be answered positively.

### 2.2.2 Treatment in the Existing Literature

The treatment of the relationship between exchange rate dynamics and the fundamentals of monetary policy rule can be categorized into two types:

The first type includes econometric models focusing on the forecasting ability of the monetary policy fundamentals for change in the exchange rate. Typically, they regress the exchange rate change on fundamentals using the following form:

$$\Delta s_{t,t+kh} = \beta \widetilde{X_t} + \beta^* \widetilde{X_t^*} + \theta \upsilon_t + \varepsilon_t \tag{2.9}$$

where $\widetilde{X_t}$ and $\widetilde{X_t^*}$ are the monetary policy fundamentals in the home and foreign countries used in these models,[4] and $\beta$ and $\beta^*$ are their corresponding parameters. $\upsilon_t$ and coefficient $\theta$ represent the part explained by factors other than the observed monetary policy fundamentals.[5] Papers using this type of model include Engel, West and Mark (2007),[6] Molodtsova and Papell (2009), and Chen and Tsang (2010).[7] In this model setting, the coefficient $\beta$ and $\beta^*$ represent the total effect of the monetary policy fundamentals on the exchange rate return through all three channels. There is no distinction between effects through different channels. Therefore, one cannot determine whether the fundamentals influence exchange rate movement by changing monetary policy expectation. In addition, the parameters are subject to bias due to the potential missing variable problem if other determinants of the currency risk premia and those of forecast error are not captured in $\upsilon_t$.

The second type of treatment simulates a model's implied exchange rate, based on the first term on the right-hand side of equation 2.4. This literature was pioneered by Engel and West (2006) (EW06, hereafter) and followed by recent papers like Mark (2009) and Binici

[4] $\widetilde{X_t}$ and $\widetilde{X_t^*}$ also include lag variables.

[5] Some papers use panel regressions, for simplicity, I use the time series representation here.

[6] Engel, West and Mark (2007) estimate a panel regression.

[7] Chen and Tsang (2010) emphasize combining the yield curve factors, which embed the expectations of the financial market participants, and the Taylor rule fundamentals, which represent the macroeconomic factors, to forecast exchange rate. Their primary focus is not the predictive power of monetary policy fundamentals.

and Cheung (2010) (BC 10, hereafter). In general, they assume certain monetary policy rule-that is, an exogenously determined interest rate reaction function to replace $E_t i^h_{t+ih}$ and $E_t i^{h*}_{t+ih}$ whenever they appear. This replacement suggests the authors' assumption that the agent perceives the central banks' adherence to these rules. With this assumption, the expected sum of the future interest rate differential is written as a function of monetary policy rule fundamentals $X_t$ and $X_t^*$. The following shows the general form of this model-implied exchange rate:

$$\Delta\widetilde{s} = \widetilde{E_t}\sum_{i=0}^{k-1}\left(i^h_{t+ih} - i^{h*}_{t+ih}\right) = \widetilde{\alpha}_t\left(\widetilde{X_t}\right) + \widetilde{\alpha}_t^*\left(\widetilde{X_t^*}\right) = \kappa\left(\widetilde{X_t}, \widetilde{X_t^*}\right) \tag{2.10}$$

where $\widetilde{\alpha}_t$ and $\widetilde{\alpha}_t^*$ are functions that map the domestic and foreign monetary policy fundamentals in these models, respectively, to $\widetilde{E_t}\sum_{i=0}^{k-1}\left(i^h_{t+ih} - i^{h*}_{t+ih}\right)$. $\kappa$ varies across models due to different assumptions of the expected monetary policy rules. These assumptions differ in the following features:

1. The macroeconomic variables to which the monetary policy responds. EW 06 and Mark (2009) assume that the agents believe the central bank follows the Taylor rule, and the fundamentals are output gap and inflation (and the real exchange rate, in EW06). BC 10 try different optimal monetary policy rules including the Taylor rule, inflation targeting, and constant money growth, among others. Therefore, the fundamentals include output, inflation, money growth and their variations.

2. Parameters of these fundamentals. Some papers take the monetary policy rule parameters from existing literature and others estimate them using the sample data. Parameters can either be homogeneous or heterogeneous in domestic and foreign countries.

3. The expectation formation process (EFP) of future macroeconomic fundamentals, if it exists in the policy rule. A typical example is the processes for output gap and inflation, which appear most often in the model with policy rules. The treatment in the existing papers uses different kinds of assumed EFPs. A constant parameter VAR assumes that agents incorporate future realized variables to form a forecast (EW 06, Engel and West 2010) or engage in constant least squares learning (Mark 09) or a fixed-year window VAR learning (BC 10).

Therefore, $\kappa$ is computed using different combinations of the above three features. The correlation between $\kappa$ and the actual exchange rate change $\Delta s_{t,t+kh}$ is computed,[8] and the subsequent conclusions about the linkage between monetary policy fundamentals and exchange rate is made.

Note that there is no guarantee that

$$\kappa\left(\widetilde{X_t}, \widetilde{X_t^*}\right) = f\left(X_t, X_t^*\right) = E_t \sum_{i=0}^{k-1} \left(i_{t+ih}^{h} - i_{t+ih}^{h*}\right) \tag{2.11}$$

if there is no evidence that the arbitrary assumptions of the expected future monetary policies in domestic and foreign countries match the actual expectations of the market participants. The conclusion that policy fundamentals influence exchange rate changes by inducing changes in expectations of future policy is therefore not found using the existing model. To do so, the correct modeling of market participants' EFP of future monetary policy—that is, the modeling of $f\left(X_t, X_t^*\right)$–is necessary. Therefore, in the next section, we discuss the modeling of the EFP of monetary policy stance.

As discussed in the above section, two sub-questions must be answered before reaching the conclusion. Therefore, the following exercise is divided into two steps. The first step is to investigate whether and how the expected sum of interest rate differentials depends on policy rule fundamentals. The answer depends on modeling the market participants' EFP for future monetary policy. If we obtain a positive answer for the first step, the second step is to evaluate whether the expected sum of interest rate differentials explains the exchange rate change in terms of co-movement and volatility. These two steps are discussed in the following sections.

## 2.3 Expectation Formation Process (EFP) of Monetary Policy Stance

To discern whether the monetary policy fundamentals determine the expected future monetary policy stance, it is necessary to know the market participants' EFP of short-term interest rates. It is then necessary to analyze whether the factors in this process are the monetary policy fundamentals. To unfold the EFP requires obtaining the market expected interest

[8] Note that this formula is not explicitly used in the above-mentioned papers. Some of these papers focus on the level exchange rate and write the expression in terms of levels. It is shown here that if they compute the exchange rate change/return, the model's implied exchange rate can be expressed in this formula.

rates, identifying the variables determining them, and the functional form matching these variables to the expected interest rates.

Concerning the market expected future monetary policy stance, survey forecasts of interest rates from professionals are believed to represent subjective market expectations. We therefore use the survey data and further study the underlying EFPs that generate them. For countries where central banks follow a rule to set short-term interest rates and the public is well informed about this, it is natural to assume that the public incorporates the monetary policy rule fundamentals in their EFPs. However, we have to further identify the functional form of EFP, which is determined by forms of the variables, such as variables in levels or growth rate form, the length of the historical data incorporated for forecasting at each period, and additional variables not included in the general interest rate reaction functions but believed to be monitored by the central banks.

One way to determine the EFP is to generate interest rate forecasts from various models. If the number of models is large enough, a model can be found that produces an interest rate close enough to the consensus forecast, and this model can represent the EFP of the market participants. A natural starting point to mimic this learning process is to use a reduced-form VAR with time-varying parameters, which allows agents to learn new information and make a new forecast each period.[9]

Using the above strategy to identify EFP based on the consensus forecast is the main deviation of our paper from the previous literature in terms of treating expectations. This treatment assures that the EFPs in the model are not arbitrarily assumed and represent the perception of the market participants.

In this paper, we focus on the price of deutsche mark and euro relative to the U.S. dollar; therefore, the expected monetary policies of Germany, the euro area and the U.S. are investigated. The primary reason for choosing these two economies is that central banks in these economies are generally found to follow a Taylor-type rule when conducting monetary policy (Clarida, Gali and Gertler 1998). This helps to reduce the set of possible fundamentals that the agents incorporate in their expectation formation. In addition, because these economies are the focus of a large body of existing papers, analyzing the exchange rate between the deutsche mark and euro and the U.S. dollar allows a direct comparison with the previous literature.

[9] These are special cases of adaptive learning, see Evans and Honkapohja (2001).

In the next section, we discuss the consensus interest rate forecasts and the VAR learning models in further detail.

### 2.3.1 Consensus Interest Rate Forecasts

We use the survey forecast of short-term interest rates in Germany and the U.S. from consensus economics. Consensus economics surveys over 240 financial and economic institutes for their forecasts for their forecast for interest rate values with 3-month maturities in one quarter and one year ahead. The professional forecasters include all kinds of financial institutions and a small number of economic research institutes.

Our monthly observation of the consensus interest rate forecast starts in October 1989 and ends in February 2008. For each country, we take the mean of the interest rate forecasts from each institute as the representative value from the market participants in that country. Due to the euro launch, from January 1999 onward, we study the dynamics of the euro-U.S. dollar exchange rate. Therefore, the relevant economy for this exchange rate shifts from Germany to the entire euro area. The mean value for euro-area interest rates forecast is composed of forecasts in five euro-area economies: Germany, France, Italy, the Netherlands and Spain.

Figures 2.1 and 2.2 plot the 3-month and 12-month consensus forecast and the actual interest rates in the U.S..[10] The consensus forecast is systematically above or below the federal funds rate before the mid-1990s, which may suggest that there was room for the Federal Reserve to work on anchoring interest rate expectation during that period compared to the late 1990s. At the same time, this also implies that perfect foresight does not apply to these market participants. Therefore, using realized interest rates to represent their expected rates is potentially misleading and justifies the use of market expectations. Therefore, the next section examines the EFP by VAR learning.

### 2.3.2 VAR Learning

As discussed above, we start with VARs to study the interest rate EFPs of the agents in Germany/the euro area and U.S. The general form of VAR for each country is represented by the following equation:

$$\mathbf{x}_t = \boldsymbol{\mu} + \sum_{j=1}^{p} \boldsymbol{\phi}_{j,t} \mathbf{x}_{t-j} + \mathbf{u}_t. \tag{2.12}$$

[10] The months at the x-axis indicates the value of the interest rates the forecast is made for and the actual interest rate at that month.

**Figure 2.1:** U.S. Short-term Interest Rate Forecast (Forecast Horizon=3 Months)-pre Euro Era

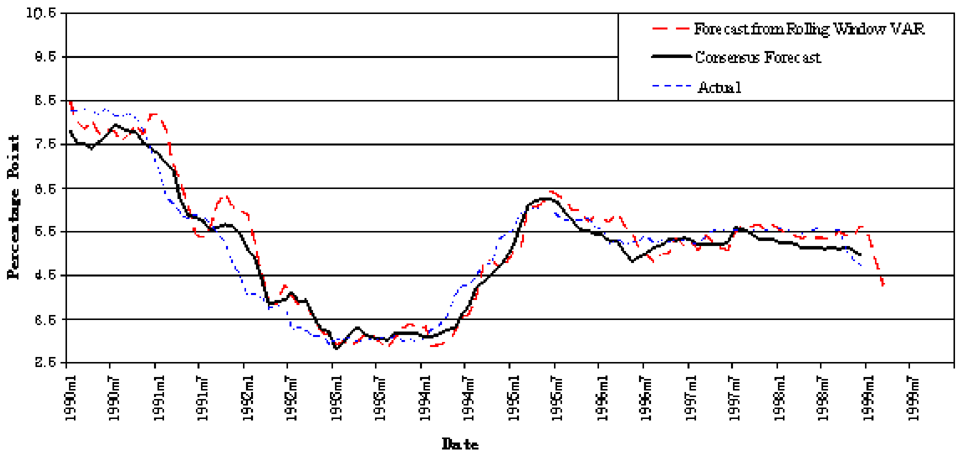
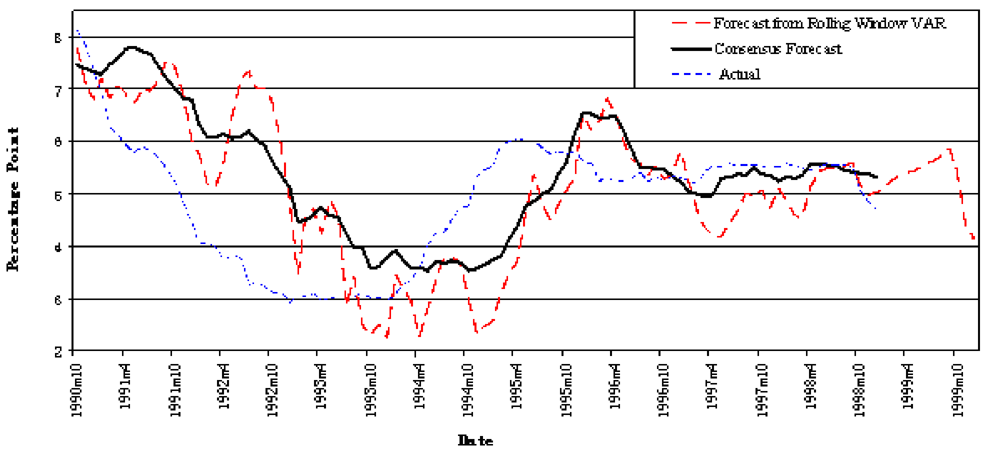



**Figure 2.2:** U.S. Short-term Interest Rate Forecast (Forecast Horizon=12 Months)-pre Euro Era



Equation 2.12 is an unrestricted VAR with time-varying parameters in $\mathbf{x}_t$ with lag $p$. $\mathbf{x}_t$ is a vector of short-term interest rate $i_t$ and other domestic variables determining $i_t$'s law of motion. $\mu$ denotes a vector of constant, and $\mathbf{u}_t$ is the vector of residuals. Note that the time-varying coefficients $\boldsymbol{\phi}_{j,t}$ allow the agents to update their beliefs about interest rates' law of motion each period. The VAR represents a learning mechanism for the agents about the central bank's monetary policy stance. We estimate this VAR using different specifications; the resulting models are the alternatives for the representative EFP . The specifications differ in the following respects.

1. The variables determine the interest rate dynamics in market participants' perceptions, which are included in . We start with Taylor-rule fundamentals as implied by Clarida, Gali and Gertler (1998). Because the Taylor rule is widely known, it is not too strong to assume that the agents in Germany or the euro area and the United States believe that relevant variables they incorporate in EFP are output gap (defined as deviation of industrial production from its HP filtered level) and inflation. In fact, both the level and growth rate of these two variables are alternatives for VAR learning specifications. In addition, given that the information set considered by central banks when taking their monetary policy is huge (literally hundreds of data series)[11] and this is likely to be known by the public, we do not exclude the possibility that agents incorporate information from a large number of other macroeconomic and financial variables. Therefore, we also adopt the factor-augmented VAR (FAVAR) based on Bernanke, Boivin, and Eliasz (2005) (BBE 05, hereafter) to generate the U.S. EFP alternatives. The following form of FAVAR is considered:

$$\begin{bmatrix} F_t \\ \mathbf{x}_t \end{bmatrix} = \sum_{j=1}^{q} \boldsymbol{\Xi}_{j,t} \begin{bmatrix} F_{t-j} \\ \mathbf{x}_{t-j} \end{bmatrix} + \upsilon_t \tag{2.13}$$

where $F_t$ denotes the vector of the unobserved factor, $\boldsymbol{\Xi}_{j,t}$ is the time-varying coefficient vector, $\upsilon_t$ is the residual and $q$ is the lag length. The factor is extracted from more than 70 macroeconomic and financial variables, as listed in Appendix 2.1.

2. Length of rolling windows. The length of rolling windows indicates the length of historical data the agents incorporate for their forecasts. Windows selected here are either fixed with length from 4 to 10 years, meaning the agents use the past 4 to 10 years' information up to the current period, or expanding, implying that the agents do not discard any historical

[11] Bernanke, Boivin, and Eliasz (2005), p.388.

data when they obtain the new one each period.

3. Lag length. Lag length ranges from 1 to 6. Lag length is either set by optimal lag selection criteria or set exogenously.

VARs with different combinations of the above features are estimated, and the forecasts of interest rates one quarter ahead $E_t^{var}(i_{t+3})$ and one year ahead $E_t^{var}(i_{t+12})$ are made each month. We thus obtain two time series of VAR generated forecasts of 3-month and 12-month interest rates. We pick the VAR that generates forecasts with the highest correlations with the consensus interest rates forecasts $E_t^{cf}(i_{t+3})$ and $E_t^{cf}(i_{t+12})$ and produce a standard deviation and autocorrelation close to those of the consensus forecasts[12]. This VAR is considered to represent the EFP of the market participants.

Our sample data span 1979:1 to 2008:2; details are available in Appendix 2.1. The establishment of the European central bank and the launch of the euro indicates that it is appropriate to assume that market participants form their euro-wide interest rate expectations incorporating euro-wide variables rather than German variables. Therefore, we split the sample into two periods. The first period spans 1979:1 to 1998:12, which is called the pre-euro era in the following sections, and the second spans 1999:1 to 2008: 2, which is the euro era.

### 2.3.3 Properties of the Market EFP

In this section, we discuss the properties of the VAR that represents the EFPs of market participants. The market EFP reveals whether the policy fundamentals is in the process of interest rate forecasts and, if so, how the information on fundamentals is processed.

We report the best-fit VARs for two countries in the pre- and post-euro eras, respectively; that is, there are four best-fit VARs. We first analyze the results for the former period.

#### EFP for Pre-euro Monetary Policy

Our consensus forecast data are available from 1989:10 onwards, so the 3-month interest rate forecasts being compared for the pre-euro era are for 1990:1 to 1998:12, and the 12-month forecasts are for 1990:10 to 1998:12.

The best VAR for the United States is a six-year fixed-rolling window VAR with four lags,

[12] We use lexicographic preference, the matches with the 3-month forecast is ordered first and the one for 12-month forecast is placed to the second order.

**Table 2.1:** Comparison between the U.S. Interest Rate Forecast from Best-fit VAR and Consensus in Pre-euro Era

| U.S. | Correlation Coefficient (Consensus, VAR) | Standard Deviation | | Auto Correlation (of Lag One) | |
|---|---|---|---|---|---|
| | | Consensus | VAR | Consensus | VAR |
| 3m ahead | 0.98 | 1.33 | 1.45 | 0.97 | 0.96 |
| 12m ahead | 0.95 | 1.13 | 1.38 | 0.97 | 0.92 |

including federal funds rate $i_t^{us}$, output (industrial production) gap, $\widehat{y}_t^{us}$ and inflation $\pi_t^{us}$. The industrial production (IP) gap is constructed as the IP deviation of the HP filtered IP. Table 2.1 shows the properties of this VAR model.

Concerning the 3-month forecast, the forecast generated from VAR has a correlation of 0.98 with the consensus forecast. Its volatility also matches the volatility of the consensus forecast well. Because we find that the consensus interest rate forecast is quite persistent with a lag one auto-correlation of 0.97, we also attempt to determine whether the VAR forecast reproduces this property. The auto correlation of lag one reaches 0.96, which confirms that the VAR-generated forecast also does a good job. Figure 2.1 shows that the VAR forecast tracks the consensus forecast very closely, especially from 1992 on. For the first two years in the 1990s, we observe that some deviations in the VAR forecast from consensus forecast are relatively larger. This may be because there were structural changes in the mid- to late-1980s, leading agents to use more recent information to form their forecasts. Therefore, forecasts based on the average relationship for the last six years are less accurate for reproducing the agents' beliefs regarding these changes.

For the 12-month forecasts, the correlation between the forecast generated from VAR and the one from consensus is lower than the 3-month forecast but still higher than 0.9. The persistency property of the consensus forecast is matched well. However, the VAR forecast has a higher volatility than the consensus forecast, which can be shown in table 2.1 and figure 2.2. Furthermore, the relative volatility of the VAR forecast to the consensus forecast is higher for the 12-month case than for the 3-month case.[13]

One fact worth mentioning is that the FAVAR, which incorporates a large amount of information on macroeconomic and financial variables, does not generate a higher correlation than the parsimonious VAR does. Table 2.2 comparison between the best-fit FAVAR forecast and the consensus interest rate forecast.

[13] This may imply that the EFP generating 3-month forecasts is different from the one generating 12-month forecasts. There is room for future research on this issue. For this paper, we assume the forecast for all horizons is generated by the same EFP.

**Table 2.2:** Comparison between the U.S. Interest Rate Forecast from Best-fit FAVAR and Consensus in Pre-euro Era

| U.S. | Correlation Coefficient (Consensus, FAVAR) | Standard Deviation | | Auto Correlation (of Lag One) | |
|---|---|---|---|---|---|
| | | Consensus | FAVAR | Consensus | FAVAR |
| 3m ahead | 0.98 | 1.33 | 1.48 | 0.97 | 0.95 |
| 12m ahead | 0.84 | 1.33 | 1.45 | 0.97 | 0.89 |

Note: The FAVAR that generates an interest rate forecast with the highest correlation with the consensus forecast is in three observed variables $\widehat{y}$ , $\pi$, $i$ and two common factors.

**Table 2.3:** Comparison between the U.S. Interest Rate Forecast from VARs and Consensus in Pre-euro Era

| Rolling Window | Variables | Lag | Correlation Coefficient (Consensus,VAR) 3-month | Correlation Coefficient (Consensus,VAR) 12-month | Standard Deviation (VAR) 3-month | Standard Deviation (VAR) 12-month |
|---|---|---|---|---|---|---|
| Expanding window | $\widehat{y}_t^{us}, \pi_t^{us}, i_t^{us}$ | 4 | 0.9208 | 0.8994 | 1.5572 (1.334) | 1.8378 (1.326) |
| Expanding window* | $\widehat{y}_t^{us}, \Delta\pi_t^{us}, \Delta i_t^{us}$ | 3 | 0.9333 | 0.8849 | 1.5449 (1.334) | 1.7588 (1.326) |
| Expanding window** | $\widehat{y}_t^{us}, \pi_t^{us}, i_t^{us}$ | 4 | 0.9208 | 0.8994 | 1.5572 (1.6901) | 1.8378 (1.3195) |
| 5-year window | $\widehat{y}_t^{us}, \pi_t^{us}, i_t^{us}$ | 4 | 0.9800 | 0.8108 | 1.5052 (1.6901) | 1.7198 (1.3195) |
| 6-year window | $\widehat{y}_t^{us}, \pi_t^{us}, i_t^{us}$ | 2 | 0.9745 | 0.8965 | 1.4403 (1.334) | 1.3891 (1.326) |
| 6-year window | $\widehat{y}_t^{us}, \pi_t^{us}, i_t^{us}$ | 3 | 0.9783 | 0.9259 | 1.4644 (1.334) | 1.4772 (1.326) |
| 4-year window | $\widehat{y}_t^{us}, \Delta\pi_t^{us}, \Delta i_t^{us}$ | 2 | 0.9889 | 0.8850 | 1.9071 (1.6901) | 2.2711 (1.3195) |

Note: The number in () denote the value for consensus forecast. $\widehat{y}$ is the output gap $\pi$ is the inflation rate, and $i$ is the short-term interest rate. * for first forecast is based on a VAR of the first 6-year data. ** for first forecast is based on a VAR of the first 5-year data.

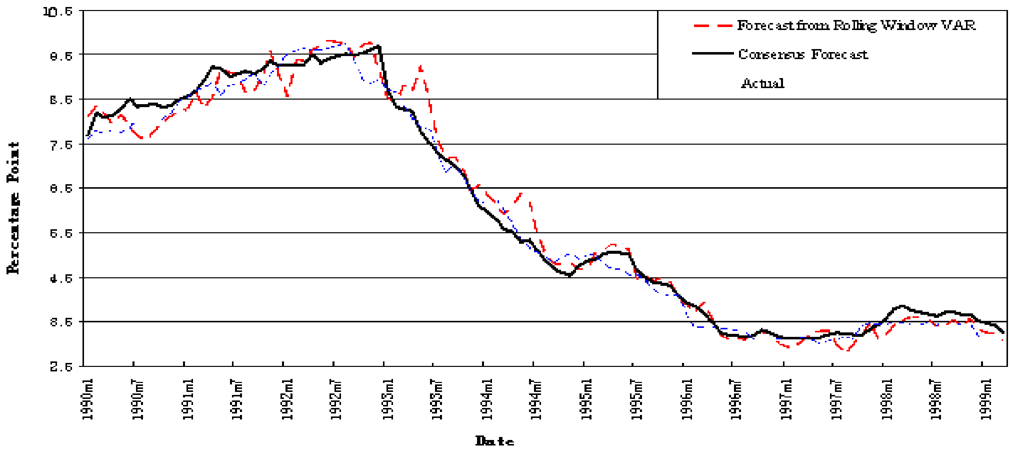
In summary, in the 1990s, U.S. market participants tended to use the information on output gap and inflation to form their expectations of future monetary policy. They perceived frequent structural changes in policy and incorporated only recent data to form their expectations. The relatively low correlation generated from the expanding window VAR in table 2.3 confirms this conjecture.

The best-fit VAR for Germany comes from the expanding window model with four lags, where the first forecast is made from the first six-year data. Variables included are output (industrial production) gap, $\widehat{y}_t^{de}$, inflation growth rate, $\Delta\ \pi_t^{us}$, and short-term interest rate changes, $\Delta\ i_t^{us}$. Interest rate forecasts are made by transforming the forecast from first difference to levels. Table 2.4 shows that the correlation between VAR and consensus forecast reaches 0.99 for the 3-month forecast and 0.95 for the 12-month forecast. A visual comparison

**Table 2.4:** Comparison between the German Interest Rate Forecast from Best-fit VAR and Consensus in Pre-euro Era

| Germany | Correlation Coefficient | Standard Deviation | | Auto Correlation (of Lag One) | |
|---|---|---|---|---|---|
| | (Consensus, VAR) | Consensus | VAR | Consensus | VAR |
| 3m ahead | 0.99 | 2.42 | 2.45 | 0.99 | 0.98 |
| 12m ahead | 0.95 | 2.03 | 2.59 | 0.99 | 0.98 |

**Figure 2.3:** German Short-term Interest Rate Forecast (Forecast Horizon=3 Months)-pre Euro Era




is provided by figures 2.3 and 2.4. From table 2.5, we know that the same VAR with three lags or with a six-year rolling window perform similarly. This indicates that forecasts based on the average relationship across all historical periods are similar to those using the most recent periods. This further indicates that agents do not perceive frequent structural changes to monetary policy and that the Bundesbank conducts a stable monetary policy and maintains good credibility. Volatility matches for 3-month forecasts perform well, and the volatility of the VAR 12-month forecast is a bit higher than the consensus forecast. We can see from figure 2.4 that the VAR forecast is more volatile before 1995, but it catches the trend and the turning points. The high persistency of the consensus forecast is well captured by the VAR forecasts.Note that in addition to the expanding window, the best-fit model for Germany differs from the one for the U.S. in the form of variables entering the VAR. The best-fit variables for Germany are interest rate differences, output gaps, and inflation growth, which means that interest rate forecasts are made by converting the interest rate difference to level. The likely reason for this is that the German consensus forecast and the actual interest rate are highly persistent processes, with a lag one autocorrelation equal to 0.99 (Table 2.6).

**Figure 2.4:** German Short-term Interest Rate Forecast (Forecast Horizon=12 Months)-pre Euro Era

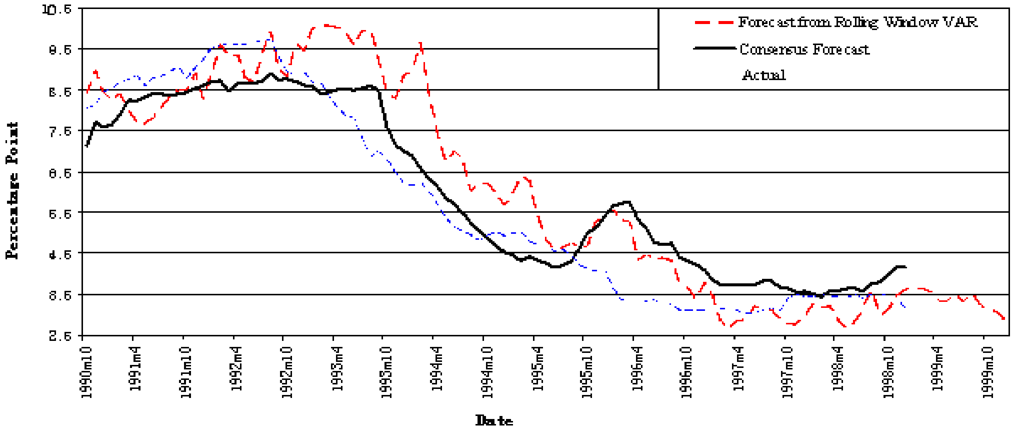



**Table 2.5:** Comparison between the German Interest Rate Forecast from VAR and Consensus in Pre-euro Era

| Rolling Window | Variables | Lag | Correlation Coefficient (Consensus,VAR) 3-month | Correlation Coefficient (Consensus,VAR) 12-month | Standard Deviation (VAR) 3-month | Standard Deviation (VAR) 12-month |
|---|---|---|---|---|---|---|
| Expanding window** | $\widehat{y}_t^{de}$ , $\Delta\pi_t^{de}$ , $\Delta i_t^{de}$ | 2 | 0.9847 | 0.9108 | 1.0261 (0.9261) | 1.2339 (0.8398) |
| Expanding window | $\widehat{y}_t^{de}$ , $\Delta\pi_t^{de}$ , $\Delta i_t^{de}$ | 3 | 0.9909 | 0.9562 | 2.4054 (2.4200) | 2.4636 (2.0254) |
| 4-year window | $\widehat{y}_t^{de}$ , $\Delta\pi_t^{de}$ , $\Delta i_t^{de}$ | 4 | 0.9734 | 0.8990 | 1.0552 (0.9261) | 1.4416 (0.8398) |
| 4-year window | $\widehat{y}_t^{de}$ , $\pi_t^{de}$ , $i_t^{de}$ | 4 | 0.9516 | 0.6498 | 0.9909 (0.9261) | 1.5787 (0.8398) |
| 6-year window | $\widehat{y}_t^{de}$ , $\Delta\pi_t^{de}$ , $\Delta i_t^{de}$ | 4 | 0.9896 | 0.9518 | 2.4504 (2.4200) | 2.5900 (2.0254) |

Note: $\widehat{y}$ is the output gap $\pi$ is the inflation rate, and $i$ is the short-term interest rate. * for first forecast is based on a VAR of the first 6-year data. ** for first forecast is based on a VAR of the first 5-year data.

Making an interest rate forecast from a VAR in the difference of these variables means that the level interest rate is an I(1) process; therefore, the time series of VAR forecast produced in each month is also an I(1) process so that they can match the high persistency. In contrast, the U.S. federal funds rate and its consensus forecast are less persistent than the German short-term rate, so a forecast generated from stationary-level VARs matches the consensus forecasts well.

**Table 2.6:** Statstical Properties of Short-term Interest Rates in Pre-euro Era

| Countries | Mean | Standard Deviation | Auto Correlation of lag | | | |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 4 | 10 |
| U.S. | 5.16 | 1.46 | 0.97 | 0.93 | 0.84 | 0.46 |
| Germany | 5.93 | 2.41 | 0.99 | 0.98 | 0.95 | 0.83 |

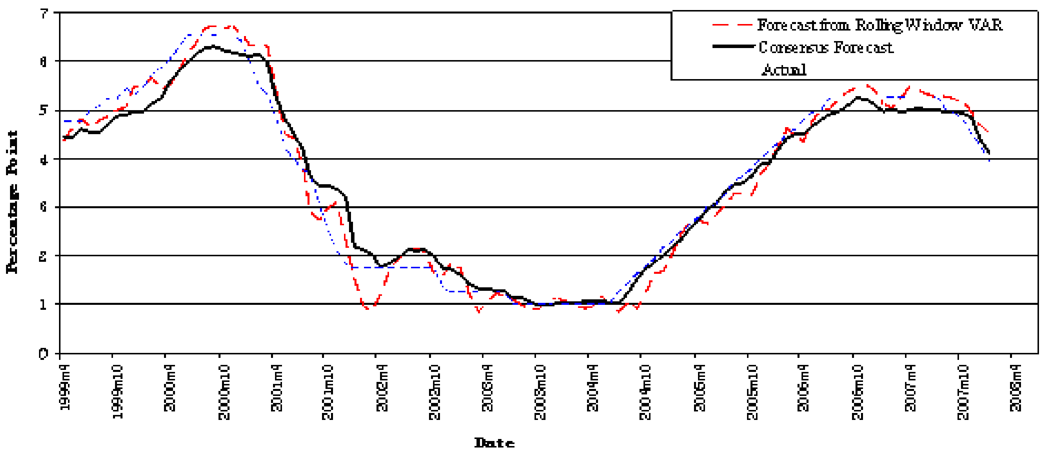
Summarizing the learning mechanism for the EFP for U.S. and German interest rates from 1990 to 1998, we find that core variables incorporated into the market participants' EFP are the output gap, inflation, and lag interest rate. VAR in the level of these variables generates the closest interest rate forecasts to the consensus forecast for the U.S., while VAR in the difference of these variables generates the best-matching interest rate forecasts. U.S. agents tend to perceive frequent structural changes of monetary policy, and the German agents believe the Bundesbank follows a stable policy rule.

#### EFP for Euro Era Monetary Policy

The interest rate forecasts for comparison in the euro era cover the horizon from 1999:4 to 2008:2. We avoid the crisis period from 2008 onward because it is publicly known that during the crisis period, central banks used non-standard measures that deviated from previous rules. Therefore, it is difficult to use a VAR that implies the rule-based expectation formation process to match the consensus forecast in this period.

For the U.S., the best VAR is a five-year expanding window VAR with four lags, including domestic output (industrial production) gap, $\widehat{y}_t^{us}$, inflation growth $\Delta\ \pi_t^{us}$ and the federal funds rate difference, $\Delta\ i_t^{us}$. The expanding window implies that the market participants perceive a stable monetary policy rule from the Federal Reserve in the late 1990s and the first eight years in the twenty-first century, which represents a significant difference compared to the previous ten years. In the euro era, the volatility and persistency of U.S. consensus interest

**Figure 2.5:** U.S. Short-term Interest Rate Forecast (Forecast Horizon=3 Months)-Euro Era




rate forecasts and actual interest rates are larger than the pre-euro era (Table 2.7 and 2.8), so the VARs in differences of variables capture the consensus forecast best. However, the VAR forecasts have a larger standard deviation than the consensus forecasts. Figures 2.5 and 2.6 show comparisons with 3- and 12-month forecasts. The trend of consensus forecasts are mostly matched by the VAR forecast, but the volatility that this model generates is higher than the consensus forecast.

**Table 2.7:** Statstical Properties of Short-term Interest Rates in Pre-euro Era

| Countries | Mean | Standard Deviation | Auto Correlation of lag | | | |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 4 | 10 |
| U.S. | 3.57 | 1.85 | 0.99 | 0.98 | 0.93 | 0.65 |
| Germany | 3.23 | 0.96 | 0.98 | 0.94 | 0.90 | 0.52 |

**Table 2.8:** Comparison between the U.S. Interest Rate Forecast from Best-fit VAR and Consensus in Euro Era

| U.S. | Correlation Coefficient | Standard Deviation | | Auto Correlation (of Lag One) | |
|---|---|---|---|---|---|
| | (Consensus, VAR) | Consensus | FAVAR | Consensus | FAVAR |
| 3m ahead | 0.99 | 1.69 | 1.89 | 0.99 | 0.99 |
| 12m ahead | 0.95 | 1.31 | 2.24 | 0.98 | 0.97 |

VAR interest rate forecasts from the same specifications also match the German consensus forecast very well. Although the VAR forecasts generate a higher standard deviation than

**Figure 2.6:** U.S. Short-term Interest Rate Forecast (Forecast Horizon=12 Months)-Euro Era

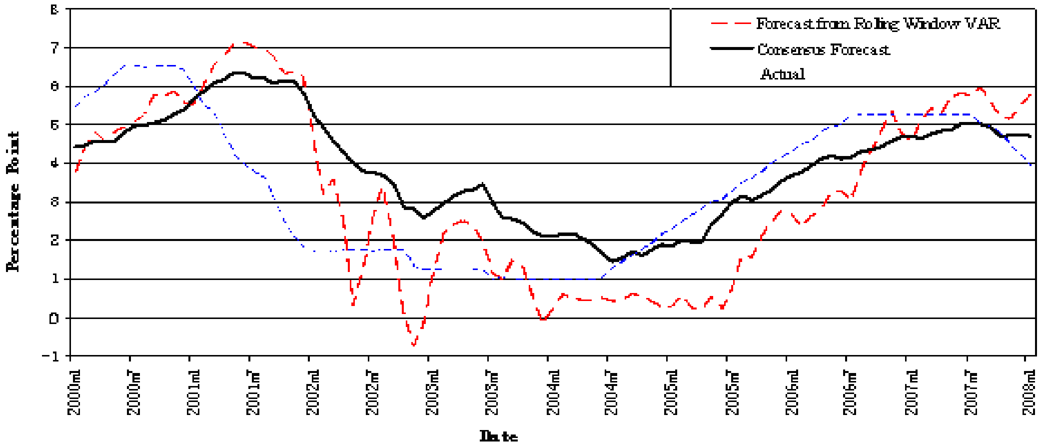



**Table 2.9:** Comparison between the U.S. Interest Rate Forecast from VARs and Consensus in the Euro Era

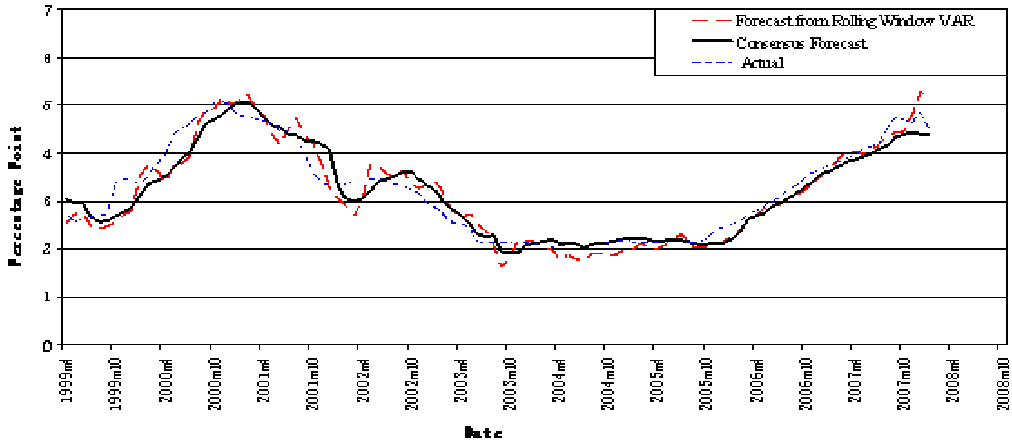
| Rolling Window | Variables | Lag | Correlation Coefficient (Consensus,VAR) 3-month | 12-month | Standard Deviation (VAR) 3-month | 12-month |
|---|---|---|---|---|---|---|
| Expanding window** | $\hat{y}_t^{us}$ , $\pi_t^{us}$ , $i$ | 4 | 0.9893 | 0.8835 | 1.7999 (1.690) | 1.6919 (1.3194) |
| 5-year window | $\hat{y}_t^{us}$ , $\pi_t^{us}$ , $i_t^{us}$ | 4 | 0.9867 | 0.6766 | 1.8220 (1.690) | 2.2222 (1.3194) |
| 5-year window | $\hat{y}_t^{us}$ , $\Delta\pi_t^{us}$ , $\Delta i_t^{us}$ | 4 | 0.9890 | 0.8850 | 1.9071 (1.6900) | 2.2711 (1.3194) |
| 5-year window | $\hat{y}_t^{us}$ , $\pi_t^{us}$ , $i_t^{us}$ | 3 | 0.6207 | 0.5141 | 1.897 (1.690) | 2.242 (1.3194) |
| 5-year window | $\hat{y}_t^{us}$ , $\Delta\pi_t^{us}$ , $\Delta i_t^{us}$ | 2 | 0.9890 | 0.8850 | 1.907 (1.690) | 2.271 (1.3194) |
| 4-year window | $\hat{y}_t^{us}$ , $\pi_t^{us}$ , $i_t^{us}$ | 4 | 0.9736 | 0.9340 | 0.9973 (1.690) | 1.0862 (1.3194) |
| 4-year window | $\hat{y}_t^{us}$ , $\Delta\pi_t^{us}$ , $\Delta i_t^{us}$ | 4 | 0.9871 | 0.8841 | 1.958 (1.690) | 2.883 (1.3194) |

Note: $\hat{y}$ is the output gap $\pi$ is the inflation rate, and $i$ is the short-term interest rate. * for first forecast is based on a VAR of the first 6-year data. ** for first forecast is based on a VAR of the first 5-year data.

**Table 2.10:** Comparison between the German Interest Rate Forecast from Best-fit VAR and Consensus in the Euro Era

| Germany | Correlation Coefficient | Standard Deviation | | Auto Correlation (of Lag One) | |
|---|---|---|---|---|---|
| | (Consensus, FAVAR) | Consensus | VAR | Consensus | VAR |
| 3m ahead | 0.97 | 0.92 | 0.99 | 0.98 | 0.96 |
| 12m ahead | 0.93 | 0.84 | 1.09 | 0.98 | 0.95 |

**Figure 2.7:** German Short-term Interest Rate Forecast (Forecast Horizon=3 Months)-Euro Era




the consensus forecasts (Table 2.10), they shows that both the 3- and 12-month forecasts are less volatile than in the pre-euro era, which is consistent with the same changes to the consensus forecasts. Figures 2.7 and 2.8 show that 3-month forecasts track the consensus tightly and that the 12-month forecasts track the consensus forecasts closely (although they are a bit volatile) in the first half of the 2000s and mostly catch the trend for the recent-year movements.

To summarize the findings, the expectation formation process of future monetary policy is a function of the s, namely, output gap, inflation and interest rates. Other information seems to be less crucial for interest rate forecasts from the perspective of the market participants. However, the functional forms vary by time, country and other factors. In the perception of the market participants, the monetary policy regime is changing over time, and this evidence is stronger in the U.S. than it is in Germany. Therefore, exercises assuming that agents perceive constant-parameter Taylor rules or impose arbitrarily assumed VAR learning processes on the agents are less likely to reflect the actual EFP of the market participants.

**Figure 2.8:** German Short-term Interest Rate Forecast (Forecast Horizon=12 Months)-Euro Era

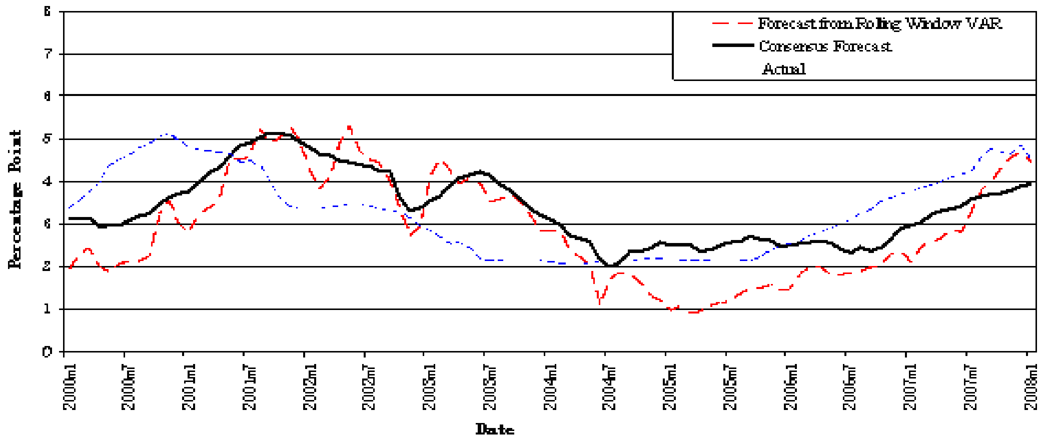



**Table 2.11:** Comparison between the German Interest Rate Forecast from VARs and Consensus in the Euro Era)

| Rolling Window | Variables | Lag | Correlation Coefficient (Consensus,VAR) 3-month | Correlation Coefficient (Consensus,VAR) 12-month | Standard Deviation (VAR) 3-month | Standard Deviation (VAR) 12-month |
|---|---|---|---|---|---|---|
| Expanding window | $\widehat{y}_t^{de}$ , $\pi_t^{de}$ , $i_t^{de}$ | 4 | 0.9710 | 0.9310 | 0.9609 (0.9260) | 0.9460 (0.9398) |
| Expanding window | $\widehat{y}_t^{de}$ , $\Delta\pi_t^{de}$ , $\Delta i_t^{de}$ | 4 | 0.9260 | 0.8397 | 0.9973 (0.9260) | 1.086 (0.9398) |
| 5-year window | $\widehat{y}_t^{de}$ , $\pi_t^{de}$ , $i_t^{de}$ | 4 | 0.9531 | 0.6361 | 0.974 (0.9260) | 1.268 (0.9398) |
| 5-year window | $\widehat{y}_t^{de}$ , $\Delta\pi_t^{de}$ , $\Delta i_t^{de}$ | 4 | 0.9771 | 0.8912 | 0.043 (0.9260) | 1.350 (0.9398) |
| 5-year window | $\widehat{y}_t^{de}$ , $\pi_t^{de}$ , $i_t^{de}$ | 3 | 0.9546 | 0.6431 | 0.9809 (0.9260) | 1.2934 (0.9398) |
| 4-year window | $\widehat{y}_t^{de}$ , $\pi_t^{de}$ , $i_t^{de}$ | 4 | 0.9734 | 0.8990 | 1.0552 (0.9260) | 1.4416 (0.9398) |
| 4-year window | $\widehat{y}_t^{de}$ , $\pi_t^{de}$ , $\Delta i_t^{de}$ | 4 | 0.9515 | 0.6498 | 0.9909 (0.9260) | 1.5787 (0.9398) |

Note: $\widehat{y}$ is the output gap $\pi$ is the inflation rate, and $i$ is the short-term interest rate. * for first forecast is based on a VAR of the first 6-year data. ** for first forecast is based on a VAR of the first 5-year data.

## 2.4 Explanatory Power of the Monetary Policy Expectations

After obtaining the expected future interest rates for different horizons, the expected sum of interest rate differentials between Germany and the U.S can be constructed and the explanatory power can be further evaluated. Because the representative EFP allows us to compute the expected interest rates in all horizons, we can go beyond the forecast horizons provided in the survey data. Therefore, we compute $E_t \sum_{i=0}^{k-1} \left( i^h_{t+ih} - i^{h*}_{t+ih} \right)$ for the horizons of three months, six months, one year, two years and four years at each point in time. Let

$$\Delta \widehat{s}_{t,t+kh} = E_t \sum_{i=0}^{k-1} \left( i^h_{t+ih} - i^{h*}_{t+ih} \right) . \tag{2.14}$$

We call $\Delta \widehat{s}_{t,t+kh}$ the (market expectation) model-implied exchange rate return. Following Engel and West (2006) and Mark (2009), one of the measurements we use to evaluate the model's explanatory power is the correlation between the model-implied exchange rate return and the actual exchange rate return. Therefore, for each horizon, we compute the corresponding correlation, which is defined as

$$corr_{kh} = cor(\Delta \widehat{s}_{t,t+kh}, \Delta s_{t,t+kh}). \tag{2.15}$$

The correlation reveals the extent to which the model-implied exchange rate return co-moves with the actual exchange rate return. If the monetary policy fundamentals influence the exchange rate change through expectations of monetary policy, the correlation of the expected interest rate differential and the actual exchange rate return should not be low.

In addition to the co-movement, we would like to know how much volatility in the actual exchange rate return can be explained by the expected interest rate differential. Therefore, we compute the relative volatility of the model-implied exchange rate return to the actual exchange rate return, as follows

$$relvol_{kh} = \frac{var(\Delta \widehat{s}_{t,t+kh})}{var(\Delta s_{t,t+kh})}. \tag{2.16}$$

The rest of the return volatility should attribute to the volatility of currency risk premium, which is the third term of equation 2.4. Note that modeling interest rate forecast can clean up the interest rate expectation measurement errors in this term, so the currency risk

**Table 2.12:** Model Comparison to Mark (2009) and Engel and West (2006) -Pre-euro Era

| 1979-1998 | | Market Expectation | Constant Gain Learning Mark (2009) | Rational Expectation EW (2006) |
|---|---|---|---|---|
| 1-quarter return | corr | 0.10 | 0.08 | -0.12 |
| | rel vol | 0.015 | 0.749 | 0.712 |
| half year return | corr | 0.13 | - | 0.03 |
| | rel vol | 0.028 | - | 0.59 |
| one-year return | corr | 0.21 | -0.14 | 0.16 |
| | rel vol | 0.056 | 0.614 | 0.47 |
| two-year return | corr | 0.27 | -0.074 | 0.09 |
| | rel vol | 0.134 | 0.576 | 0.57 |
| four-year return | corr | 0.58 | 0.350 | 0.03 |
| | rel vol | 0.912 | 0.534 | 1.17 |

Note: *corr* is the correlation of the model implied exchange rate and actual exchange rate change. *rel vol* is the part of exchange rate return volatility that is explained by the model.

premium only include liquidity premium, portfolio adjustments[14] and so on, and excludes this measurement errors.

### Explanatory Power in the Pre-euro Era

The correlations for pre-euro era data are shown in the first column of table 2.12. The model-implied exchange rate return is moderately correlated with the actual return for the short horizon and strongly correlated for the medium horizon. In particular, the correlation between 3-month exchange rate returns is 0.1. This correlation increases along with the return horizon; it reaches 0.21 for the one-year return and reaches a value of nearly 0.6 for the four-year return.

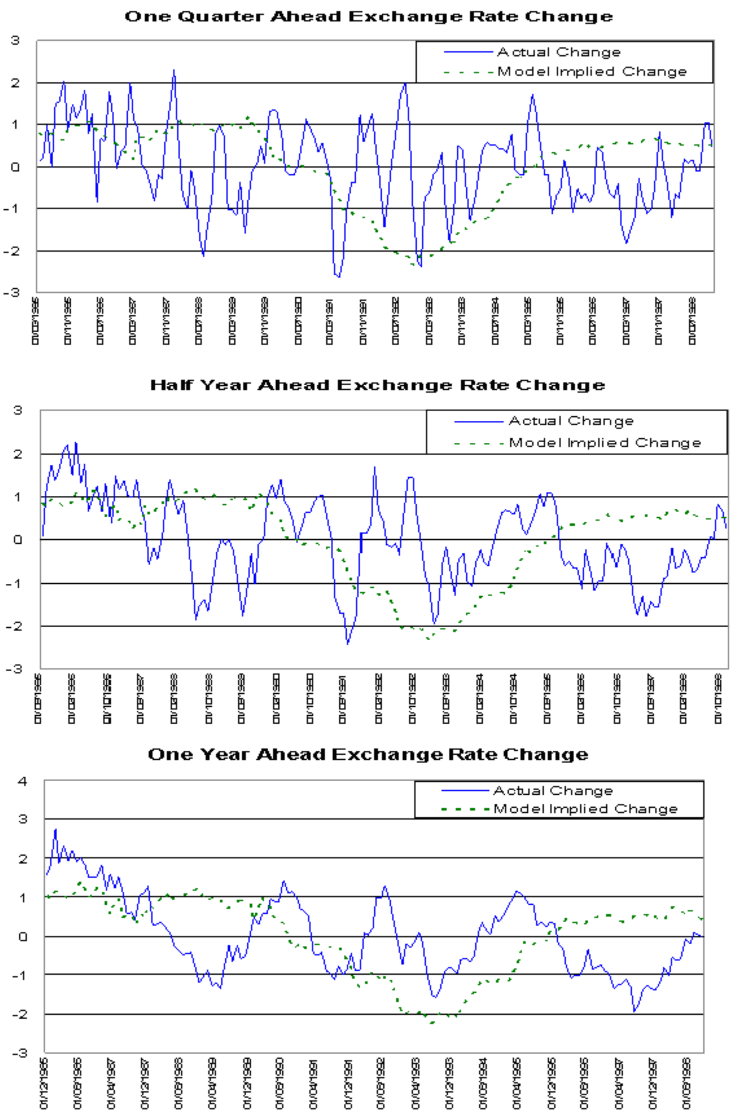
The volatility ratio of the model-implied return relative to the actual return is quite small for the horizon up to two years. However, it starts to increase for returns over a 3-year horizon and reaches 0.9 for the 4-year horizon return. This result suggests that most of the volatility of the short-horizon exchange rate return comes from the volatility of currency risk premium and the exchange rate forecast error. However, the volatility of returns over medium horizon of three to four years is driven by the volatility of expected future monetary policies.

Figure 2.9 and 2.10 plot the comparison between the exchange rate return implied by the market expectation model and the actual exchange rate return over different horizons[15]. The short-term returns over three to six months are dominated by noises, and the model-implied

[14] See Engel and West (2010) for details.

[15] To compare the co-movements, the exchange rate returns are standardized to have zero means and standard deviations of one.

**Figure 2.9:** Exchange Rate Return Comparison_1 (DMark per U.S. dollar)

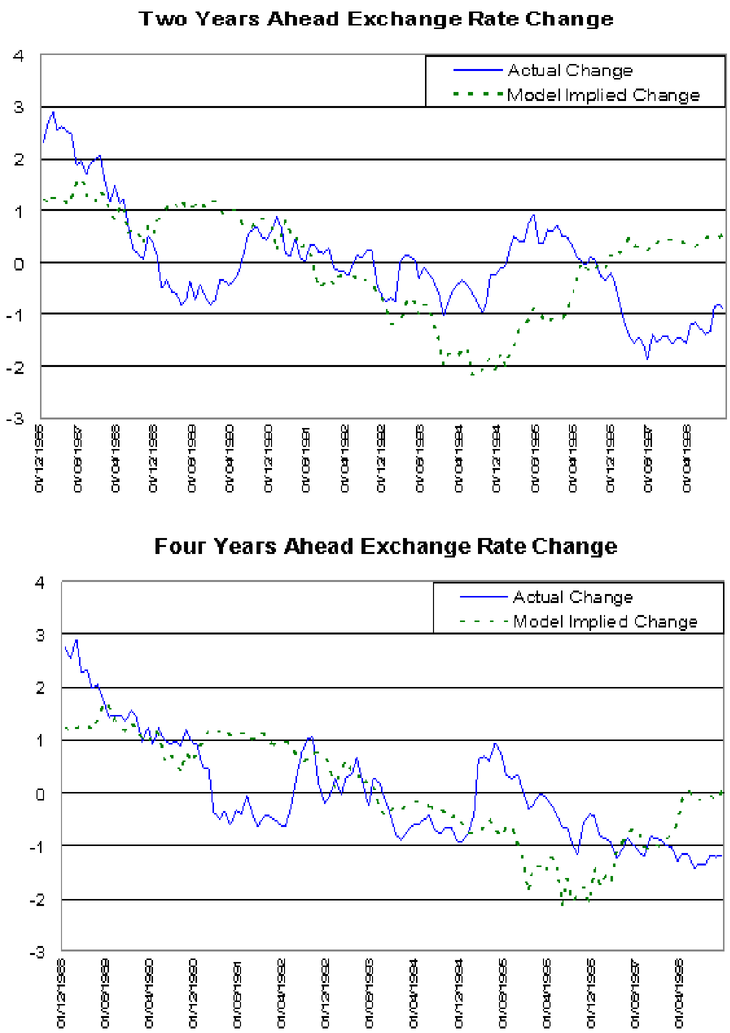



return is less capable of capturing the fluctuations. For the longer horizons, noises add up, and the model-implied exchange rate returns catch the main trend of the actual movements. For instance, the model-implied return over four-year horizons tracks the actual return very well during the period from late 1989 to late 1999 and from 1992 to 1994.

This result indicates that we observe an impact of monetary policy fundamental on exchange rate change through the channel of monetary policy expectations. It also sheds light on the problem in the literature that the policy fundamentals have little influence on exchange rate change through this channel despite influencing the exchange rate level.[16] The fact that

[16] The literature includes Engel and West (2006) and Mark (2009), where a moderate correlation is found

**Figure 2.10:** Exchange Rate Return Comparison_2 (DMark per U.S. dollar)



the correlation increases with the return horizon also suggests that the UIP is more likely to hold for assets with longer maturity.

What do we gain from the consensus based expectation measurement compared to the existing literature, in addition to cleaning up the expectation measurement errors in the currency risk premium we mentioned above? We discuss this in the following by comparing with EW06 and Mark (2009) in table 2.12.[17] Recall that EW06 assumes constant Taylor rules for both countries and rational expectation while Mark (2009) assumes a constant gain learning environment for the market participants. The comparison shows that for each horizon, the correlation from the market expectation model is much higher than what have been found in EW06 and Mark (2009). These two papers find that the model generated exchange return barely correlates with the actual return over short horizon and only moderately correlates with it over longer horizon (with a correlation of 0.35). This result indicates that with market based expectations of monetary policy, , the policy fundamentals are moderately able to explain the movement of exchange rate over the short horizons and are very influential over longer horizons.

#### Explanatory Power in the Euro Era

The euro-era correlations between the model-implied return and the actual return differ from the pre-euro era in two respects: larger magnitude and negative signs. The results are shown in table 2.13. In particular, the magnitude of the correlation is 0.38 for 3-month return and increases to 0.66 for the 2-year return before decreasing to 0.4 for the 4-year return. The larger magnitude means that the expected future monetary policy stance has more co-movements with the actual exchange rate return, thus leading the fundamental effects of monetary policy on the exchange rate through the expectation of monetary policy to be stronger. The negative correlations imply that a higher expected sum of future euro-area interest rates than the U.S. counterpart is associated with an appreciation of the euro relative to the U.S. dollar. The same holds true for the expected sum of future U.S. interest rates. This implies that the UIP does not hold. It also suggests that the sum of the expected risk premium (the second term of equation 2.4) and the exchange rate forecast errors (the third term of equation 2.4) is positive. This finding is in contrast to the uncovered interest parity prediction but consistent with

for the exchange rate level while very low correlations are found for exchange rate changes.

[17] Since EW06 and Mark (2009) cover the same sample period, we replicate EW06 and take the quarterly estimate directly from Mark (2009) for comparison.

**Table 2.13:** Properties of Model Implied Exchange Rate Return with Market Participants' Expectation-Euro Era

| | | |
|---|---|---|
| 1-quarter return | corr | -0.38 |
| | rel vol | 0.006 |
| half year return | corr | -0.52 |
| | rel vol | 0.013 |
| one-year return | corr | -0.60 |
| | rel vol | 0.025 |
| two-year return | corr | -0.66 |
| | rel vol | 0.061 |
| four-year return | corr | -0.40 |
| | rel vol | 0.81 |

Note: corr is the correlation of the model implied exchange rate and actual exchange rate change. rel vol is the part of exchange rate return volatility that is explained by the model.

the large body of empirical evidence documenting this interest-parity puzzle.[18] It is worth exploring the change from the UIP's likelihood of holding for assets with longer maturity in the pre-euro era to the UIP not holding at all. This may also indicate that the excess return for high interest rate currency changes from possibly negative to positive after the euro launch.

The volatility of the return explained by the market expectation model has a pattern similar to the one in the Pre-euro Era but is smaller. We plot the actual exchange rate return and the negative model-implied return over different horizons in figure 2.11 and 2.12. We flip the sign of for the sake of visualizing the co-movements. For this sample period, the negative model-implied changes track the trend of the actual changes quite well, even for short horizons. The co-movement of the two time series is strongest over the two-year horizon, when they have the highest correlation. Taking the two-year return as an example, the model-implied return tracks the actual return very closely over the entire sample period; in particular, it matches the turning points in April and August 2003 and December 2006 very well.

Therefore, we can conclude that in the pre-euro era, the market expectation model-implied exchange rate moderately explain the short-term euro-dollar exchange rate return. In the euro era, in terms of correlation, the model-implied return has moderate explanatory power for the short term and high explanatory power for medium- to long-term returns. The correlation changes from being positive in the pre-euro era to negative in the euro era. However, this

[18] Papers include Fama (1984), Flood and Rose (1996) etc. Lustig and Verdelhan (2007) propose explanation of the positive excess return in terms of consumption growth and risk hedging.

**Figure 2.11:** Exchange Rate Return Comparison_3 (euro per U.S. dollar)

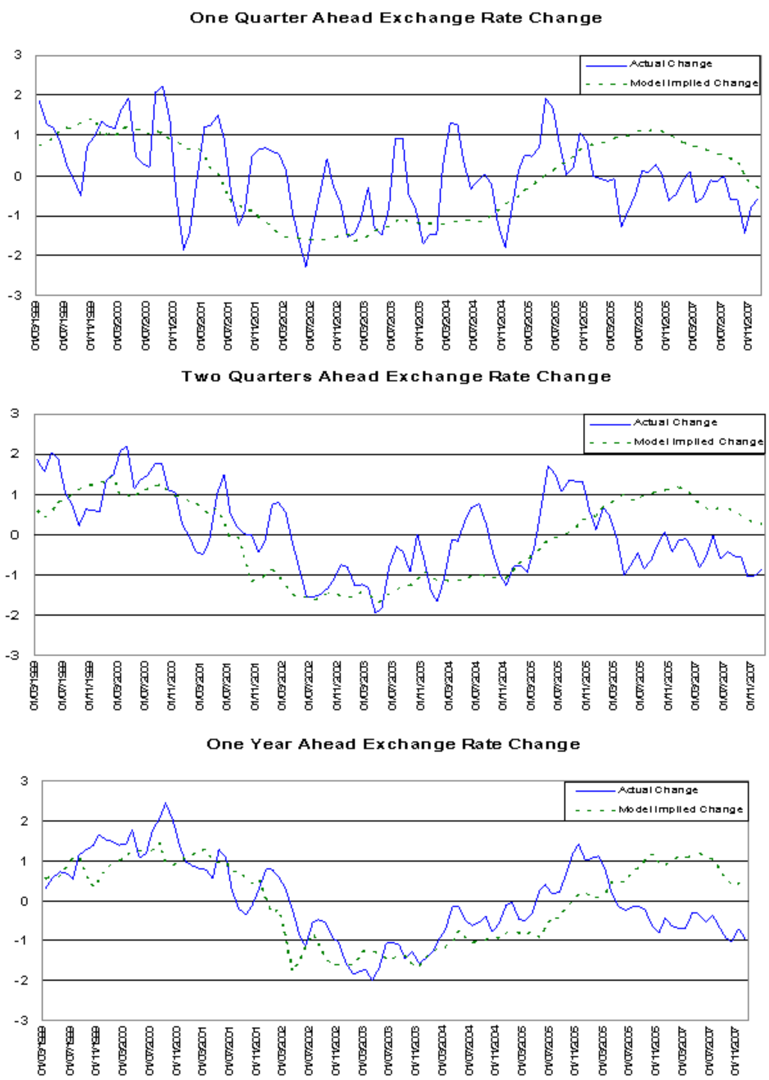
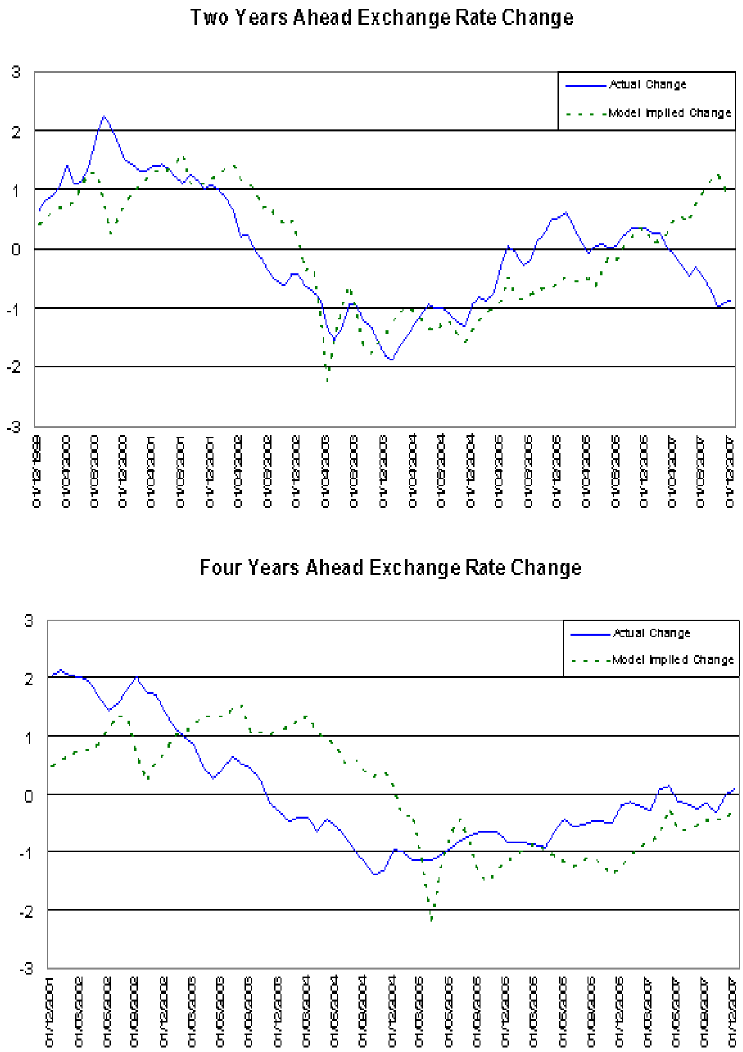


**Figure 2.12:** Exchange Rate Return Comparison_4 (euro per U.S. dollar)



model-implied return explains only a small fraction of the actual return volatility for short-term returns, whereas it explains most of the volatility for the medium-run return of about four years. From the above analysis, we know that the macroeconomic fundamentals to which monetary policy reacts influence the exchange rate change/return by inducing changes in future monetary policy and that this channel was more important following the launch of the euro.

## 2.5 Predictive Power of the Monetary Policy Expectations

Because the expected sum of interest rates co-moves with the exchange rate returns, we go a step further to use this expected sum of interest rate differential (market expectation model) to predict exchange rate changes and examine its predictive power.

At each month $t$, we make a forecast for the $kh$-month ahead exchange rate change using the expected future interest rate differential, which is based on information up to $t$:

$$\Delta s_{t,t+kh}^{F79-98} = E_t \sum_{i=0}^{k-1} \left( i_{t+ih}^{h} - i_{t+ih}^{h*} \right) \tag{2.17}$$

Note that the euro era, we obtain a negative correlation between the expectation-implied return and the actual return, so we use a negative expected interest rate to make forecasts:

$$\Delta s_{t,t+kh}^{F99-08} = -E_t \sum_{i=0}^{k-1} \left( i_{t+ih}^{h} - i_{t+ih}^{h*} \right) \tag{2.18}$$

Statistics for the forecast error for each forecast horizon can be found by computing the root-mean-square-error (RMSE).[19] In particular, It is customary to use the random walk model as a benchmark for forecasting exchange rate change, we thus evaluate the predictive power of this model by analyzing the RMSE ratio of $\Delta s_{t,t+kh}^{F}$ relative to a driftless random walk, indicating no change in the exchange rate. If the ratio is less than one, it means that the forecast error of this model is smaller than the forecast error from a random walk model; that is, in conventional terms, the model beats the random walk model. The ratios for different horizons are shown in table 2.14.

The first finding from this table is that all ratios are smaller than one. We further test

[19] The RMSE is the square root of the mean of the same horizon forecast made at each month.

**Table 2.14:** RMSE Ratio Relative to Driftless Random Walk

| | 1979-1998 | 1998-2008 |
|---|---|---|
| 1-quarter return | *0.89* | **0.87** |
| half year return | **0.89** | **0.87** |
| one-year return | **0.88** | **0.87** |
| two-year return | **0.87** | **0.95** |
| four-year return | **0.90** | 0.96 |
| six-year return | **0.73** | 1.30 |

Note: The number in italics denotes being significant under CW test at 10% significance level, numbers in bold are significant at 5% significance level.

the significance using the CW test. The results show that for a one-quarter exchange rate return in the first sample period, the test rejects the random walk hypothesis at the 10% level. For the same return in the second sample period and returns of horizons up to two years, the market expectation model beats the random walk significantly at the 5% level. This is also true for the four-year return in the first period. This is in contrast to a large number of papers that use only macroeconomic fundamentals to make their forecasts and find that models beat the random walk only over a four-year horizon. The model does slightly better for the mark-dollar exchange rate in the pre-euro era, and the forecasting ability increases with the horizons of exchange rate returns.

## 2.6 Conclusion

This paper explores the linkage between monetary policy fundamentals and exchange rate return through the channel of monetary policy expectations. We decompose the exchange return into three components: market expectations of future short-term interest rates, market expectations of future currency risk premia and the exchange rate forecast error. We then examine whether and how the monetary policy fundamentals determine the interest rate expectations and, in turn, how the expected interest rates determine exchange rate dynamics. In particular, we model the market expectations of monetary policy based on consensus forecasts from market participants. This avoids mismeasurement from arbitrary assumptions about expectations.

Our analysis of the deutsche mark and euro prices relative to the U.S. dollar from 1979 to 2008 shows that the monetary policy fundamentals influence the exchange rate return through the monetary policy expectation channel. Modeling market expectations of monetary policy

| Variable | Source | Sample Period | Remark |
|---|---|---|---|
| Exchange Rate | IFS | 1979: 1-1998:12 | Deutsche Mark price per U.S. dollar. |
| | CEIC | 1995:1-2008:2 | Euro price per U.S. dollar. |
| Note: The above are all original data used in Engel and West (2006). | | | |

based on consensus forecasts considerably improves the explanatory and predictive power of the monetary policy fundamentals over the existing literature.

The findings also suggest that expectation formation processes of monetary policy change over time and differ across countries and that a single learning mechanism is not able to represent these processes. Moreover, Taylor rule fundamentals have considerable explanatory power for exchange rate returns once monetary policy expectations are modeled to be consistent with market expectations. The expected sum of future interest rate differentials is a good candidate for an out-of-sample forecast of exchange rate returns. It outperforms the random walk model for most of the forecast horizons and sample periods in our exercise.

Results also indicate that macroeconomic fundamentals such as the output gap and inflation rate have good explanatory and predictive power and that unsatisfactory results in previous papers may be attributable to the mismeasurement of the monetary policy expectation and, in turn, an incorrect functional form of the monetary policy fundamentals in the exchange rate model. This should be considered before analyzing currency risk premia or searching for other factors to forecast exchange rate returns.

## 2.7 Appendix 2.1: Data Description

**Consensus interest rate forecast:** forecast for interest rate with 3 month maturity 3-month and 12-month ahead. Source: consensus economics, 1989:10-2008:2.

**Exchange Rate:**

**Data for VAR learning:**

**Data for U.S. FAVAR learning:** all data are from are from CEIC and IFS database with the sample period from 1978:1 to 1998:12, variables are listed as following:

Industrial Production

1. Industrial Production Index: Seasonally Adjusted
2. Industrial Production Index: Crude Oil

| **Germany** 1979: 1-1998:12 | | |
|---|---|---|
| **Variables** | **Source** | **Remark** |
| Industrial Production | IFS 66.c and Bundesbank | Logarithm is taken. Data are combined from |
| Consumer Price Index | IFS 64. and Bundesbank | West German data for 1979-1990 and |
| | | German data from 1990-1998. Adjustment to smooth the data according to |
| | | Engel and West (2006) is involved. |
| Money Market Rate | IFS 60b | |
| Note: The above are all original data used in Engel and West (2006). | | |

| **United States** 1979: 1-1998:12 | | |
|---|---|---|
| **Variables** | **Source** | **Remark** |
| Industrial Production Index | IFS 66.c | Logarithm is taken. |
| Consumer Price Index | IFS 64. | |
| Federal Funds Rate | IFS 60b | |
| Note: The above are all original data used in Engel and West (2006). | | |

| **Euro Area** 1995:1-2008:2 | | |
|---|---|---|
| **Variables** | **Source** | **Remark** |
| Industrial Production Index | CEIC (Eurostat EUBGADGA) | Logarithm is taken. |
| Harmonized Consumer Price Index | CEIC (ECB EUICB) | Seasonally adjusted. |
| Money Market Rate | CEIC (ECB EUMCAC) | Euro interbank market 3-month rate. |

| **United States** 1995:1-2008:2 | | |
|---|---|---|
| **Variables** | **Source** | **Remark** |
| Industrial Production | CEIC (IMF 217893801) | Logarithm is taken. Seasonally adjusted. |
| Consumer Price Index | CEIC (IMF 217892101) | Logarithm is taken. Seasonally adjusted by the author. |
| Federal Funds Rate | IFS | |
| Note: The above are all original data used in Engel and West (2006). | | |

3. Industrial Production Index: Seasonally Adjusted: Final Product

4. Industrial Production Index: Seasonally Adjusted: Consumer Goods

5. Industrial Production Index: Seasonally Adjusted: Consumer Goods: Durable (DU)

6. Industrial Production Index: Seasonally Adjusted: Consumer Goods: Non-Durable(ND)

7. Industrial Production Index: Seasonally Adjusted: Equipment: Business

8. Industrial Production Index: Seasonally Adjusted: Intermediate Product: NI: BS: General

9. Industrial Production Index: Seasonally Adjusted: Materials

10. Industrial Production Index: Seasonally Adjusted: Materials: Non-Energy: Durable

11. Industrial Production Index: Seasonally Adjusted: Materials: Non-Energy: Non-Durable

12. Industrial Production Index: Seasonally Adjusted: Manufacturing: SIC

13. Industrial Production Index: Seasonally Adjusted: Manufacturing: Durable

14. Industrial Production Index: Seasonally Adjusted Manufacturing: Non-Durable

15. Industrial Production Index: Seasonally Adjusted: Mining

16. Industrial Production Index: Seasonally Adjusted: Electric & Gas Utilities

Personal Income

18. Personal Income (PI): Seasonally Adjusted

19. Personal Income: Seasonally Adjusted: Disposable: Personal Income

Employment & Labour

21. Unemployment: By Duration: 15 Weeks & Over: 15 to 26 Weeks

22. Unemployment: By Duration: 15 Weeks & Over: 27 Weeks & Over

25. Employment: NF: Seasonally Adjusted: Goods Producing

26. Employment: NF: Seasonally Adjusted: NR: Mining

27. Employment: NF: Seasonally Adjusted Construction (CO)

28. Employment: NF: Seasonally Adjusted: Manufacturing: Durable

29. Employment: NF: Seasonally Adjusted: Manufacturing: Non-Durable

31. Employment: NF: Seasonally Adjusted: Trade, Transportation & Utilities

33. Employment: NF: Seasonally Adjusted: Utilites

35. Employment: NF: Seasonally Adjusted: Government

Housing

38. Private Housing Units Started: Midwest

Manufacturing

42. Manufacturing Index: Seasonally Adjusted: New Orders
43. Manufacturing Index: Seasonally Adjusted: New Orders: Excluding Defense
44. Manufacturing Index: Seasonally Adjusted: New Orders: Durable Goods
45. Manufacturing Index: Seasonally Adjusted: New Orders: Non Durable Goods

Consumer Price Index

46. Consumer Price Index: Urban
48. Consumer Price Index: Urban: Transport
49. Consumer Price Index: Urban: Medical Care
50. Consumer Price Index Urban: All Commodities
51. Consumer Price Index Urban: Durables
52. Consumer Price Index Urban: Services
53. Consumer Price Index Urban: All Items Less Food
54. Consumer Price Index Urban: All Items Less Shelter
55. Consumer Price Index Urban: All Items Less Medical Care

Produce Price Index

56. Producer Price Index: Seasonally Adjusted: Intermediate Materials (IM)
57. Producer Price Index: Seasonally Adjusted: Finished Goods
58. Producer Price Index: Seasonally Adjusted: Finished Goods: Finished Consumer Goods
59. Producer Price Index: Seasonally Adjusted: Crude Materials (CM)
60. Producer Price Index: Industrial Commodities

Stocks & Equity

61. Equity Market Index: Month End: NYSE Composite
62. Index: Standard & Poors: 500

Reserves & Money Supply

63. Depository Institution Reserve: Seasonally Adjusted
64. Depository Institution Reserve: Seasonally Adjusted: Non-Borrowed
65. Money Supply M1: Seasonally Adjusted

66. Money Supply M2: Seasonally Adjusted

67. Money Supply M3: Institution al. Money Market Funds

68. Reserve Assets.

69. Consumer Credit Outstanding: Seasonally Adjusted: Non-revolving

70. Commercial Banks: Credit: Loans and Lease (LL)

Consumption

71. Personal Consumption Expenditure (PCE): Seasonally Adjusted

72. Personal Consumption Expenditure: Seasonally Adjusted: GD: Durable Goods (DG)

73. Personal Consumption Expenditure: Seasonally Adjusted: GD: Nondurable Goods (NG)

74. Personal Consumption Expenditure: Seasonally Adjusted: Services (SE)

75. Personal Consumption Expenditure: Seasonally Adjusted: Durable Goods: MV: New Autos

Personal Income

76. Personal Income (PI): Seasonally Adjusted

77. Personal Income: Seasonally Adjusted: Disposable Personal Income

# Chapter 3

# International Transmission of Bank and Corporate Distress

## 3.1 Introduction

The recent crisis demonstrated how rapidly financial distress can be transmitted to the domestic economy and across borders. The U.S. subprime crisis weakened balance sheets of banks, households and corporates put major financial institutions in that economy and other advanced economies on the brink of bankruptcy, were it not for large government bailouts. The subsequent tightening of global financial conditions, together with the seizure of capital markets, reduced the availability of funding for nonfinancial corporations around the world, hampering their capacity to produce, export and invest. Households (and consumption) in advanced economies were also hit: many individuals lost their jobs and experienced large declines in net worth. Confidence fell around the world, and with it, activity.

Indeed, studies by Gilchrist et al (2009), Marcucci and Quagliariello (2008), Jacobson et al, 2005, and Carlson et al (2008 show that the credit channel is the main channel of transmission of financial distress, the strength of which hinges on that of the financial accelerator—the extent to which borrowing costs depend on the external finance premium that reflects borrowers' net worth (Bernanke and Gertler, 1995; Bernanke, Gertler and Gilchrist, 1999; and Kiyotaki and Moore, 1997).

The evidence on the transmission of financial distress has mostly been limited to advanced economies and seldom uses a framework that integrates macroeconomic, financial and (nonfinancial) corporate sector variables. For example, recent papers on credit risk (Cartensen et al, 2008; and Pesaran et al, 2006) examined the spillover effects of credit risk shocks in a multi-country context, using a global vector autoregression model (Dees et al, 2007), but with the credit risk modeled separately from macroeconomic variables. Financial distress in these papers is measured as bank capital or borrowers' default risk, proxied by corporate bond spreads, credit default swap spreads or data on actual defaults. These data are available only for a limited number of (mostly advanced) economies, which limits the scope of analysis.

This paper attempts to fill the void in the literature by providing an integrated analysis of the linkages between bank and (nonfinancial) corporate sectors in the global economy. It does so by introducing forward-looking measures of default risk for banks and corporates into a Global Vector Autoregression (GVAR) model proposed by Pesaran, Schuermann and Weiner (2004). Bank and corporate default risk is proxied by the respective Expected Default Frequencies (EDFs) from Moody's cartensen Credit Edge. The EDF uses information on a bank's or corporate's balance sheet and equity market data, and is often referred to as the equity market-implied default risk (Vassalou and Xing, 2004). The limited data requirements for calculating the EDFs mean that such measures can be created for a large number of financial and non-financial corporate firms across the world, including those from emerging markets, which is a great advantage for the analysis of international spillovers. In addition to the EDFs, the GVAR model includes macroeconomic variables, such as industrial production, real short-term interest rates, real effective exchange rates and real stock prices; oil prices are treated as a global factor).

Like the earlier studies, the study finds linkages between the financial sector and the real economy, with distress in the banking or corporate sector having significant effects on activity in domestic economies. In particular, the results show that bank distress amplifies corporate distress, reduces industrial production and stock prices, and tends to be accompanied by a depreciation of real effective exchange rates and lower real short-term interest rates. Corporate distress has broadly similar macroeconomic effects.

Bank and corporate distress are also found to have significant global repercussions, albeit with striking differences for advanced and emerging economies. International spillovers are stronger when financial distress originates in large advanced economies, particularly the United States. The impact of corporate distress originating in advanced economies on growth in emerging economies tends to be larger than the impact of advanced economies' bank distress, consistent with a more prominent role of trade channels in the transmission of advanced economies' shocks to emerging economies. In contrast, advanced economies tend to be more vulnerable to bank distress than corporate distress, reflecting the greater role of the financial sector in these economies.

These conclusions are qualitatively robust to a variety of changes in model specification, including alternative weights and ordering of variables. When bank and corporate default measures are excluded from the model, the effects of shocks are similar in direction but smaller in magnitude. Thus, bank and corporate balance sheet channels appear to be an important amplifier of the international transmission of shocks, consistent with the financial accelerator mechanism and findings by Dees et al (2007). The findings also appear broadly consistent with experiences during the recent financial crisis.

The rest of the paper is organized as follows. Section II presents the GVAR framework and describes the data, particularly Moody's KMV EDFs. Section III discusses the results of selected shocks. Section IV concludes.

## 3.2 Methodology and Data

The GVAR model of Pesaran, Schuermann and Weiner (2004) provides a multilateral dynamic framework for the analysis of interdependence and international transmission of country-specific shocks among a large number of economies.

### 3.2.1 Structure of the GVAR Model

The structure of the GVAR model can be summarized as the follows. Consider $N + 1$ economies, indexed by $i = 0, 1, 2, ..., N$, and a vector $\mathbf{x}_{it}$ of $k_i$ domestic variables for each economy. Stacking the vectors of country-specific variables,

$$x_t = \begin{pmatrix} x'_{0t}, & x'_{1t}, & \cdots, & x'_{Nt} \end{pmatrix}, \tag{3.1}$$

a VAR in $x_t$ would contain too many parameters to be estimated if the time dimension $T$ of the data is not much larger than the number of economy $N$. Instead of regressing $x_{i,t}$ on

$$x_{-i,t} = \begin{pmatrix} x'_{0t}, & x'_{1t}, & \cdots, & x'_{i-1,t}, & x'_{i+1,t}, & ,..., & x'_{N,t} \end{pmatrix}, \tag{3.2}$$

without any restriction, GVAR links $x_{i,t}$ to a $k_i^* \times 1$ vector $x_{i,t}^*$, where

$$x_{lit}^* = \sum_{j=0}^{N} \omega_{lij} x_{ljt}, \quad l = 1, 2, ..., k_i^*. \tag{3.3}$$

The weight $\omega_{lij}$ captures the spillover effect of variable $l$ of foreign economy $j$ on variable $l$ of domestic economy $i$. Since $\omega_{lij}$measures the relative importance of economy $j$ to economy $i$, the spillover effect of variable $l$ is in proportion to the weight chosen to measure the relative importance. Therefore, each economy's component of GVAR is given as a VARX* $(p_i, q_i)$:

$$x_{it} = a_{io} + a_{i1} \cdot t + \sum_{s=1}^{p_i} \Phi_{is} x_{i,t-s} + \sum_{s=0}^{q_i} \Lambda_{is} x_{i,t-s}^* + \sum_{s=0}^{r_i} \Psi_{is} d_{t-s} + u_{it} \tag{3.4}$$

with $u_{it} \overset{iid}{\sim} (0, \sum_i)$, where $d_{t-s}$ is the observed common factor of $q \times 1$ dimension and $\varepsilon_{it}$ is $iid$ across time. Country-specific vector $x_{i,t-s}^*$ reflects interdependence among economies and serves as a proxy for the unobserved common effects across economies. The country-specific foreign variables and common factors are treated as weakly exogenous (if confirmed by statistical tests), i.e., they are "long-run forcing" country-specific domestic variables. The term "long-run forcing" means that in the equations for foreign variables, the coefficients on the error-correction terms are set to zero. The dynamics of foreign variables are not influenced by deviations from the long-run equilibrium path, in contrast to the dynamics of domestic variables.

The VARX* can be estimated economy by economy using the ordinary least squares (OLS) method or rank-reduced approach if the cross-dependence of the idiosyncratic shock is sufficiently small, that is:

$$\sum_{j=0}^{N} Cov\left(\varepsilon_{lit}, \varepsilon_{sjt}\right)/N \to 0 \tag{3.5}$$

all $i \neq j$, $l$ and $s$.

From equation (3.3), it can be seen that

$$z_{it} = W_i x_t i = 1,\ 2, \cdots, N \tag{3.6}$$

where $z_{it} = \begin{pmatrix} x_{it}^{'} & x_{it}^{*'} \end{pmatrix}$ and $W_i$ is an appropriately defined weighting scheme. Thus, stacking

(3.4) across $i$, the endogenous variables can be solved for in a global system:

$$Gx_t = a_{i0} + a_{i1} \cdot t + \sum_{s=1}^{p} \Phi_s x_{t-s} + \sum_{s=0}^{r} \Psi_s d_{t-s} + u_t \tag{3.7}$$

thus

$$x_t = G^{-1}a_{i0} + G^{-1}a_{i1} \cdot t + G^{-1}\sum_{s=1}^{p} \Phi_s x_{t-s} + G^{-1}\sum_{s=0}^{r} \Psi_s d_{t-s} + G^{-1}u_t \tag{3.8}$$

where $p = \max\{p_i, q_i\}$, $r = \max\{r_i\}$, and

$$G = \begin{pmatrix} A_0 W_0 \\ A_1 W_1 \\ \vdots \\ A_N W_N \end{pmatrix}, H_s = \begin{pmatrix} B_{s,0} W_0 \\ B_{s,1} W_1 \\ \vdots \\ B_{s,N} W_N \end{pmatrix}, u_t = \begin{pmatrix} u_{0,t} \\ u_{1,t} \\ \vdots \\ u_{N,t} \end{pmatrix}. \tag{3.9}$$

Equation (3.8) is a VAR for the complete set of domestic variables for all economies.

The advantage of the GVAR model is that it makes the estimation of (3.8) feasible by accounting for interdependence among economies and then estimating the partial system on a economy-by-economy basis, which implies allowing for modeling a large number of economies. The impulse response is computed based on (3.8).

The vector for domestic variables is given by:

$$x_{it} = \begin{pmatrix} edfb_{it} & edfn_{it} & r_{it} & y_{it} & p^s_{it} & q_{it} \end{pmatrix}' \tag{3.10}$$

where $edfb_{it}$ denotes the logarithm of asset-weighted average expected default frequency (EDF) of banks and $edfn_{it}$ for (nonfinancial) corporates, $r_{it}$ is the real money market rate, $y_{it}$ is the logarithm of industrial production, $p^s_{it}$ the logarithm of real share price index, and $q_{it}$ is the logarithm of the real effective exchange rate.

The vector for foreign variables for each economy except the United States is given by:

$$x^*_{it} = \begin{pmatrix} edfb^*_{it} & edfn^*_{it} & r^*_{it} & y^*_{it} & p^{s*}_{it} \end{pmatrix}'. \tag{3.11}$$

We do not construct foreign effective exchange rates to minimize the number of parameters to be estimated, since information about foreign economies' currency is captured in the (trade-weighted) real effective exchange rate $q_{it}$.

The foreign variable for the United States is constructed as:

$$x^*_{us,t} = y^*_{us,t} \tag{3.12}$$

Given the large influence of the U.S. financial variables on global markets, the U.S. foreign financial variables are less likely to be weakly exogenous for the U.S. domestic variables. That is the main reason we do not include the U.S. foreign financial variables in the equations for the United States.

The spot oil price is included as a common factor $d_{t-s}$ to remove the common component in the reduced form residuals. Another candidate for inclusion as a common factor could be the index of global stock price volatility VIX, to ensure that the EDF shocks are purely idiosyncratic. However, because the VIX is driven by volatility in U.S. share prices, it is not weakly exogenous to the U.S. variables. Adding it separately will not augment the information content of the model.

Equations (3.3) and (3.4) show that the spillover effect of a foreign variable on a domestic variable is proportional to the weight$\omega_{lij}$, which measures the relative importance of economy $i$ to economy $j$ in transmission. Since the transmission channels for financial variables are likely to be different from the transmission channels for the variables measuring real activity, we use financial weights to construct foreign financial variables — EDFs, real money market rate, share price index and real effective exchange rate — and trade weights for industrial production.

### 3.2.2 Sample, Variables and Weights

The GVAR model covers 30 economies, including 21 advanced—Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong S.A.R., Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Singapore, Spain, Sweden, Switzerland, the United Kingdom, and the United States—and 9 emerging economies—Brazil, China, India, Indonesia, Malaysia, Mexico, the Philippines, South Africa, and Turkey.

Macroeconomic and financial data are of monthly frequency and cover the period from January 1996 to December 2008. All data, except the EDFs, are obtained from the IMF's *International Financial Statistics*, CEIC and GDS. The sample period is constrained by the availability of data for emerging economies. See Appendix 3.1 for detailed information about data sources and transformations as well as descriptive statistics. In particular, note that the standard deviations of bank and corporate EDFs are similar, implying that the effects of shocks to these variables are comparable.

Measures of financial distress, EDFs, are from Moody's KMV (MKMV). MKMV is a commercial product that uses a modified version of the Merton model (1974) to calculate the expected default frequency (EDFs) for 35,000 financial institutions and nonfinancial corporates in 55 economies (see Gray and Malone, 2008; and Gray, Merton and Bodie, 2008, for details). A firm is in default when the market value of its assets falls short of its debt obligations. The likelihood of default depends on the current value and risk (volatility) of its assets relative to the promised payments on the debt (defined as the default barrier). The implied asset value and volatility are estimated by applying a modified version of the Merton model to equity market data and balance sheet information. For more details on the Merton model and contingent claims analysis, see Appendix 3.2.

The EDFs combine equity price data with data on firms' balance sheet data and often exhibit nonlinear characteristics, reflecting the impact of a broad range of factors, such as the structure of a firm's balance sheet and investors' risk appetite, on the probability of the firm's default. For example, correlations between EDFs for U.S. banks and corporates and U.S. stock prices, in level terms, are 0.3 and 0.6 respectively, while correlations between changes in the respective variables (which are used in the GVAR model) are close to zero. To create country-specific measures of EDFs, we use the time-varying asset-weighted averages of one year-ahead EDFs for all banks and (nonfinancial) corporates. The average number of banks and corporates in emerging and advanced economies does not vary significantly, suggesting that the coverage of firms should not bias the results. See Appendix 3.1 for the number of firms in each country.

In GVAR, the bilateral dependence of domestic variable on a foreign variable is proportional to the country-specific weight used to form foreign variables. We use broad financial and trade weights to form foreign values of financial and macroeconomic variables, respectively. This is in contrast to the previous GVAR literature which uses trade weights or narrow financial weights (covering only bank lending relationship) to form foreign values of financial variables (Dees and others, 2007; Galesi and Sgherri, 2009, respectively). Using the above mentioned financial weights advances the GVAR literature in the direction of improving the model's ability to capture the financial channels of shock transmission.

Financial weights are constructed using currency exposure measures of Lane and Shambaugh (2009), which summarize bilateral financial asset positions in five instruments: portfolio equity, direct investment, portfolio debt, other general bank-related debt, and reserves. We take the average weight from 1999 to 2004 (the latest data for which Lane and Shambaugh's data are available) as a fixed weight for the four financial variables in the model (Table 3.9 to Table 3.11). To construct measures of foreign industrial production, we use trade weights. These weights are constructed based on the IMF's *Direction of Trade Statistics* as the share of bilateral goods trade in total trade, averaged over the period from 1996 to 2008 (Table 3.12 to Table 3.14).

Data limitations, especially for data on financial asset positions, prevent us from using time-varying weights. However, this may not be a major issue as the bilateral patterns of assets and liabilities for most countries in the sample have remained broadly stable during 1999–2004. Also, as shown in Pesaran et al (2006), the GVAR results are robust to using time-varying (trade) weights. We explore alternative ways to form foreign financial and real sector variables as part of robustness checks.

### 3.2.3 Impulse Responses

Given the short sample period, the study focuses on short-run dynamics. The model is estimated in first differences as the macroeconomic and financial data are found to be integrated of order 1. Identifying the complete set of shocks in equation (3.8) and computing the impulse response functions in a GVAR model is not straightforward. It requires imposing an enormous amount of identification restrictions due to the large number of economies covered in the study. Therefore, we identify shocks following the approach in Dees and others (2007) and Binder, Chen and Zhang (2010).

To identify shocks to EDFs of U.S. banks and corporates, for example, we first identify structural shocks in the VARX* for the United States, using Cholesky decomposition and assuming a Wold ordering of $\left[\begin{array}{cccccc} y_{it} & r_{it} & p^s_{it} & q_{it} & edfn_{it} & edfb_{it} \end{array}\right]$. Ordering industrial production first means that it does not respond contemporaneously to the financial shocks. The real short-term interest rate is assumed to react contemporaneously to industrial production shocks, consistent with a Taylor rule. Share prices are allowed to respond to industrial production and the real interest rate, as they reflect expected future macroeconomic fundamentals. The exchange rate is assumed to react to all variables except the EDFs.

The EDFs are assumed to react to all four variables on the grounds that the industrial production shock affects future profits of banks and corporates and hence their default probabilities, while the real interest rate, share price index and the exchange rate also enter into the calculation of the EDFs through the maturity and composition structure of institutions' balance sheets. We assume that bank EDFs respond to shocks to corporate EDFs, and not the other way around, because loans to corporates constitute a significant portion of banks' assets. An increased likelihood of corporate default is likely to affect bank default probabilities as the quality of banks loan portfolio deteriorate. Of course, one may argue that an unexpected change of bank default probability due to, say, the shortage of liquidity can raise corporate default probabilities because of the tightening of lending conditions. Placing banks' EDFs before corporates' EDFs in the GVAR does not alter the main findings.

The U.S. domestic variables are assumed not to react to shocks to other economies' variables, which amounts to ordering the U.S. economy first. As part of robustness checks, we confirm that an alternative ordering of the remaining economies does not change the impulse response function for the U.S. shocks.

After identifying the EDF shocks, we compute impulse responses of the other variables in the global solution in equation (3.8) based on correlations between the reduced form shock of each variable and the identified structural shock of the EDF. Such an identification scheme means that zero correlation between the structural EDF shocks and other domestic variables in each economy need not be imposed and the transmission of the shock is determined without any additional restrictions. The impulse response of variables in other economies are computed similarly to the generalized impulse response, which leaves the contemporaneous correlations of the U.S. EDF shocks and structural shocks in other countries unrestricted.

We consider temporary shocks to U.S. bank and corporate distress. Each shock is assumed to last for one month and amount to a one percentage point increase in the default probability of banks and corporates. Since we have controlled for changes in the macroeconomic fundamentals and stock prices that may affect the EDFs, the innovation to the residual should be interpreted as an unexpected shock that worsens the balance sheets of firms and augments the EDF. The correlations of the U.S. EDF shocks and the contemporaneous macroeconomic and financial variables are close to zero.

These shocks usefully illustrate the channels through which bank and corporate distress can be transmitted across the world. However, they are not necessarily suggestive of patterns of contagion during financial crises because bank and corporate distress is likely to be more persistent and greater in magnitude than what is assumed in the paper. Distress during crises may also be associated with nonlinear effects, for example, owing to changes in market liquidity. Such nonlinear effects are not captured in the GVAR.

## 3.3 Transmission of Bank and Corporate Distress

The results show that financial distress has significant effects on domestic economies activity, with bank and corporate default, equity prices and real activity being affected in tandem. The strength of international spillovers from bank and corporate distress depends on the importance of the economy where the shock originates from. Although the macroeconomic effects of bank and corporate distress are in many ways similar, there are also notable differences. In particular, corporate distress in advanced economies has a larger impact on economic growth in emerging economies than bank distress in advanced economies. On the other hand, advanced economies are more vulnerable to bank distress than to corporate distress. These results are robust to various changes in specification. In addition, we find that controlling for the strength of bank and corporate balance sheets in GVAR amplifies the effects of real and financial sector shocks.

### 3.3.1 Domestic Impact of Bank and Corporate Distress

The impulse response functions associated with a 1 percentage point increase in the probability of default of U.S. banks show that the expected probability of corporate defaults immediately starts to rise, with the impact peaking at about 0.3 percentage points one month after the initial shock (Figure 3.1). The co-movement between bank and corporate default risk (albeit with a lag) reflects the transmission of the shock through the banks' balance sheets, whereby weaker banks tighten lending conditions, hurting borrowers' balance sheets and pushing up their default risk. Higher bank and corporate default risks lead to declines in stock prices (with a maximum impact of 10 percentage points one month after the initial shock) as investors anticipate weaker earnings. The effects on corporate default risk and stock prices are statistically significant at the 90 percent significance level, underscoring the importance of financial and balance sheet channels in the transmission of financial distress.

Other macroeconomic variables move in the expected direction. Industrial production falls, with the maximum impact of 0.3 percentage points two months after the initial shock. The real short-term interest rate rises during the first month after the shock, consistent with the tightening of lending conditions, but over the subsequent months, it declines, likely reflecting an easing of monetary policy. The effects on industrial production and the real interest rate are statistically significant, albeit only two-three months after the initial shock. Prior to this, responses are typically statistically insignificant. The real effective exchange rate depreciates in the first two months after the initial bank distress shock, consistent with slowing economic activity, rising corporate default risk and declining stock prices. These effects are statistically insignificant during the full one year after the shock.

The effects of a 1 percentage point increase in the default probability of U.S. corporates on financial variables are broadly similar to those of an increase in banks distress risk, confirming close linkages between the health of the corporate and banking sector (Figure 3.2). Bank default risk rises (with the maximum impact of about 0.3 percentage points) within a month after the increase in corporate default risk, as the deterioration in corporate balance sheets worsens the quality of banks' loan portfolio. Stock prices fall (with the maximum impact of about 13 percentage points). These effects are statistically significant, as before, pointing to the strength of linkages between distress in bank and corporate balance sheets and financial markets.

Other macroeconomic variables behave as expected. Industrial production declines, although this effect is statistically insignificant. The real effective exchange rate appreciates by about 2 percentage points, and this effect is statistically significant. One possible explanation is that a shock to corporate default risk may be akin to a negative supply-side shock and be associated with a pickup in inflation. The real interest rate declines as in the case of a bank distress risk shock, although the decline is statistically insignificant.

Shocks to the default probabilities of banks and corporates in other economies have similar effects. The degree of co-movement in the default risk of banks and corporates varies, possibly reflecting different degree of financial development, the importance of the corporate sector exposures for banks, and availability of alternative financing sources for (nonfinancial) corporates.

### 3.3.2 International Propagation of Bank and Corporate Distress

Bank and corporate distress in systemically important economies have significant international implications. For example, a 1 percentage point increase in the default probability of U.S. banks immediately raises the probability of German banks' default by about 0.2 percentage points, possibly reflecting an expectation of a tightening of funding conditions and losses on holdings of U.S. assets as well as weaker demand for German export products (Figure 3.3). The default probability of German corporates rises by approximately the same magnitude as the default probability of German banks immediately after the shock. Industrial production in Germany declines by a larger magnitude than that in the United States, possibly because the real effective exchange rate for the euro appreciates in contrast to that for the dollar. Bank distress may also have a larger impact on real activity in Germany than in the United States, because bank credit is a more important source of funding for German corporates than for their U.S. counterparts.

The impact of an increase in the default probability of U.S. banks on emerging economies is also significant. For example, as shown in Figure 3.4, a 1 percentage point increase in the default probability for the U.S. banks raises the default probability of Brazilian corporates (with the maximum impact close to 1 percentage point). This is a larger effect than that on German corporates, albeit with a one month lag in contrast to the immediate impact on the default risk of German corporates. The larger impact on the corporate default risk in Brazil is consistent with a larger decline in industrial production (by close to 5 percentage points on impact), more than double the impact on Germany's industrial production. It may reflect the fact that Brazil experiences a dual shock of lower demand from the United States and other advanced economy partners, namely Europe and Japan. Although the immediate impact on industrial production is significant, a large depreciation of the exchange rate, helps mitigate the impact on real economic activity and the initial decline in industrial production quickly unwinds. Share prices fall by as much as 15 percent.

Surprisingly at the first glance, the default risk of Brazilian (and Mexican) banks declines in response to the increase in the default risk of U.S. banks. One possible explanation is that the quality of banks' loan books improves as high-quality domestic borrowers substitute away from foreign bank borrowing toward domestic banks. Another explanation, put forward by Kamil and Rai (forthcoming), is that foreign banks' involvement in Latin America tends to differ from that in other regions: it is mostly conducted through local subsidiaries, with loans denominated in domestic currency and funded through domestic deposits. These differences may help explain why global deleveraging has not affected Latin America as much as other emerging markets during the recent financial crisis.

In contrast to Brazil, an increase in the default probability of U.S. banks has an adverse impact on the default probability for both Chinese banks and corporates. These probabilities rise by about 0.5 percentage points in the first month after the shock (Figure 3.5). The impact on stock prices and real effective exchange rate is smaller than those in Brazil. The effects on the real interest rate and industrial production are statistically insignificant over the entire horizon of one year.

The direction of the effects of shocks to the default probability of U.S. corporates on Germany, Brazil and China is broadly similar to those of shocks to the default risk of U.S. banks (Figures 3.6 – 3.8). The effects on the default probability of Chinese banks and corporates are larger in magnitude, suggesting that production chain linkages between China and the United States tend to be larger than those through the financial channels, which is consistent with China's capital account being closed.

The effects of the U.S. bank and corporate distress on other advanced and emerging economies are summarized in Figures 3.9 – 3.10. Distress in U.S. banks and corporates has a significant adverse impact throughout the world, with the magnitude of the impact depending on the strength of financial and trade linkages of the economy in question to the United States, where the shock originates, as well as various structural features of the economy and its policy framework. A 1 percentage point increase in the default probability of U.S. banks is estimated to result in a 0.3–0.5 percentage point increase in the default probability of banks in China, India, Japan and other advanced Europe. The impact on the euro area, Pacific (including Australia and New Zealand) is smaller, around 0.1–0.2 percentage points, while the default probability of the Latin American banks tends to improve, as discussed above.

Distress in the U.S. banking sector tends to be transmitted to the nonfinancial corporate sector, particularly in Latin America and emerging Asia. The apparently close relation between U.S. bank distress and corporate distress in emerging economies may reflect the price sensitivity and reliance of emerging economies' corporates on overseas borrowing from advanced economies' banks, particularly from the United States. The magnitude of the shock transmission to Japan, Pacific (Australia and New Zealand), the euro area and other advanced economies in Europe is weaker, possibly because of their greater reliance on the domestic sources of funding in contrast to the role of overseas financing in emerging economies.

Industrial production falls in all advanced and emerging economies in response to distress in the U.S. corporate sector. Japan and Latin America are most affected, reflecting their close production and trade linkages with the United States and the composition of their trading partner groups more generally. Consistent with the decline in real activity and a rise in default risk of banks and corporates, stock markets fall across the world. India, Latin America, Newly Industrialized Economies in Asia, and the euro area experience the largest declines in real stock prices (around 15 percentage points). Like in response to U.S. bank distress, a decline in stock prices in China is much smaller than in India, reflecting, among other things, its less open capital account and less developed capital markets. Effects on the real effective exchange rate are mixed, ranging from a 6 percentage point appreciation in Japan to close to 5 percentage point depreciation in Latin America, Australia and New Zealand. The effects of a 1 percentage point increase in the default probability of U.S. corporates are broadly similar to those of the shock to the default probability of U.S. banks.

The aggregation of the impact on emerging and advanced economies shows the similarities and differences in the effects of the U.S. bank and corporate distress on these economies' financial distress (Figure 3.11). U.S. bank distress has a larger impact on the default probability of banks in advanced economies than those in emerging economies, consistent with the former's greater financial openness and integration. The impact of U.S. bank distress on advanced economies' (and global) industrial production is also greater than in response to the U.S. corporate distress, possibly reflecting larger financial accelerator effects associated with the shocks originating in the banking sector as well as greater financial openness of advanced economies than emerging economies. The impact of U.S. bank distress on corporate distress is larger for emerging economies than advanced economies possibly owing to the greater reliance of emerging economies' corporates (especially larger firms) on overseas financing or their greater price sensitivity to financial conditions proxied by U.S. bank distress.

The effects of bank and corporate distress on other macroeconomic and financial variables in advanced and emerging economies are also quite different (Figures 3.11–3.12). First, the impact of U.S. corporate distress on industrial production in emerging economies is considerably larger than that in advanced economies (about 3.5 percentage points compared to less than 1 percentage point), consistent with greater trade openness of these economies than that of advanced economies. Other possible reasons are a larger impact on emerging economies' banks and appreciating exchange rates under the U.S. corporate distress shock. Second, the impact of the U.S. corporate distress shock on industrial production in emerging economies also exceeds that of the U.S. bank distress shock, possibly owing to greater importance of trade channels than financial channels in the transmission of shocks to emerging economies. Third, emerging economies' central banks tend to respond more aggressively to shocks emanating from the U.S. corporate sector than from the U.S. banking sector, as reflected in a decline in real interest rates under the former shock and an increase under the latter. This could reflect stronger concerns about the impact of U.S. corporate distress on real activity than direct impact from U.S. bank distress on its own, given strong production linkages. All in all, the findings are broadly consistent with recent crisis experiences, including the larger impact on banking sectors and economic growth in advanced economies than emerging economies.

Shocks to the default probability of banks and corporates in other economies have similar, albeit weaker effects than those of the U.S. shocks, consistent with other economies' smaller role in the global economy and finance than that of the United States.

### 3.3.3 Robustness Analysis

The results are qualitatively robust to a variety of changes in model specifications, including applying the average of trade and financial weights to foreign variables instead of using financial weights for financial variables and trade weights for the real activity variables. The averages take into account the possibility that shocks to all variables are transmitted through both trade and financial channels equally. The results remain very similar to those based on the original specification, including the effects on domestic and spillovers to other economies. However, the magnitude of the effects on the real interest rate vary for some economies, suggesting that the nature of transmission channels has significant bearing on the macroeconomic effects of shocks, particularly on inflation, and hence the monetary policy response.

The results are also robust to using an alternative Wold ordering, particularly, switching the order of bank and corporate default probabilities to allow for the corporate EDF to respond to the bank EDF shock contemporaneously. The rationale for this modification is to allow for the possibility that bank and corporate balance sheets to worsen following a tightening of monetary policy and lending conditions. The results are qualitatively consistent with those based on the original specification, although the ordering of economies by the maximum impact of shocks changes slightly.

Similarly, replacing the real effective exchange rates with bilateral real exchange rates also does not affect the results significantly. The number of observations is insufficient to test the robustness of the results to changes in the sample time period. However, we confirmed that the exclusion of a limited number of economies from the sample does not affect the results significantly.

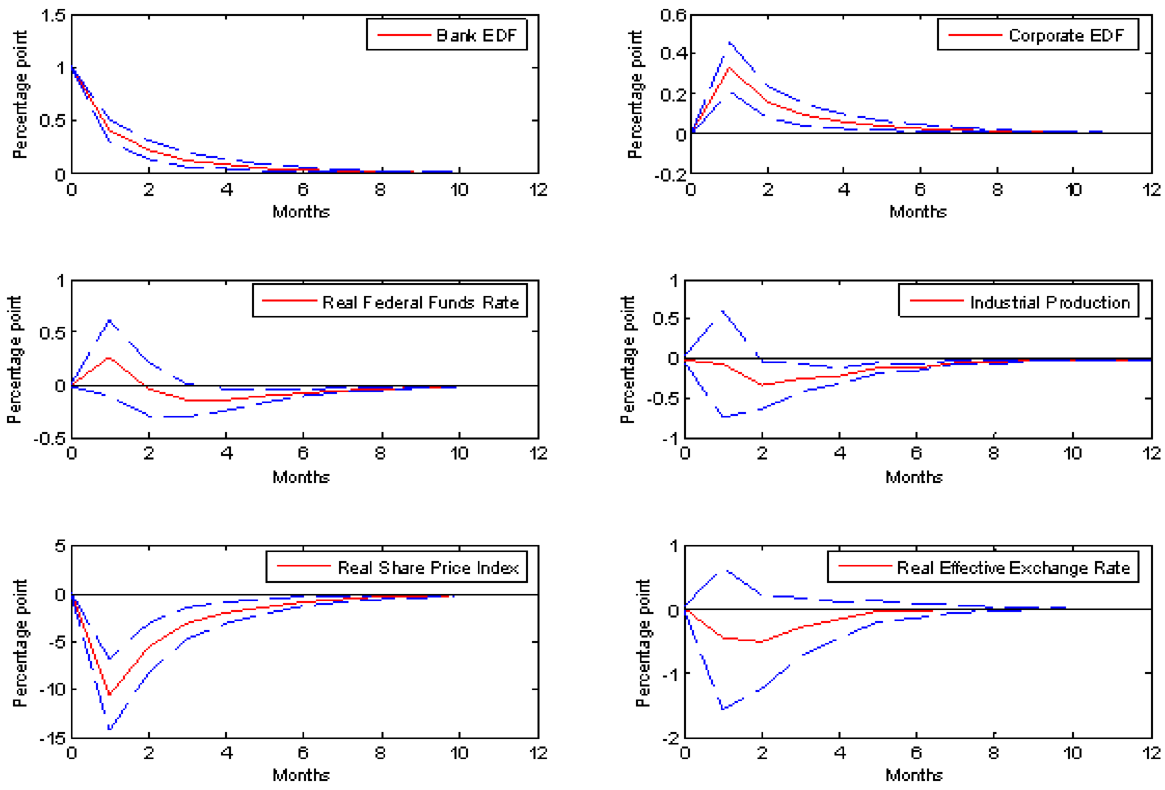
In addition to the above robustness tests, we examined how the inclusion of bank and corporate default probabilities in the GVAR model affects the direction and magnitude of the macroeconomic effects of shocks and their transmission. We find that the inclusion of these credit risk measures tends to amplify the transmission of shocks (Figure 3.13). This finding suggests that incorporating additional measures of bank and corporate credit risk in a macroeconomic VAR model helps better account for the various financial accelerator mechanisms and bank capital channels.

## 3.4 Conclusion

This paper examined how distress in banks and corporates affects domestic economies and gets transmitted to other economies. The analysis is based on a parsimonious GVAR model covering 30 advanced and emerging economies and including not only macroeconomic and financial variables such as stock prices and interest rates but also forward-looking measures of default probabilities for banks and corporates. The model controls for common global shocks, such as oil prices, and uses broad measures of financial exposures to account for various financial channels through which shocks are transmitted across the world.

The analysis confirms strong macro-financial linkages within domestic economies and globally. Bank and corporate distress, especially when originating in systemically important economies, can have adverse implications for global real activity, with stark differences between advanced and emerging economies. Growth in emerging economies is more sensitive to corporate than bank distress, while the opposite is true for advanced economies. This finding may reflect a lower level of financial development of emerging economies compared to advanced economies. Lower financial openness and greater trade openness of emerging economies may also play a role as it implies greater importance of trade and production linkages as channels through which emerging economies are integrated in the global economy. These conclusions are qualitatively robust to a variety of changes in model specification and broadly consistent with experiences during the recent financial crisis.

**Figure 3.1:** Domestic Impact of One Percentage Point Increase in the U.S. Bank Default Probability (In percentage points)



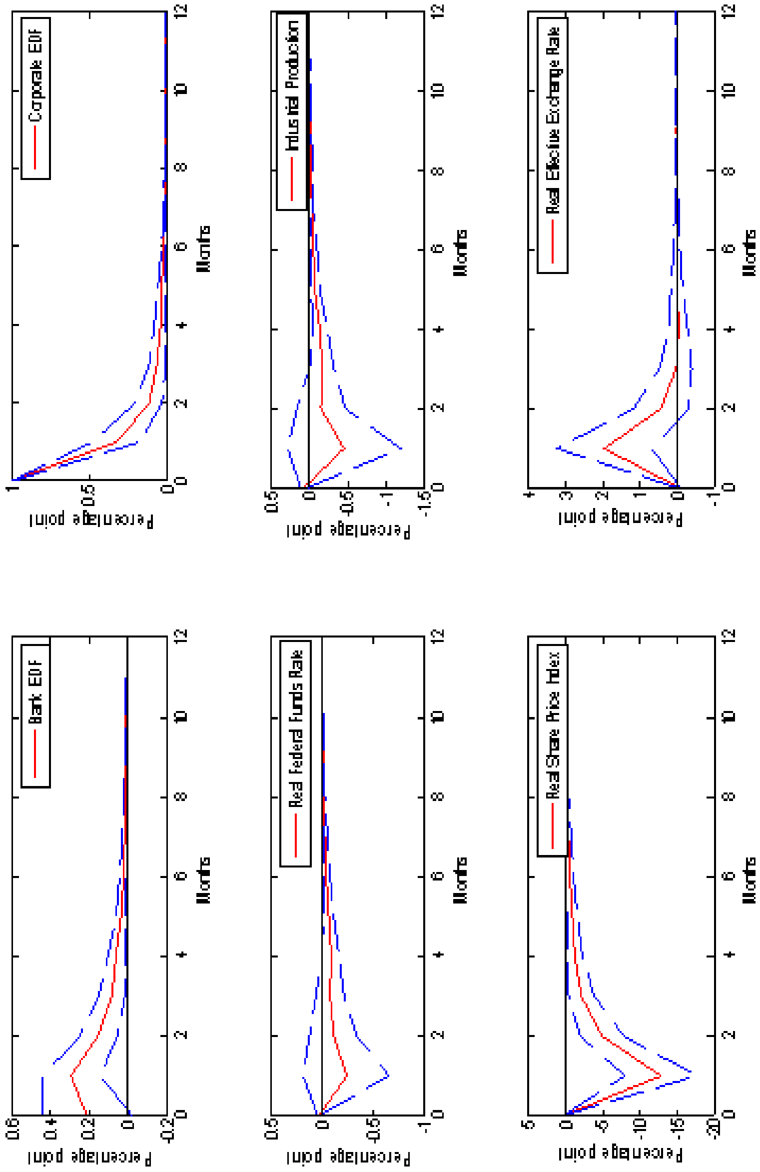
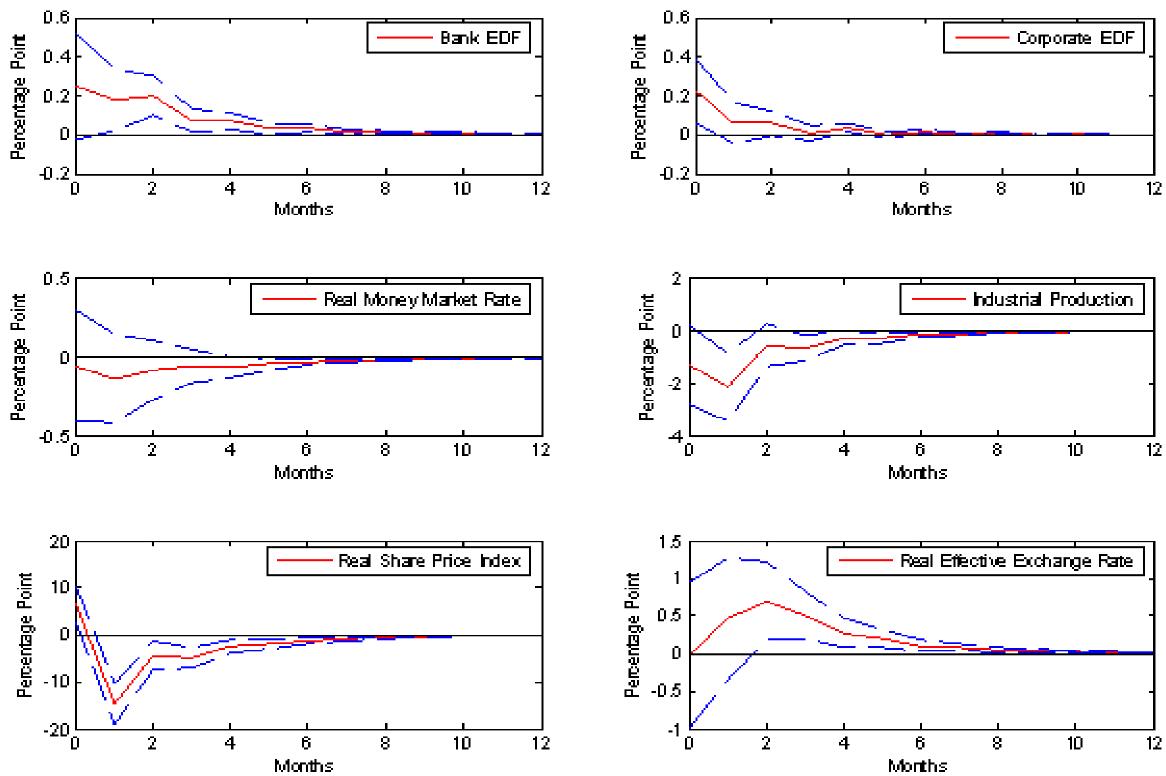



**Figure 3.2:** Domestic Impact of One Percentage Point Increase in the U.S. Corporate Default Probability (In percentage points)

**Figure 3.3:** Impact of One Percentage Point Increase in the U.S. Bank Default Probability on Germany (In percentage points)



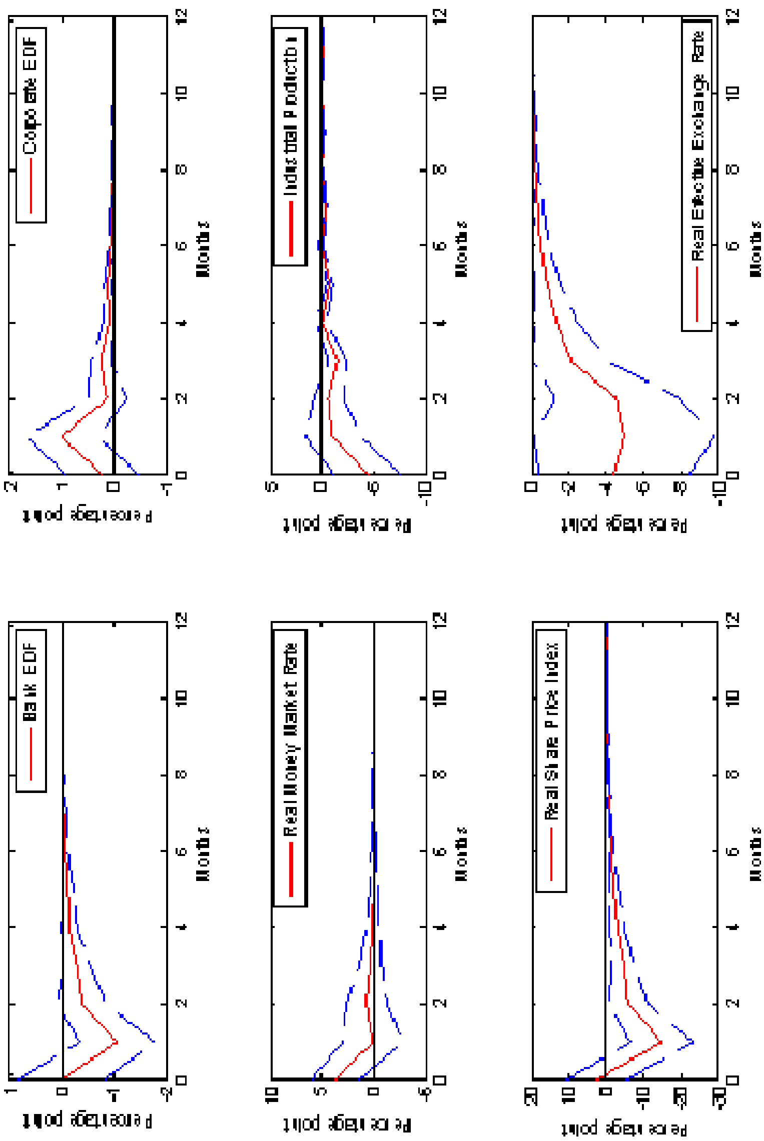



**Figure 3.4:** Impact of One Percentage Point Increase in the U.S. Bank Default Probability on Brazil (In percentage points)

**Figure 3.5:** Impact of One Percentage Point Increase in the U.S. Bank Default Probability on China (In percentage points)

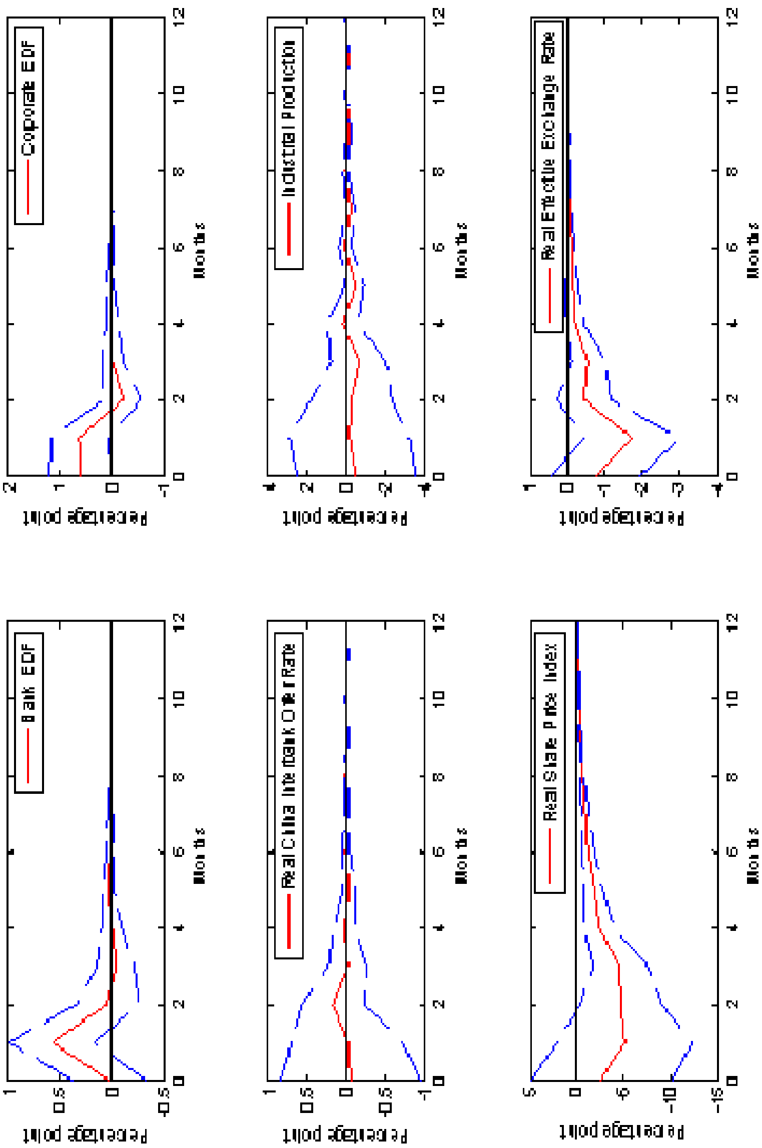


**Figure 3.6:** Impact of One Percentage Point Increase in the U.S. Corporate Default Probability on Germany (In percentage points)

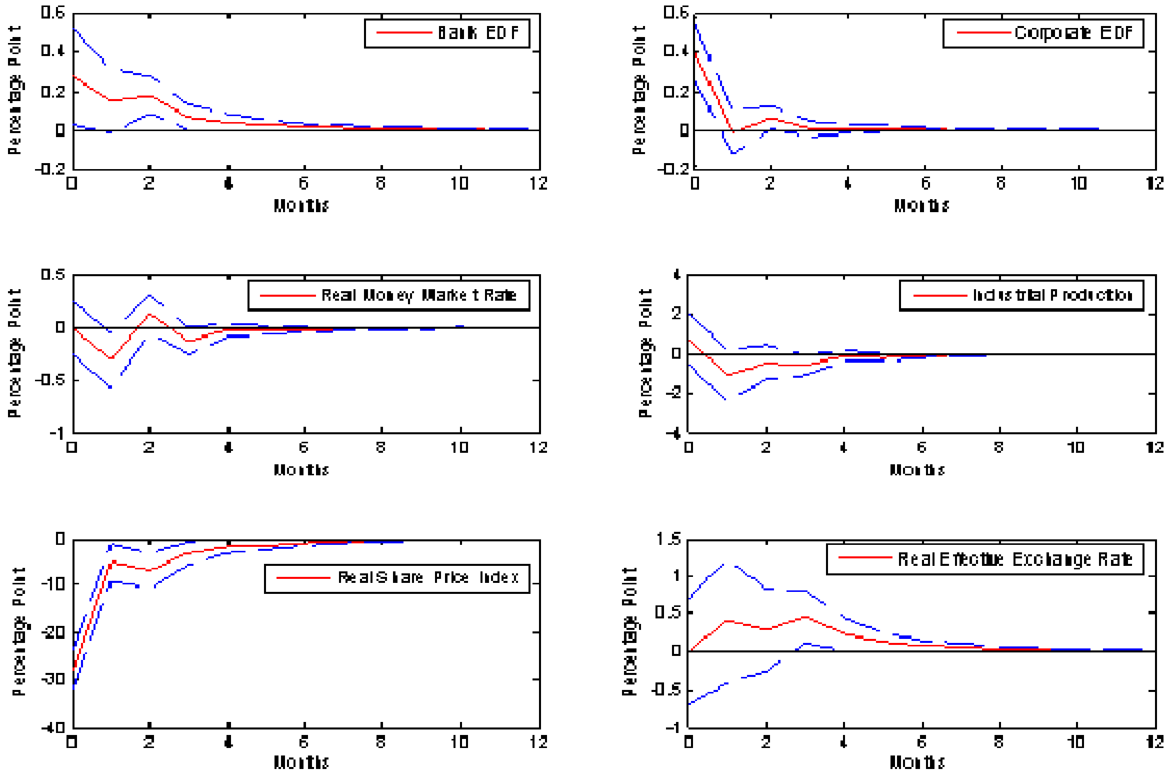


**Figure 3.7:** Impact of One Percentage Point Increase in the U.S. Corporate Default Probability on Brazil (In percentage points)

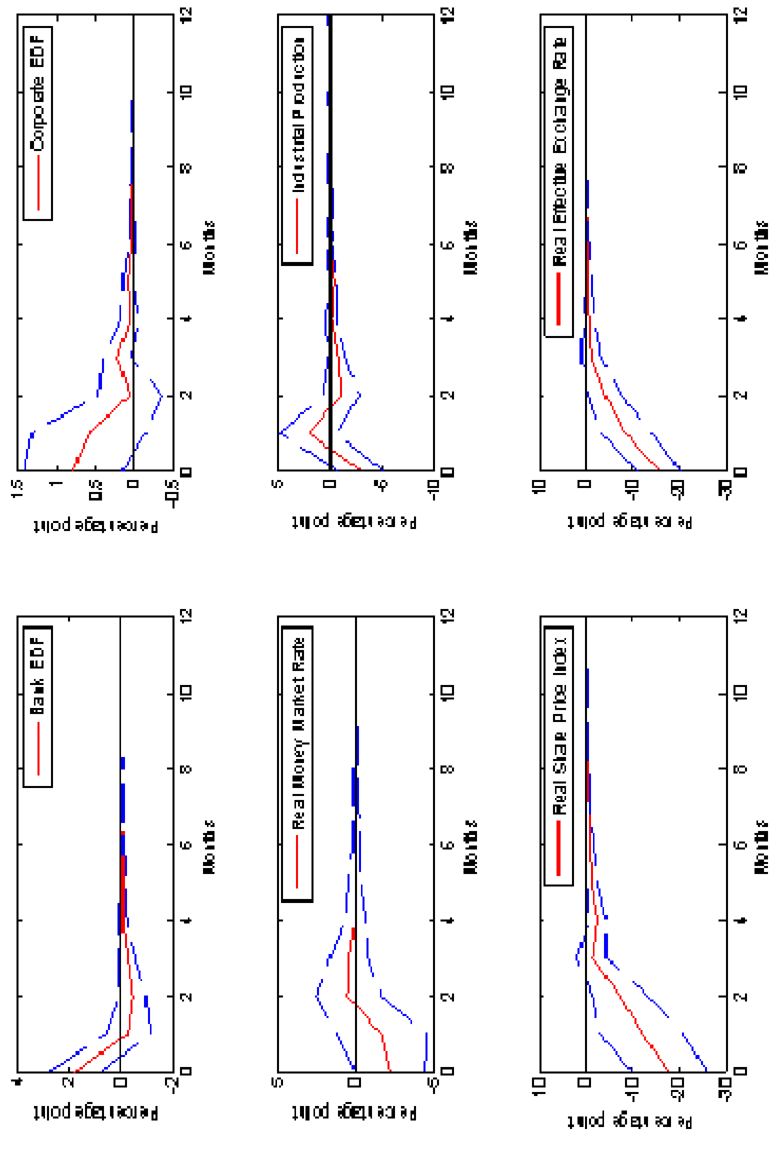


**Figure 3.8:** Impact of One Percentage Point Increase in the U.S. Corporate Default Probability on China (In percentage points)

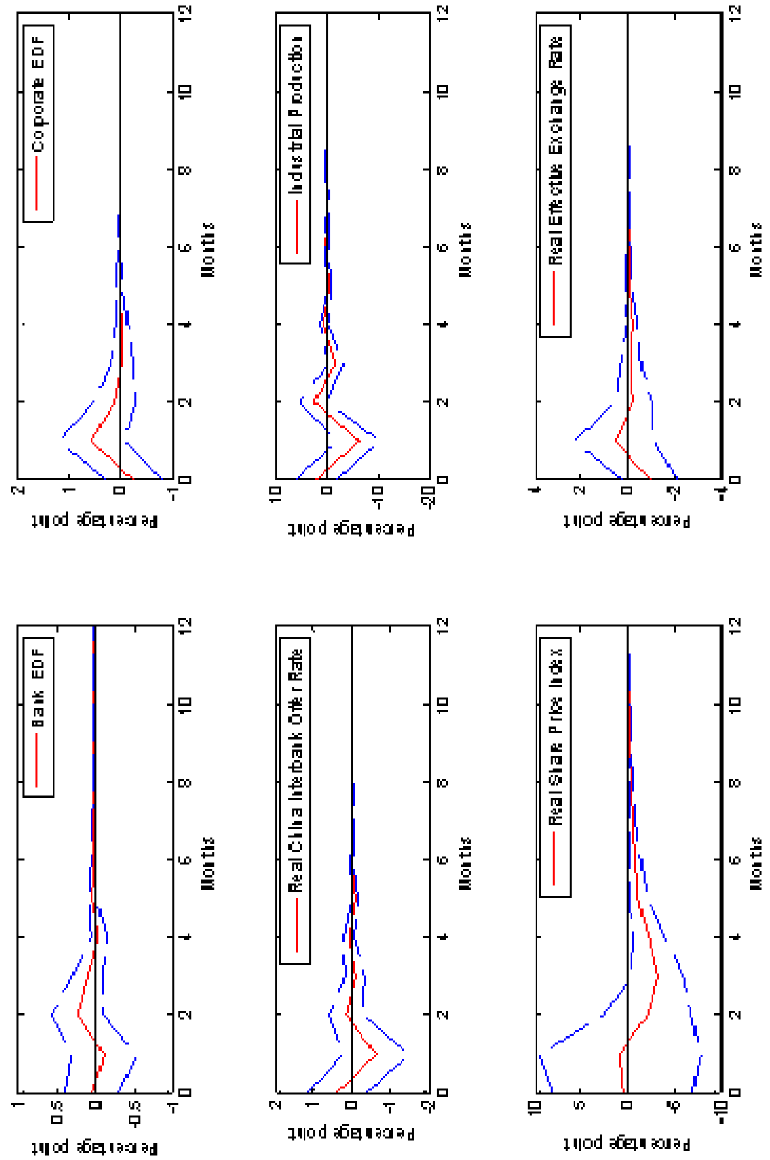
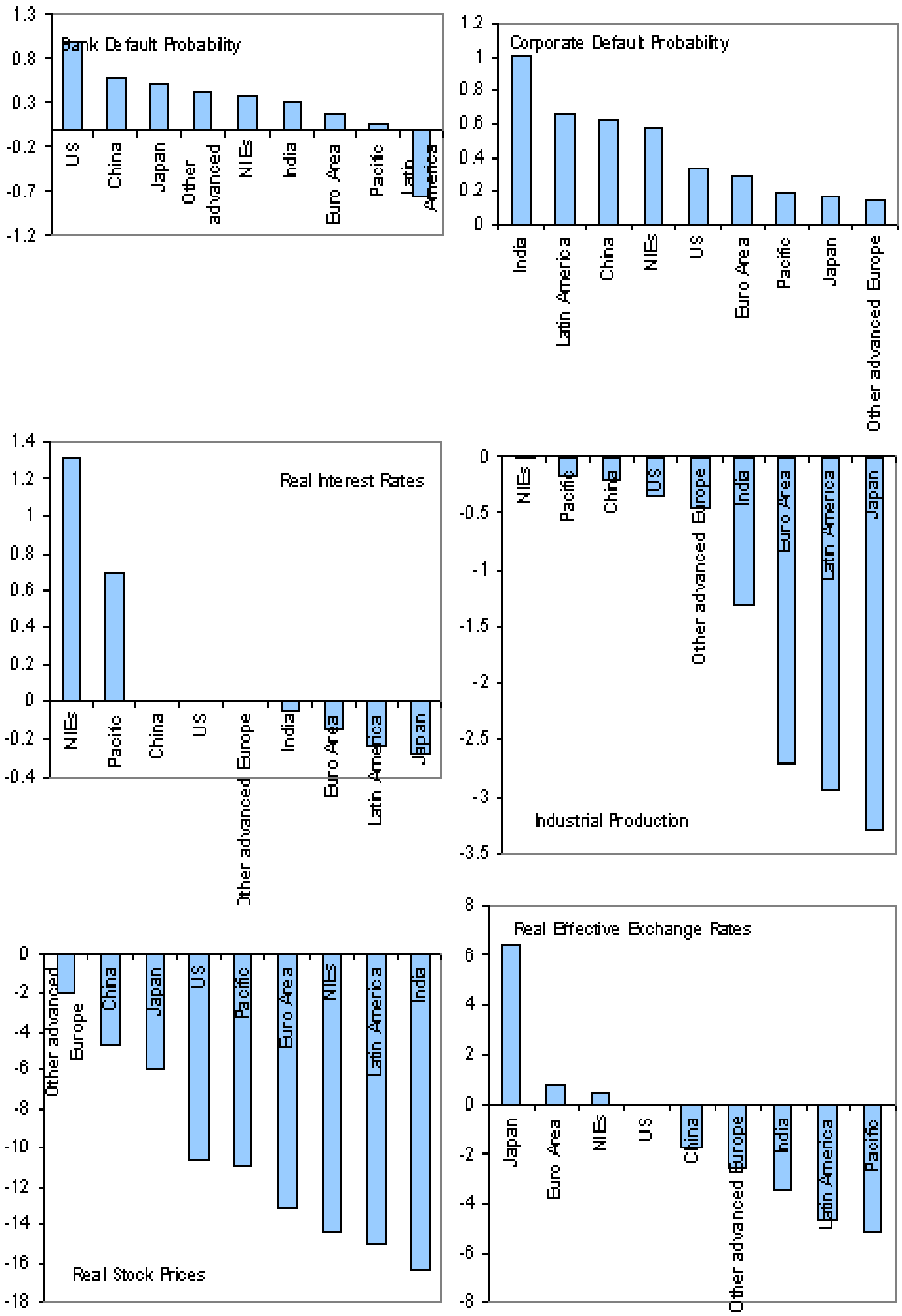
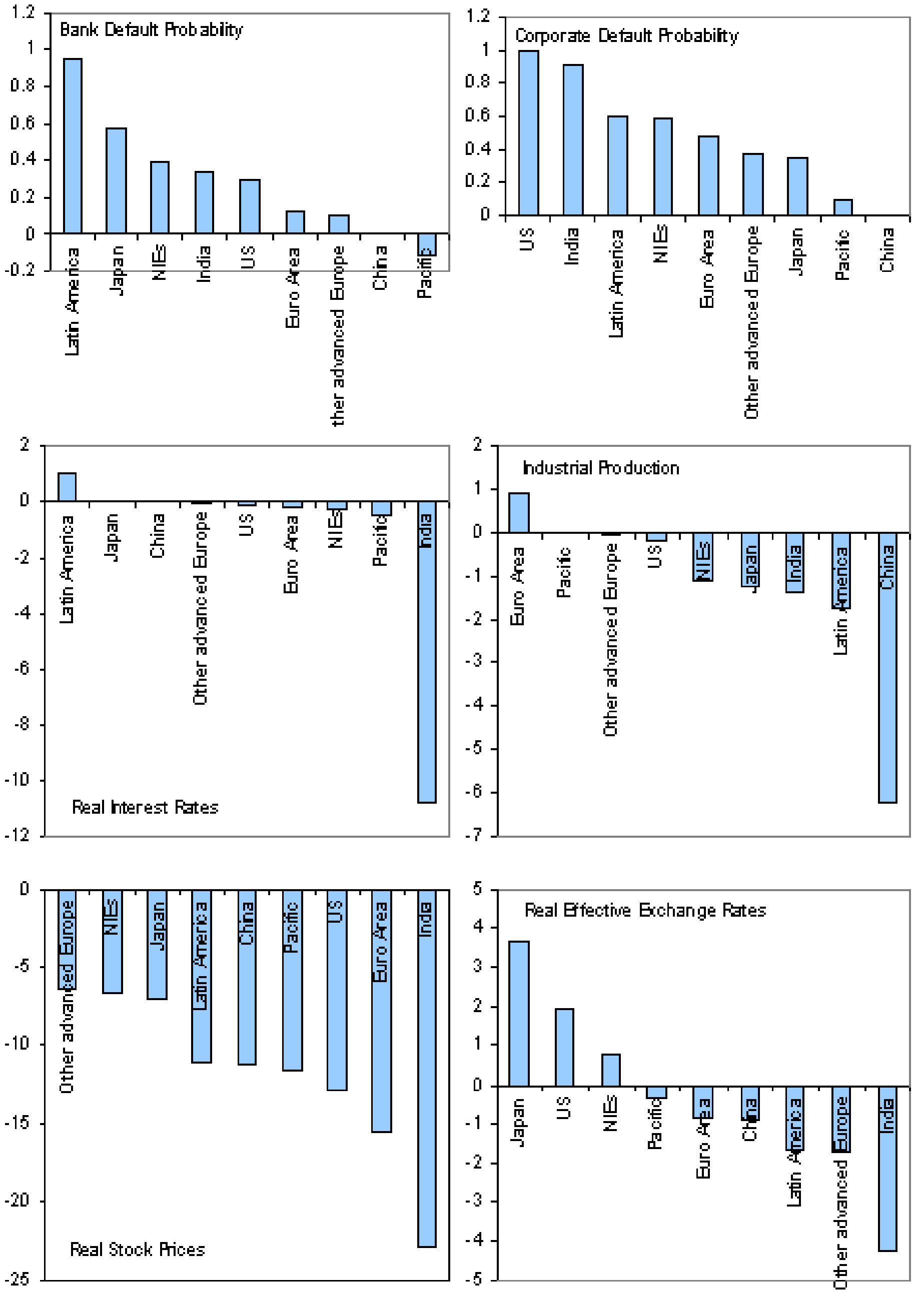


**Figure 3.9:** Maximum Impact of One Percentage Point Increase in the U.S. Bank Default Probability (In percentage points)



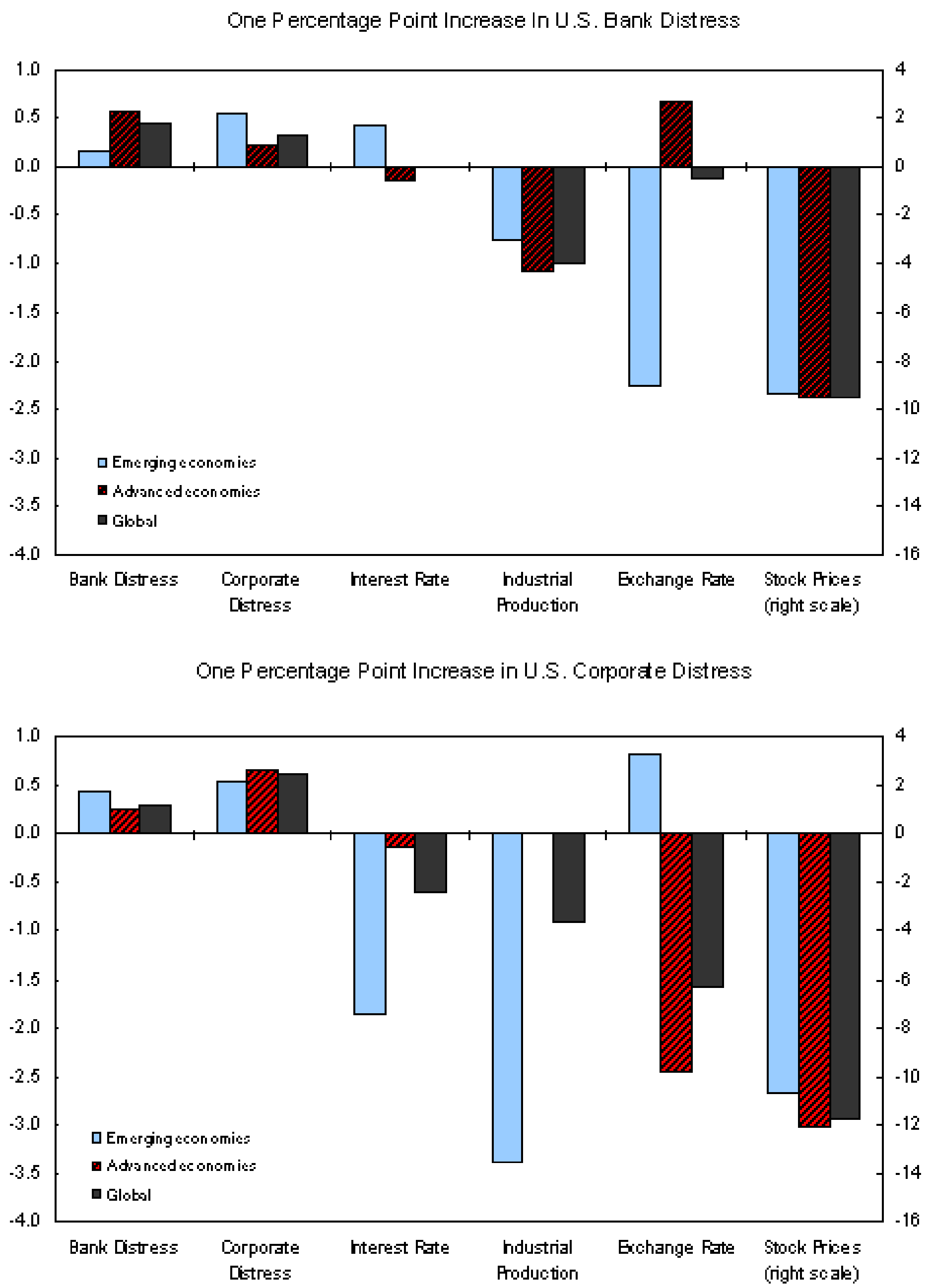

Source: Authors' estimates.

**Figure 3.10:** Maximum Impact of One Percentage Point Increase in the U.S. Corporate Default Probability (In percentage points)




Source: Authors' estimates.
Note: Weighted by PPP-adjusted GDP.

**Figure 3.11:** Average Impact on Advanced and Emerging Economies (In percentage points)




Source: Authors' estimates.

**Figure 3.12:** Global Transmission of U.S. Bank and Corporate Distress

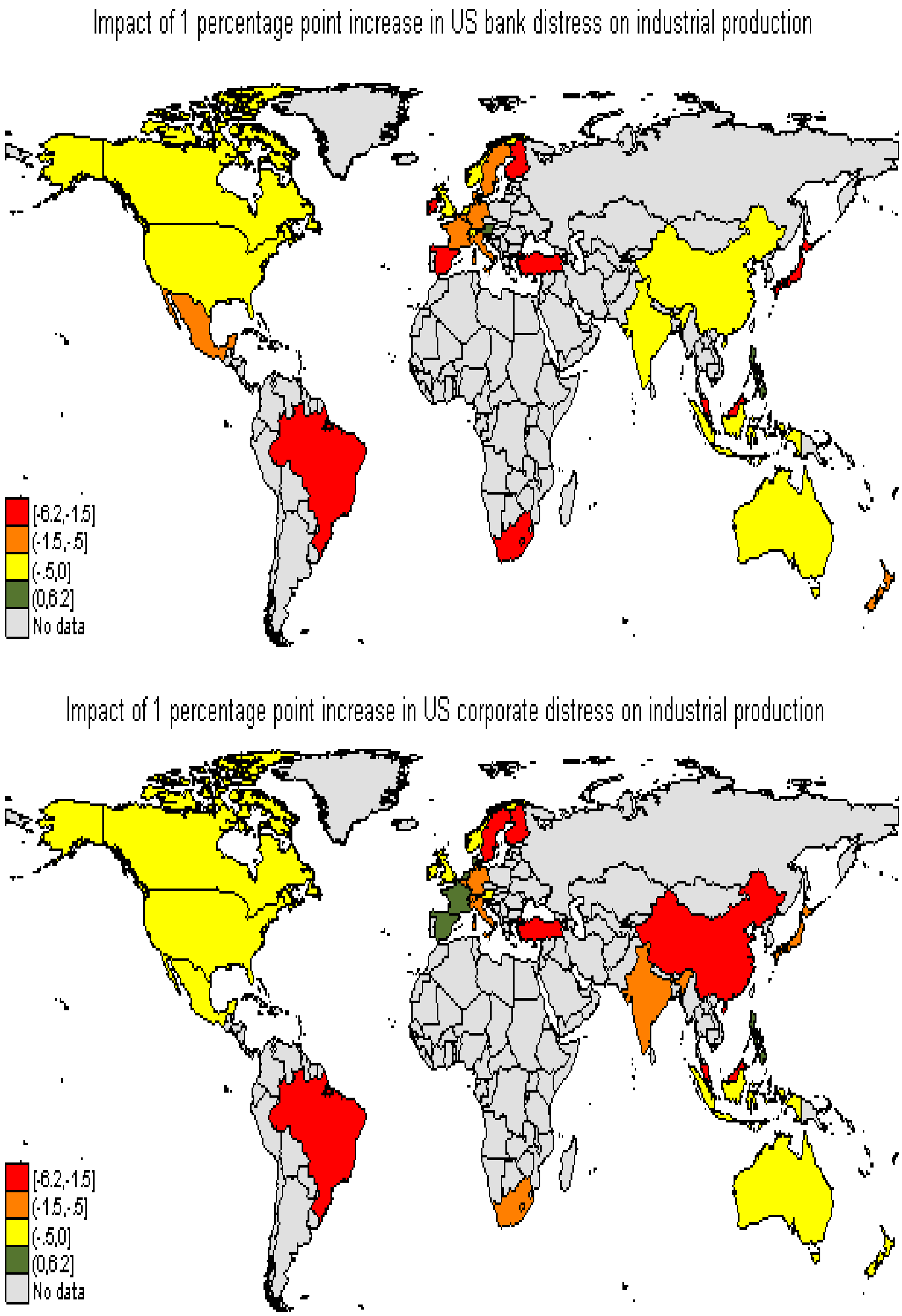
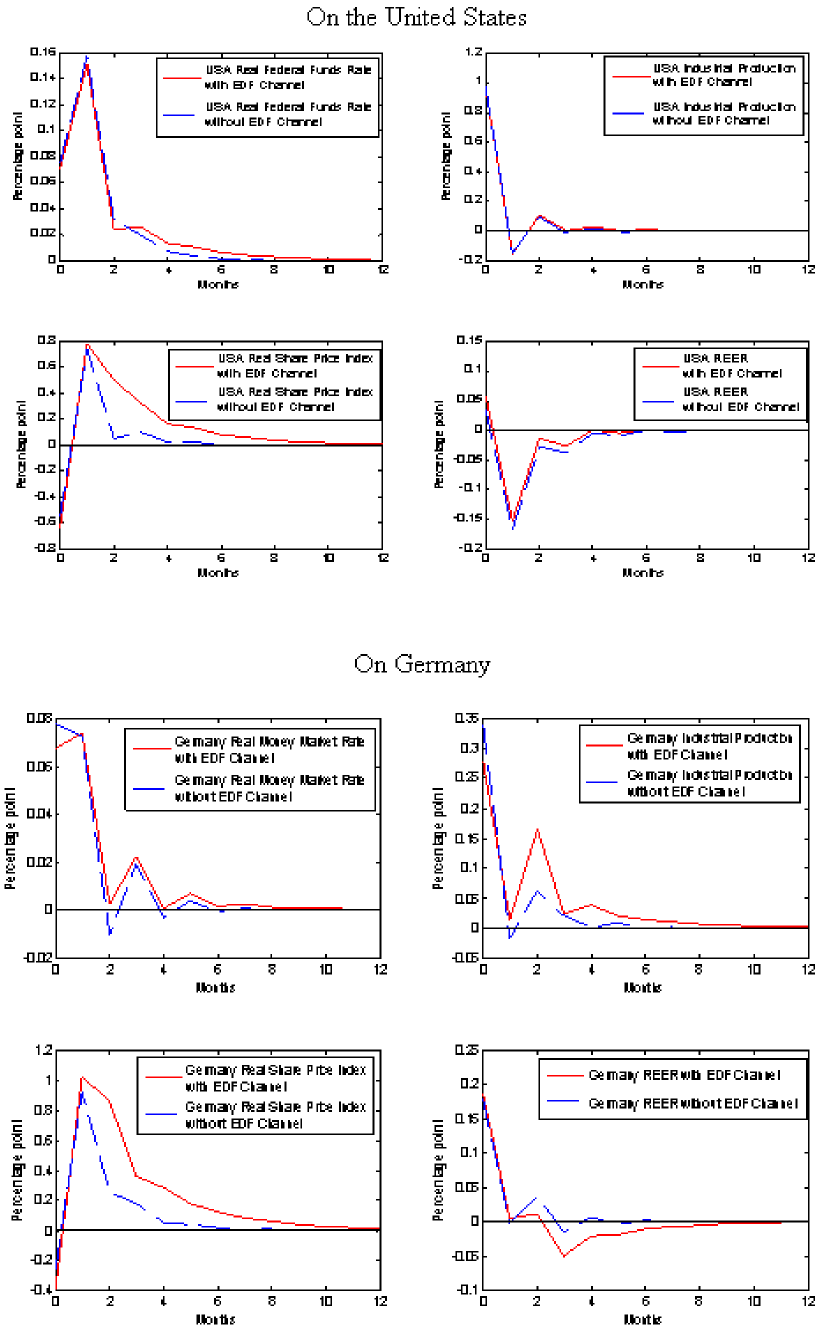


**Figure 3.13:** Impact of One Percentage Point Decline in the U.S. Industrial Production (In percentage points)




Source: Authors' Estimates

## 3.5 Appendix 3.1: Data Description

This appendix describes the sources and construction of data series that are used in the main text.

**Table 3.1:** Definitions and Sources of Variables

| Variable | Description | Source | Notes |
|---|---|---|---|
| *edfb* | Asset weighted one year ahead expected default probability of financial firms | Moody's KMV | Data for China from March 1996 to April 1997 are not available, and are interpolated in a linear manner. |
| *edfn* | Asset weighted one year ahead expected default probability of nonfinancial firms | Moody's KMV | Missing data for October 1996 are interpolated. |

Table 3.1 continues on Next Page

| Variable | Description | Source | Notes |
|---|---|---|---|
| $y$ | Logarithm of industrial production index | GDS for Australia and New Zealand; CEIC for Brazil, China, Hong Kong SAR, Indonesia, Malaysia, Philippines, Singapore and South Africa; IFS for all other economies. | Data for China is the value added of industry, which to our knowledge the closest available measure of the industrial production. The series is spliced with the implied value from the year on year growth value from 1995 January onwards. All data from CEIC and for India are available in seasonally unadjusted form and adjusted using Census X12 in EViews. |

Table 3.1 continues on Next Page

| Variable | Description | Source | Notes |
|---|---|---|---|
| $r$ | Money market rate deflated by consumer price index (CPI) | Money market rates are from IFS and CEIC. Consumer price indices for Australia and New Zealand are from GDS, while the rest economies are from IFS. The 7 day weighted average CHIBOR is used for China. | Data for Sweden from December 2004 onwards are not available in the IFS, and the policy-related interest rate from the GDS is taken instead. Missing data for September 1992 is interpolated. |
| $p^s$ | Logarithm of share price index deflated by CPI | IFS | |
| $q$ | Logarithm of real effective exchange rate | Data for Hong Kong SAR, Indonesia, Mexico and Turkey are from CEIC, while the rest are from IFS. | |
| $p^o$ | Logarithm of world spot petroleum price | IFS | |
| End of Table 3.1 | | | |

**Table 3.2:** Number of Firms

| Country | Corporates | Banks |
|---|---|---|
| Australia | 1542 | 8 |
| Austria | 65 | 6 |
| Belgium | 105 | 2 |
| Brazil | 257 | 26 |
| Canada | 1218 | 9 |
| China | 1913 | 14 |
| Denmark | 118 | 37 |
| Finland | 113 | 3 |
| France | 605 | 22 |
| Germany | 631 | 14 |
| Hong Kong | 793 | 9 |
| India | 1980 | 39 |
| Indonesia | 269 | 26 |
| Ireland | 57 | 2 |
| Italy | 229 | 23 |
| Japan | 3436 | 95 |
| Malaysia | 816 | 9 |
| Mexico | 90 | 3 |
| Netherlands | 123 | 3 |
| New Zealand | 110 | n.a. |
| Norway | 168 | 22 |
| Philippines | 137 | 16 |
| Singapore | 548 | 3 |
| South Africa | 268 | 9 |
| Spain | 106 | 8 |
| Sweden | 366 | 6 |
| Switzerland | 185 | 26 |
| Turkey | 186 | 16 |
| United Kingdom | 1333 | 10 |
| United States | 4367 | 443 |
| Average | 738 | 31 |
| Advanced | 858 | 36 |
| Emerging | 458 | 20 |
| Total | 22134 | 909 |
| Advanced | 18013 | 728 |
| Emerging | 4121 | 181 |

**Table 3.3:** Descriptive Statistics — Expected Default Frequency of Banks

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Australia | 0.004 | 0.000 | 0.310 | -0.311 | 0.047 | 0.634 | 27.965 |
| Austria | 0.006 | -0.001 | 3.188 | -2.994 | 0.358 | 0.759 | 72.291 |
| Belgium | 0.013 | 0.000 | 1.306 | -0.056 | 0.111 | 10.569 | 122.022 |
| Brazil | -0.003 | -0.015 | 5.445 | -5.127 | 0.807 | -0.103 | 32.637 |
| Canada | 0.001 | -0.003 | 0.552 | -0.565 | 0.076 | 0.213 | 41.514 |
| Switzerland | 0.002 | -0.001 | 0.630 | -1.283 | 0.156 | -3.061 | 34.851 |
| China | -0.004 | -0.001 | 3.306 | -1.273 | 0.427 | 2.647 | 26.301 |
| Denmark | 0.008 | 0.000 | 1.151 | -1.137 | 0.147 | 0.765 | 51.681 |
| Finland | -0.045 | -0.006 | 0.936 | -5.650 | 0.502 | -9.023 | 101.920 |
| France | 0.001 | -0.001 | 0.558 | -0.488 | 0.072 | 0.659 | 41.124 |
| Germany | 0.011 | -0.002 | 1.028 | -1.019 | 0.187 | 1.400 | 21.546 |
| Hong Kong SAR | 0.005 | -0.004 | 2.882 | -1.951 | 0.342 | 2.672 | 40.569 |
| India | 0.014 | -0.013 | 1.039 | -0.488 | 0.205 | 1.239 | 7.528 |
| Indonesia | 0.000 | -0.009 | 3.452 | -5.336 | 1.110 | -0.598 | 8.524 |
| Ireland | 0.025 | -0.002 | 2.314 | -0.374 | 0.212 | 8.391 | 89.490 |
| Italy | 0.001 | -0.001 | 0.270 | -0.216 | 0.048 | 0.747 | 13.713 |
| Japan | 0.033 | 0.008 | 2.393 | -1.267 | 0.317 | 2.129 | 25.252 |

Table 3.3 continues on Next Page.

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Malaysia | 0.000 | -0.019 | 2.471 | -2.755 | 0.623 | -0.425 | 9.730 |
| Mexico | -0.013 | -0.032 | 19.686 | -16.651 | 3.212 | 0.224 | 18.646 |
| Netherlands | 0.002 | -0.001 | 0.198 | -0.140 | 0.032 | 1.988 | 18.363 |
| New Zealand | 0.010 | -0.004 | 3.437 | -3.257 | 0.474 | 0.613 | 34.884 |
| Norway | 0.007 | -0.003 | 2.772 | -2.501 | 0.305 | 1.243 | 73.579 |
| Philippines | 0.014 | -0.008 | 2.245 | -2.563 | 0.488 | -0.125 | 12.639 |
| Singapore | 0.001 | -0.002 | 1.236 | -1.808 | 0.227 | -1.773 | 34.035 |
| South Africa | 0.002 | -0.001 | 0.462 | -0.686 | 0.118 | -0.106 | 13.017 |
| Spain | 0.001 | 0.000 | 0.097 | -0.042 | 0.017 | 1.799 | 10.740 |
| Sweden | 0.000 | -0.003 | 3.478 | -3.473 | 0.401 | 0.040 | 73.277 |
| Turkey | 0.014 | -0.039 | 2.434 | -2.914 | 0.588 | 0.103 | 10.648 |
| United Kingdom | 0.005 | -0.004 | 0.384 | -0.396 | 0.069 | 0.591 | 17.728 |
| United States | 0.026 | 0.001 | 1.169 | -0.240 | 0.148 | 4.795 | 31.579 |

End of Table 3.3

**Table 3.4:** Descriptive Statistics — Expected Default Frequency of Corporates

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Australia | 0.012 | -0.004 | 1.233 | -0.920 | 0.180 | 1.777 | 26.685 |
| Austria | 0.013 | -0.004 | 4.254 | -4.189 | 0.499 | 0.139 | 66.508 |
| Belgium | 0.001 | -0.004 | 0.458 | -0.477 | 0.090 | 0.517 | 14.699 |
| Brazil | -0.021 | -0.046 | 3.770 | -2.207 | 0.691 | 1.245 | 9.891 |
| Canada | 0.012 | -0.007 | 0.617 | -0.412 | 0.146 | 1.293 | 7.663 |
| Switzerland | 0.000 | -0.001 | 0.624 | -0.649 | 0.112 | -0.032 | 19.479 |
| China | 0.001 | 0.000 | 4.332 | -1.979 | 0.639 | 1.982 | 18.223 |
| Denmark | 0.002 | -0.001 | 0.153 | -0.192 | 0.048 | -0.131 | 6.254 |
| Finland | 0.002 | -0.001 | 0.397 | -0.682 | 0.082 | -2.790 | 36.956 |
| France | 0.004 | -0.003 | 2.035 | -1.945 | 0.280 | 0.415 | 35.728 |
| Germany | 0.002 | -0.004 | 1.076 | -1.066 | 0.150 | 0.640 | 36.892 |
| Hong Kong SAR | 0.008 | -0.004 | 0.842 | -0.574 | 0.194 | 0.778 | 6.570 |
| India | 0.016 | -0.015 | 1.481 | -0.840 | 0.337 | 0.838 | 6.114 |
| Indonesia | 0.016 | -0.002 | 3.107 | -3.551 | 0.799 | 0.042 | 7.885 |
| Ireland | 0.018 | -0.001 | 1.432 | -0.947 | 0.232 | 2.461 | 19.474 |
| Italy | 0.003 | -0.003 | 0.737 | -0.444 | 0.126 | 1.714 | 14.966 |
| Japan | 0.013 | 0.010 | 0.711 | -0.700 | 0.203 | -0.189 | 6.069 |

Table 3.4 continues on Next Page.

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Malaysia | 0.012 | -0.007 | 2.840 | -3.334 | 0.674 | -0.557 | 12.190 |
| Mexico | 0.000 | -0.010 | 0.840 | -0.538 | 0.181 | 0.827 | 7.662 |
| Netherlands | 0.004 | -0.002 | 0.557 | -0.806 | 0.152 | -0.397 | 11.273 |
| New Zealand | 0.003 | -0.001 | 1.408 | -1.087 | 0.187 | 2.145 | 34.805 |
| Norway | 0.009 | -0.002 | 0.802 | -0.730 | 0.156 | 0.654 | 14.815 |
| Philippines | 0.027 | 0.008 | 1.561 | -1.500 | 0.457 | -0.201 | 4.979 |
| Singapore | 0.015 | 0.000 | 1.711 | -1.661 | 0.317 | 0.030 | 14.415 |
| South Africa | 0.002 | -0.004 | 1.347 | -1.638 | 0.247 | -0.463 | 20.534 |
| Spain | 0.002 | -0.002 | 0.455 | -0.472 | 0.068 | -0.695 | 31.807 |
| Sweden | 0.003 | -0.002 | 1.140 | -1.065 | 0.177 | 0.074 | 23.870 |
| Turkey | 0.016 | -0.011 | 1.474 | -1.628 | 0.413 | 0.424 | 6.696 |
| United Kingdom | 0.004 | -0.003 | 0.320 | -0.247 | 0.064 | 0.585 | 9.937 |
| United States | 0.009 | 0.000 | 0.463 | -0.506 | 0.121 | 0.399 | 8.268 |

End of Table 3.4

**Table 3.5:** Descriptive Statistics — Industrial Production

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Australia | 0.001 | 0.001 | 0.018 | -0.013 | 0.006 | 0.197 | 3.140 |
| Austria | 0.003 | 0.004 | 0.065 | -0.047 | 0.020 | 0.073 | 3.813 |
| Belgium | 0.001 | -0.001 | 0.069 | -0.077 | 0.023 | 0.147 | 4.171 |
| Brazil | 0.001 | 0.002 | 0.054 | -0.135 | 0.021 | -1.952 | 14.489 |
| Canada | 0.001 | 0.000 | 0.035 | -0.029 | 0.010 | -0.058 | 4.297 |
| Switzerland | 0.002 | 0.003 | 0.044 | -0.037 | 0.011 | -0.026 | 5.190 |
| China | 0.010 | 0.010 | 0.109 | -0.120 | 0.025 | -0.656 | 10.144 |
| Denmark | 0.001 | 0.000 | 0.116 | -0.113 | 0.029 | -0.083 | 5.630 |
| Finland | 0.003 | 0.002 | 0.081 | -0.087 | 0.025 | -0.048 | 3.866 |
| France | 0.000 | 0.002 | 0.039 | -0.041 | 0.012 | -0.163 | 4.080 |
| Germany | 0.001 | 0.002 | 0.029 | -0.041 | 0.014 | -0.507 | 3.194 |
| Hong Kong SAR | -0.003 | -0.002 | 0.036 | -0.041 | 0.011 | 0.291 | 4.740 |
| India | 0.005 | 0.006 | 0.193 | -0.114 | 0.026 | 1.364 | 22.569 |
| Indonesia | 0.001 | 0.001 | 0.258 | -0.283 | 0.077 | -0.274 | 6.967 |
| Ireland | 0.006 | 0.006 | 0.129 | -0.226 | 0.058 | -0.529 | 4.658 |
| Italy | -0.001 | 0.000 | 0.037 | -0.047 | 0.014 | -0.321 | 3.618 |
| Japan | 0.005 | 0.005 | 0.065 | -0.042 | 0.015 | 0.081 | 5.007 |

Table 3.5 continues on Next Page.

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Malaysia | 0.004 | 0.005 | 0.089 | -0.077 | 0.029 | 0.117 | 3.181 |
| Mexico | 0.002 | 0.003 | 0.037 | -0.025 | 0.010 | 0.045 | 4.207 |
| Netherlands | 0.001 | 0.002 | 0.083 | -0.105 | 0.027 | -0.238 | 5.326 |
| New Zealand | 0.000 | 0.000 | 0.032 | -0.024 | 0.008 | 0.266 | 4.334 |
| Norway | 0.000 | 0.000 | 0.113 | -0.098 | 0.029 | 0.072 | 5.137 |
| Philippines | -0.002 | -0.004 | 0.158 | -0.198 | 0.051 | 0.046 | 5.084 |
| Singapore | 0.003 | -0.001 | 0.272 | -0.214 | 0.070 | 0.318 | 4.488 |
| South Africa | 0.001 | 0.000 | 0.106 | -0.081 | 0.028 | 0.231 | 4.498 |
| Spain | 0.000 | -0.001 | 0.265 | -0.191 | 0.059 | 0.551 | 6.345 |
| Sweden | 0.001 | 0.002 | 0.040 | -0.028 | 0.012 | 0.003 | 3.165 |
| Turkey | 0.002 | 0.006 | 0.130 | -0.159 | 0.051 | -0.352 | 4.154 |
| United Kingdom | -0.001 | 0.000 | 0.021 | -0.046 | 0.008 | -1.156 | 7.986 |
| United States | 0.001 | 0.002 | 0.020 | -0.041 | 0.007 | -1.778 | 12.408 |

End of Table 3.5

**Table 3.6:** Descriptive Statistics — Real Effective Exchange Rate

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Australia | 0.000 | 0.004 | 0.048 | -0.136 | 0.024 | -1.482 | 8.970 |
| Austria | 0.000 | 0.000 | 0.037 | -0.026 | 0.007 | 1.048 | 10.087 |
| Belgium | 0.000 | -0.001 | 0.032 | -0.018 | 0.007 | 0.689 | 4.524 |
| Brazil | -0.002 | 0.000 | 0.234 | -0.219 | 0.051 | -0.406 | 10.116 |
| Canada | 0.000 | 0.001 | 0.044 | -0.101 | 0.017 | -1.127 | 10.131 |
| Switzerland | -0.001 | -0.002 | 0.048 | -0.033 | 0.012 | 0.683 | 5.031 |
| China | 0.001 | 0.003 | 0.076 | -0.083 | 0.015 | -0.421 | 10.578 |
| Denmark | 0.000 | 0.001 | 0.022 | -0.021 | 0.007 | 0.147 | 3.561 |
| Finland | 0.000 | -0.001 | 0.041 | -0.026 | 0.010 | 0.602 | 4.880 |
| France | 0.000 | 0.000 | 0.029 | -0.021 | 0.007 | 0.473 | 4.668 |
| Germany | -0.001 | -0.001 | 0.034 | -0.023 | 0.009 | 0.652 | 4.669 |
| Hong Kong SAR | -0.001 | 0.000 | 0.043 | -0.044 | 0.011 | 0.121 | 5.368 |
| India | 0.000 | 0.001 | 0.059 | -0.043 | 0.014 | 0.012 | 5.289 |
| Indonesia | -0.002 | 0.001 | 0.245 | -0.605 | 0.080 | -2.698 | 24.981 |
| Ireland | 0.002 | 0.002 | 0.042 | -0.036 | 0.012 | 0.057 | 4.381 |
| Italy | 0.001 | 0.001 | 0.032 | -0.021 | 0.008 | 0.495 | 4.323 |
| Japan | -0.001 | -0.004 | 0.104 | -0.049 | 0.025 | 1.092 | 5.058 |

Table 3.6 continues on Next Page.

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Malaysia | -0.001 | 0.000 | 0.130 | -0.116 | 0.023 | -0.053 | 15.756 |
| Mexico | 0.003 | 0.005 | 0.060 | -0.145 | 0.023 | -1.847 | 13.395 |
| Netherlands | 0.000 | 0.000 | 0.034 | -0.022 | 0.008 | 0.730 | 5.155 |
| New Zealand | -0.001 | -0.001 | 0.053 | -0.069 | 0.020 | -0.265 | 3.135 |
| Norway | 0.000 | 0.000 | 0.043 | -0.062 | 0.015 | -0.635 | 4.679 |
| Philippines | -0.001 | -0.001 | 0.079 | -0.105 | 0.023 | -0.353 | 6.755 |
| Singapore | 0.000 | 0.000 | 0.080 | -0.083 | 0.012 | -0.224 | 25.848 |
| South Africa | -0.004 | -0.005 | 0.082 | -0.162 | 0.040 | -0.733 | 5.287 |
| Spain | 0.001 | 0.001 | 0.020 | -0.017 | 0.006 | 0.104 | 4.108 |
| Sweden | -0.002 | -0.003 | 0.036 | -0.051 | 0.014 | -0.364 | 3.724 |
| Turkey | 0.001 | 0.004 | 0.123 | -0.109 | 0.035 | -0.155 | 5.354 |
| United Kingdom | 0.000 | 0.000 | 0.042 | -0.087 | 0.016 | -1.480 | 10.339 |
| United States | 0.000 | 0.000 | 0.062 | -0.039 | 0.013 | 0.520 | 6.151 |

End of Table 3.6

**Table 3.7:** Descriptive Statistics — Real Short-Term Interest Rate

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Australia | -0.016 | 0.013 | 1.877 | -2.013 | 0.416 | 0.245 | 10.162 |
| Austria | -0.006 | -0.010 | 0.971 | -1.159 | 0.319 | -0.195 | 3.832 |
| Belgium | -0.016 | -0.009 | 0.920 | -1.040 | 0.372 | -0.128 | 3.207 |
| Brazil | -0.056 | -0.087 | 21.414 | -8.806 | 2.788 | 3.693 | 31.134 |
| Canada | -0.023 | -0.045 | 1.577 | -1.314 | 0.491 | 0.179 | 3.746 |
| Switzerland | -0.007 | -0.011 | 0.953 | -1.071 | 0.386 | 0.185 | 3.088 |
| China | -0.020 | 0.050 | 2.680 | -2.372 | 0.812 | -0.190 | 3.722 |
| Denmark | -0.004 | -0.004 | 0.818 | -0.831 | 0.320 | 0.063 | 2.849 |
| Finland | -0.029 | -0.050 | 0.581 | -1.634 | 0.327 | -0.737 | 5.629 |
| France | -0.009 | -0.002 | 0.750 | -0.933 | 0.294 | -0.043 | 3.384 |
| Germany | -0.008 | -0.007 | 0.843 | -0.836 | 0.305 | 0.103 | 3.087 |
| Hong Kong SAR | -0.005 | 0.009 | 11.295 | -11.477 | 1.562 | -0.125 | 37.051 |
| India | -0.063 | -0.001 | 72.590 | -59.944 | 8.753 | 1.562 | 45.611 |
| Indonesia | -0.044 | 0.052 | 48.138 | -31.525 | 6.459 | 1.696 | 26.268 |
| Ireland | -0.009 | 0.008 | 1.153 | -1.355 | 0.396 | -0.284 | 3.878 |
| Italy | -0.025 | -0.010 | 0.479 | -0.755 | 0.224 | -0.368 | 3.293 |
| Japan | -0.007 | -0.001 | 1.904 | -1.496 | 0.333 | 0.617 | 10.827 |

Table 3.7 continues on Next Page.

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Malaysia | -0.028 | 0.007 | 4.358 | -5.464 | 0.900 | -1.140 | 16.611 |
| Mexico | 0.018 | 0.035 | 15.832 | -8.452 | 2.144 | 2.354 | 23.300 |
| Netherlands | -0.008 | 0.012 | 0.819 | -1.194 | 0.271 | -0.439 | 4.609 |
| New Zealand | -0.019 | 0.003 | 1.099 | -2.215 | 0.401 | -1.159 | 8.431 |
| Norway | -0.009 | -0.023 | 2.039 | -2.951 | 0.604 | -0.571 | 7.499 |
| Philippines | -0.039 | -0.078 | 17.715 | -17.799 | 2.535 | 0.343 | 34.022 |
| Singapore | -0.032 | -0.034 | 3.973 | -3.087 | 0.710 | 0.187 | 11.996 |
| South Africa | -0.035 | -0.078 | 4.153 | -1.991 | 0.744 | 1.042 | 8.851 |
| Spain | -0.026 | -0.003 | 0.921 | -1.140 | 0.324 | -0.323 | 4.027 |
| Sweden | -0.037 | -0.020 | 1.513 | -0.999 | 0.377 | 0.401 | 4.679 |
| Turkey | -0.158 | -0.075 | 360.066 | -323.166 | 41.747 | 1.016 | 60.209 |
| United Kingdom | -0.014 | 0.002 | 2.806 | -2.745 | 0.586 | 0.069 | 9.505 |
| United States | -0.019 | -0.026 | 2.006 | -1.040 | 0.444 | 0.868 | 6.494 |

End of Table 3.7

**Table 3.8:** Descriptive Statistics — Real Stock Price

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Australia | 0.001 | 0.010 | 0.064 | -0.136 | 0.037 | -1.170 | 4.679 |
| Austria | 0.007 | 0.013 | 0.374 | -0.269 | 0.065 | 0.246 | 10.487 |
| Belgium | 0.000 | 0.008 | 0.117 | -0.297 | 0.050 | -1.749 | 10.214 |
| Brazil | 0.008 | 0.018 | 0.210 | -0.498 | 0.099 | -1.287 | 7.003 |
| Canada | 0.003 | 0.011 | 0.111 | -0.226 | 0.049 | -1.332 | 6.615 |
| Switzerland | 0.003 | 0.012 | 0.119 | -0.204 | 0.049 | -0.942 | 4.773 |
| China | 0.006 | 0.001 | 0.279 | -0.282 | 0.082 | 0.210 | 4.091 |
| Denmark | 0.003 | 0.013 | 0.097 | -0.267 | 0.048 | -1.629 | 8.689 |
| Finland | 0.003 | 0.021 | 0.258 | -0.355 | 0.084 | -0.734 | 5.251 |
| France | 0.002 | 0.011 | 0.124 | -0.194 | 0.058 | -0.657 | 3.677 |
| Germany | 0.001 | 0.010 | 0.177 | -0.273 | 0.064 | -0.961 | 5.322 |
| Hong Kong SAR | 0.002 | 0.007 | 0.203 | -0.264 | 0.070 | -0.509 | 4.393 |
| India | 0.003 | 0.014 | 0.156 | -0.205 | 0.070 | -0.451 | 2.982 |
| Indonesia | -0.004 | 0.005 | 0.249 | -0.402 | 0.098 | -1.147 | 6.464 |
| Ireland | -0.002 | 0.009 | 0.145 | -0.239 | 0.061 | -1.049 | 4.869 |
| Italy | 0.001 | 0.009 | 0.124 | -0.227 | 0.054 | -0.668 | 5.599 |
| Japan | -0.004 | -0.004 | 0.109 | -0.243 | 0.049 | -0.679 | 5.730 |

Table 3.8 continues on Next Page.

| | Mean | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Malaysia | -0.003 | 0.002 | 0.237 | -0.248 | 0.067 | -0.058 | 5.317 |
| Mexico | 0.006 | 0.016 | 0.161 | -0.359 | 0.074 | -1.029 | 6.080 |
| Netherlands | -0.001 | 0.009 | 0.148 | -0.315 | 0.058 | -1.425 | 8.059 |
| New Zealand | 0.003 | 0.008 | 0.871 | -0.981 | 0.134 | -0.917 | 34.713 |
| Norway | 0.004 | 0.016 | 0.117 | -0.330 | 0.061 | -1.606 | 8.072 |
| Philippines | 0.010 | 0.001 | 1.133 | -0.828 | 0.230 | 0.659 | 9.526 |
| Singapore | -0.002 | 0.009 | 0.250 | -0.283 | 0.075 | -0.461 | 5.279 |
| South Africa | 0.002 | 0.012 | 0.100 | -0.220 | 0.056 | -1.097 | 5.103 |
| Spain | 0.005 | 0.007 | 0.141 | -0.218 | 0.058 | -0.704 | 4.576 |
| Sweden | 0.004 | 0.012 | 0.148 | -0.199 | 0.064 | -0.681 | 3.773 |
| Turkey | 0.001 | 0.004 | 0.367 | -0.418 | 0.116 | -0.155 | 4.480 |
| United Kingdom | 0.002 | 0.005 | 0.081 | -0.131 | 0.039 | -0.780 | 3.811 |
| United States | 0.001 | 0.004 | 0.098 | -0.181 | 0.039 | -1.020 | 5.883 |

End of Table 3.8

Table 3.9 to Table 3.11 report currency exposure measures constructed by Lane and Shambaugh (2009) for bilateral financial asset positions in five instruments: portfolio equity, direct investment, portfolio debt, other general bank-related debt, and reserves. We take the average weight from 1999 to 2004 (the latest data for which Lane and Shambaugh's data are available) as a fixed weight for the four financial variables in the model. The financial weights for Euro zone countries after 1999 are computed using the weight of the Euro zone, multiplying which with the share of the country weight in the Euro zone based on the 1998 weight.

Table 3.12 to Table 3.14 report average trade weights for 1996-2008, which are used for constructing measures of foreign industrial production. The estimates are based on the IMF's Direction of Trade Statistics (2009).

**Table 3.9:** Financial Weights

| | Australia | Austria | Belgium | Brazil | Canada | China | Denmark | Finland | France | Germany | Hong Kong |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 0.0% | 0.0% | 0.2% | 0.1% | 0.8% | 0.1% | 0.1% | 0.1% | 1.6% | 5.5% | 2.1% |
| Austria | 0.4% | 0.0% | 1.2% | 0.1% | 0.4% | 0.1% | 0.3% | 0.1% | 5.0% | 33.9% | 0.2% |
| Belgium | 0.1% | 0.3% | 0.0% | 0.3% | 0.9% | 0.1% | 0.5% | 0.3% | 20.5% | 15.6% | 0.1% |
| Brazil | 0.1% | 0.1% | 0.5% | 0.0% | 1.0% | 0.1% | 0.1% | 0.0% | 2.2% | 5.4% | 0.0% |
| Canada | 1.3% | 0.2% | 0.7% | 1.0% | 0.0% | 0.1% | 0.2% | 0.2% | 2.9% | 5.2% | 1.1% |
| China | 0.2% | 0.0% | 0.4% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 1.6% | 5.6% | 12.4% |
| Denmark | 0.9% | 0.5% | 0.5% | 0.3% | 0.8% | 0.3% | 0.0% | 1.0% | 4.0% | 13.1% | 0.4% |
| Finland | 0.3% | 0.6% | 2.9% | 0.1% | 0.4% | 0.3% | 1.8% | 0.0% | 4.8% | 14.0% | 0.2% |
| France | 0.4% | 0.4% | 9.0% | 0.8% | 2.1% | 0.2% | 0.2% | 0.1% | 0.0% | 14.1% | 0.2% |
| Germany | 0.5% | 2.0% | 3.5% | 0.4% | 0.4% | 0.4% | 0.3% | 0.3% | 12.1% | 0.0% | 0.3% |
| Hong Kong | 0.9% | 0.0% | 0.4% | 0.0% | 0.6% | 25.4% | 0.0% | 0.0% | 1.6% | 6.6% | 0.0% |
| India | 2.5% | 0.0% | 0.8% | 0.2% | 1.1% | 0.7% | 0.2% | 0.0% | 3.4% | 12.9% | 0.5% |
| Indonesia | 0.2% | 0.0% | 0.3% | 0.0% | 0.0% | 1.9% | 0.0% | 0.0% | 1.2% | 10.7% | 1.4% |
| Ireland | 0.4% | 0.2% | 0.9% | 0.1% | 0.2% | 0.0% | 0.1% | 0.2% | 6.1% | 16.2% | 0.4% |
| Italy | 0.4% | 0.5% | 2.1% | 1.2% | 0.5% | 0.1% | 0.1% | 0.1% | 11.3% | 14.7% | 0.2% |
| Japan | 0.0% | 0.0% | 0.5% | 0.0% | 0.0% | 0.2% | 0.0% | 0.0% | 1.4% | 9.5% | 0.0% |
| Malaysia | 2.0% | 0.0% | 1.0% | 0.0% | 0.3% | 0.7% | 0.0% | 0.0% | 1.6% | 5.0% | 3.3% |

Table 3.9 continues on Next Page.

| | Australia | Austria | Belgium | Brazil | Canada | China | Denmark | Finland | France | Germany | Hong Kong |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mexico | 0.1% | 0.0% | 0.2% | 0.3% | 0.2% | 0.1% | 0.0% | 0.0% | 1.0% | 2.3% | 0.1% |
| Netherlands | 0.9% | 0.6% | 8.6% | 0.7% | 1.1% | 0.2% | 0.4% | 0.3% | 8.5% | 16.4% | 0.9% |
| New Zealand | 22.4% | 0.0% | 0.2% | 0.0% | 5.0% | 0.1% | 0.1% | 0.1% | 2.0% | 6.2% | 0.8% |
| Norway | 0.9% | 0.3% | 1.3% | 0.2% | 1.9% | 0.0% | 3.0% | 1.6% | 3.0% | 10.9% | 0.2% |
| Philippines | 0.9% | 0.0% | 0.3% | 0.0% | 0.0% | 2.6% | 0.0% | 0.0% | 1.6% | 5.1% | 2.0% |
| Singapore | 1.9% | 0.0% | 0.4% | 0.0% | 0.2% | 4.5% | 0.0% | 0.0% | 1.4% | 5.7% | 5.9% |
| South Africa | 1.0% | 0.1% | 0.6% | 0.2% | 0.1% | 0.1% | 0.0% | 0.6% | 2.5% | 5.2% | 0.6% |
| Spain | 0.0% | 0.4% | 0.7% | 7.1% | 0.3% | 0.2% | 0.3% | 0.1% | 10.0% | 26.0% | 0.0% |
| Sweden | 0.7% | 0.7% | 0.2% | 0.7% | 0.9% | 0.3% | 3.9% | 5.3% | 4.6% | 8.7% | 0.2% |
| Switzerland | 0.9% | 0.5% | 1.4% | 0.4% | 1.1% | 0.1% | 0.2% | 0.3% | 6.2% | 12.1% | 0.4% |
| Turkey | 0.0% | 0.0% | 0.1% | 0.0% | 0.1% | 0.0% | 0.0% | 0.1% | 0.4% | 25.6% | 0.0% |
| United Kingdom | 1.4% | 0.1% | 1.1% | 0.2% | 0.8% | 0.1% | 0.3% | 0.2% | 5.3% | 12.1% | 1.0% |
| United States | 2.8% | 0.4% | 1.6% | 2.3% | 9.8% | 0.6% | 0.5% | 0.8% | 6.2% | 8.7% | 2.2% |

End of Table 3.9

**Table 3.10:** Financial Weights, continued 1

| | India | Indonesia | Ireland | Italy | Japan | Malaysia | Mexico | Netherlands | New Zealand | Norway | Philippines |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 4.9% | 0.2% | 0.0% | 1.5% | 0.1% | 0.2% | 0.0% | 1.8% | 5.4% | 0.1% | 0.0% |
| Austria | 3.1% | 0.0% | 0.5% | 5.9% | 0.0% | 0.0% | 0.0% | 4.6% | 0.0% | 0.0% | 0.0% |
| Belgium | 2.2% | 0.0% | 2.5% | 4.7% | 0.0% | 0.0% | 0.0% | 18.2% | 0.0% | 0.0% | 0.0% |
| Brazil | 1.7% | 0.0% | 0.5% | 2.6% | 0.0% | 0.0% | 0.3% | 3.8% | 0.0% | 0.1% | 0.0% |
| Canada | 4.6% | 0.5% | 1.5% | 1.9% | 0.1% | 0.1% | 0.6% | 2.2% | 0.2% | 0.2% | 0.1% |
| China | 6.6% | 0.0% | 0.0% | 2.2% | 0.1% | 0.0% | 0.0% | 0.8% | 0.0% | 0.0% | 0.0% |
| Denmark | 3.2% | 0.0% | 0.6% | 2.8% | 0.1% | 0.2% | 0.1% | 5.8% | 0.1% | 2.1% | 0.0% |
| Finland | 2.9% | 0.0% | 0.7% | 2.9% | 0.1% | 0.0% | 0.0% | 11.3% | 0.0% | 2.4% | 0.0% |
| France | 3.0% | 0.1% | 1.0% | 6.3% | 0.1% | 0.0% | 0.1% | 11.2% | 0.0% | 0.1% | 0.0% |
| Germany | 3.9% | 0.1% | 1.8% | 6.5% | 0.1% | 0.1% | 0.3% | 5.8% | 0.1% | 0.2% | 0.0% |
| Hong Kong | 4.9% | 0.0% | 0.1% | 2.2% | 0.0% | 0.6% | 0.0% | 1.1% | 0.9% | 0.0% | 0.2% |
| India | 0.0% | 0.4% | 0.1% | 4.5% | 0.1% | 0.2% | 0.1% | 2.5% | 0.0% | 0.0% | 0.1% |
| Indonesia | 14.4% | 0.0% | 0.0% | 1.5% | 0.0% | 0.0% | 0.0% | 1.7% | 0.0% | 0.0% | 0.0% |
| Ireland | 4.2% | 0.0% | 0.0% | 6.1% | 0.1% | 0.0% | 0.1% | 4.3% | 0.0% | 0.1% | 0.0% |
| Italy | 4.0% | 0.0% | 0.7% | 0.0% | 0.0% | 0.0% | 0.1% | 12.8% | 0.1% | 0.0% | 0.0% |
| Japan | 3.2% | 0.2% | 0.0% | 2.1% | 0.0% | 0.8% | 0.0% | 0.8% | 0.0% | 0.0% | 0.0% |

Table 3.10 continues on Next Page.

| | India | Indonesia | Ireland | Italy | Japan | Malaysia | Mexico | Netherlands | New Zealand | Norway | Philippines |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Malaysia | 9.7% | 1.2% | 0.1% | 1.2% | 0.1% | 0.0% | 0.0% | 1.5% | 0.1% | 0.0% | 0.6% |
| Mexico | 1.3% | 0.0% | 0.0% | 0.9% | 0.1% | 0.1% | 0.0% | 0.4% | 0.0% | 0.0% | 0.0% |
| Netherlands | 2.8% | 0.1% | 1.8% | 3.9% | 0.1% | 0.1% | 0.3% | 0.0% | 0.1% | 0.3% | 0.1% |
| New Zealand | 5.4% | 0.4% | 0.5% | 1.1% | 0.0% | 0.2% | 0.0% | 1.1% | 0.0% | 0.0% | 0.0% |
| Norway | 3.3% | 0.0% | 0.4% | 1.4% | 0.0% | 0.1% | 0.1% | 2.9% | 0.1% | 0.0% | 0.0% |
| Philippines | 6.1% | 0.1% | 0.1% | 1.6% | 0.1% | 0.1% | 0.0% | 0.7% | 0.0% | 0.0% | 0.0% |
| Singapore | 5.4% | 2.2% | 0.0% | 2.0% | 0.4% | 7.2% | 0.0% | 1.6% | 0.3% | 0.0% | 0.8% |
| South Africa | 1.3% | 0.1% | 1.8% | 1.6% | 0.2% | 0.3% | 0.2% | 3.6% | 0.0% | 0.0% | 0.1% |
| Spain | 2.9% | 0.1% | 0.2% | 4.3% | 0.2% | 0.0% | 0.1% | 2.8% | 0.0% | 0.0% | 0.0% |
| Sweden | 3.0% | 0.0% | 2.0% | 2.4% | 0.0% | 0.0% | 0.3% | 9.2% | 0.0% | 4.0% | 0.0% |
| Switzerland | 3.9% | 0.1% | 0.8% | 3.7% | 0.1% | 0.1% | 0.3% | 3.7% | 0.1% | 0.2% | 0.1% |
| Turkey | 4.0% | 0.0% | 0.2% | 0.1% | 0.0% | 0.0% | 0.0% | 2.6% | 0.0% | 0.0% | 0.0% |
| United Kingdom | 5.7% | 0.1% | 1.0% | 4.7% | 0.1% | 0.1% | 0.2% | 5.6% | 0.1% | 0.3% | 0.0% |
| United States | 10.7% | 0.5% | 1.9% | 3.4% | 0.5% | 0.4% | 2.9% | 9.7% | 0.3% | 0.6% | 0.3% |

End of Table 3.10

**Table 3.11:** Financial Weights, continued 2

| | Singapore | South Africa | Spain | Sweden | Switzerland | Turkey | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|
| Australia | 0.5% | 0.1% | 0.2% | 0.2% | 1.0% | 0.0% | 16.9% | 56.2% |
| Austria | 0.1% | 0.0% | 0.5% | 0.5% | 3.8% | 0.0% | 5.9% | 33.2% |
| Belgium | 0.0% | 0.1% | 1.4% | 0.9% | 2.4% | 0.1% | 4.8% | 24.0% |
| Brazil | 0.0% | 0.0% | 9.3% | 0.0% | 1.4% | 0.0% | 3.0% | 67.7% |
| Canada | 0.6% | 0.1% | 0.6% | 0.5% | 1.9% | 0.1% | 9.7% | 61.8% |
| China | 0.0% | 0.0% | 0.1% | 0.0% | 0.9% | 0.0% | 2.3% | 66.5% |
| Denmark | 0.2% | 0.1% | 0.8% | 6.8% | 4.2% | 0.0% | 10.0% | 40.8% |
| Finland | 0.2% | 0.0% | 0.8% | 14.5% | 3.4% | 0.0% | 9.8% | 25.5% |
| France | 0.4% | 0.0% | 4.6% | 0.6% | 3.9% | 0.1% | 10.7% | 30.2% |
| Germany | 0.3% | 0.2% | 2.1% | 0.8% | 4.2% | 0.2% | 10.1% | 43.0% |
| Hong Kong | 1.1% | 0.0% | 0.1% | 0.1% | 1.4% | 0.0% | 9.9% | 41.9% |
| India | 0.5% | 0.0% | 0.2% | 0.4% | 1.6% | 0.0% | 6.0% | 60.8% |
| Indonesia | 2.5% | 0.0% | 0.0% | 0.0% | 0.9% | 0.0% | 5.2% | 58.0% |
| Ireland | 0.1% | 0.1% | 1.1% | 0.3% | 2.4% | 0.0% | 16.8% | 39.5% |
| Italy | 0.1% | 0.1% | 5.1% | 0.4% | 5.1% | 0.1% | 9.5% | 30.4% |
| Japan | 0.7% | 0.0% | 0.0% | 0.0% | 1.1% | 0.0% | 7.6% | 71.6% |
| Malaysia | 6.6% | 0.5% | 0.0% | 0.0% | 0.9% | 0.0% | 5.6% | 57.9% |

Table 3.11 continues on Next Page.

| | Singapore | South Africa | Spain | Sweden | Switzerland | Turkey | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|
| Mexico | 0.0% | 0.1% | 0.5% | 0.0% | 0.8% | 0.0% | 1.6% | 89.9% |
| Netherlands | 0.5% | 0.1% | 3.0% | 0.8% | 4.6% | 0.1% | 9.9% | 32.7% |
| New Zealand | 0.5% | 0.0% | 0.3% | 0.2% | 1.0% | 0.0% | 10.1% | 42.3% |
| Norway | 0.6% | 0.1% | 0.4% | 5.8% | 2.7% | 0.0% | 13.6% | 45.0% |
| Philippines | 1.3% | 0.0% | 0.1% | 0.0% | 1.0% | 0.0% | 3.1% | 73.3% |
| Singapore | 0.0% | 0.0% | 0.0% | 0.1% | 1.4% | 0.0% | 7.0% | 51.4% |
| South Africa | 0.2% | 0.0% | 0.9% | 0.1% | 7.8% | 0.1% | 42.8% | 27.8% |
| Spain | 0.0% | 0.0% | 0.0% | 0.1% | 2.2% | 0.2% | 9.1% | 32.6% |
| Sweden | 0.4% | 0.0% | 1.1% | 0.0% | 4.3% | 0.0% | 11.8% | 35.1% |
| Switzerland | 0.8% | 0.1% | 0.8% | 0.5% | 0.0% | 0.1% | 10.6% | 50.7% |
| Turkey | 0.0% | 0.0% | 0.1% | 0.0% | 1.9% | 0.0% | 4.2% | 60.5% |
| United Kingdom | 0.4% | 0.4% | 1.5% | 0.9% | 3.4% | 0.0% | 0.0% | 52.8% |
| United States | 2.1% | 0.5% | 2.0% | 1.8% | 5.5% | 0.2% | 20.9% | 0.0% |

End of Table 3.11

**Table 3.12:** Trade Weights

| | Australia | Austria | Belgium | Brazil | Canada | China | Denmark | Finland | France | Germany | Hong Kong |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 0.0% | 0.4% | 0.6% | 0.6% | 1.7% | 13.8% | 0.4% | 0.7% | 2.3% | 4.5% | 2.1% |
| Austria | 0.4% | 0.0% | 2.1% | 0.4% | 0.7% | 1.9% | 0.8% | 0.8% | 5.0% | 48.9% | 0.4% |
| Belgium | 0.4% | 1.0% | 0.0% | 0.7% | 0.7% | 2.2% | 0.7% | 0.7% | 17.0% | 21.1% | 0.6% |
| Brazil | 0.9% | 0.5% | 1.2% | 0.0% | 2.4% | 9.9% | 0.4% | 0.7% | 4.4% | 9.9% | 1.1% |
| Canada | 0.4% | 0.2% | 0.5% | 0.5% | 0.0% | 4.0% | 0.2% | 0.2% | 1.1% | 1.8% | 0.3% |
| China | 2.8% | 0.3% | 1.2% | 1.8% | 2.0% | 0.0% | 0.4% | 0.7% | 2.3% | 6.6% | 15.1% |
| Denmark | 0.5% | 1.2% | 2.5% | 0.4% | 0.7% | 2.9% | 0.0% | 3.1% | 5.8% | 23.6% | 0.8% |
| Finland | 1.2% | 1.3% | 3.0% | 0.9% | 1.0% | 4.4% | 4.4% | 0.0% | 5.3% | 17.9% | 0.8% |
| France | 0.5% | 1.2% | 9.4% | 0.9% | 0.8% | 2.9% | 1.0% | 0.7% | 0.0% | 21.2% | 0.6% |
| Germany | 0.6% | 6.2% | 6.2% | 1.0% | 0.8% | 4.7% | 2.1% | 1.3% | 12.8% | 0.0% | 0.6% |
| Hong Kong | 1.1% | 0.2% | 0.7% | 0.4% | 1.0% | 49.5% | 0.3% | 0.3% | 1.4% | 3.1% | 0.0% |
| India | 4.2% | 0.3% | 1.0% | 0.9% | 2.3% | 0.9% | 0.4% | 0.4% | 2.0% | 4.7% | 4.4% |
| Indonesia | 4.8% | 0.2% | 1.0% | 0.9% | 1.2% | 9.7% | 0.2% | 0.4% | 1.6% | 3.8% | 2.2% |
| Ireland | 0.6% | 0.4% | 7.8% | 0.2% | 0.6% | 1.5% | 1.0% | 0.5% | 6.1% | 9.7% | 0.7% |
| Italy | 0.8% | 3.3% | 4.0% | 1.3% | 0.9% | 3.8% | 1.0% | 0.8% | 15.7% | 21.8% | 0.9% |
| Japan | 4.0% | 0.4% | 5.9% | 1.3% | 1.7% | 2.1% | 0.5% | 0.4% | 3.2% | 7.0% | 4.9% |
| Malaysia | 3.1% | 0.2% | 0.6% | 0.5% | 0.8% | 9.3% | 0.2% | 0.3% | 1.7% | 3.9% | 4.9% |

Table 3.12 continues on Next Page.

| | Australia | Austria | Belgium | Brazil | Canada | China | Denmark | Finland | France | Germany | Hong Kong |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mexico | 0.2% | 0.1% | 0.1% | 1.2% | 2.5% | 3.8% | 0.1% | 0.1% | 0.7% | 2.7% | 0.2% |
| Netherlands | 0.4% | 1.3% | 12.1% | 1.0% | 0.6% | 4.6% | 1.5% | 1.2% | 9.1% | 26.6% | 0.7% |
| New Zealand | 26.1% | 0.3% | 1.4% | 0.4% | 1.9% | 8.7% | 0.6% | 0.4% | 2.1% | 4.4% | 1.5% |
| Norward | 0.2% | 0.6% | 2.6% | 0.6% | 3.6% | 2.6% | 5.6% | 2.6% | 8.2% | 14.1% | 0.3% |
| Philippines | 1.8% | 0.1% | 0.8% | 0.4% | 0.9% | 7.4% | 0.1% | 0.3% | 1.2% | 4.0% | 7.1% |
| Singapore | 3.2% | 0.2% | 0.6% | 0.4% | 0.5% | 10.1% | 0.2% | 0.3% | 2.5% | 3.8% | 7.7% |
| South Africa | 1.3% | 0.4% | 1.3% | 29.0% | 0.7% | 3.7% | 0.2% | 28.7% | 1.9% | 6.5% | 0.5% |
| Spain | 0.5% | 1.2% | 4.2% | 1.2% | 0.5% | 3.6% | 1.0% | 0.8% | 22.5% | 18.8% | 0.3% |
| Sweden | 0.9% | 1.3% | 4.2% | 0.7% | 0.9% | 2.8% | 8.9% | 6.8% | 6.1% | 16.6% | 0.8% |
| Switzerland | 0.6% | 4.1% | 2.3% | 0.8% | 0.9% | 2.1% | 0.9% | 0.7% | 11.0% | 29.8% | 2.0% |
| Turkey | 0.6% | 1.5% | 3.1% | 0.8% | 0.8% | 5.9% | 1.0% | 1.0% | 9.1% | 21.2% | 0.4% |
| United Kingdom | 1.2% | 0.8% | 4.9% | 0.7% | 2.0% | 3.4% | 1.4% | 1.1% | 10.0% | 14.8% | 2.2% |
| United States | 1.2% | 0.4% | 1.5% | 2.0% | 24.3% | 11.7% | 0.3% | 0.3% | 3.0% | 5.8% | 1.4% |

End of Table 3.12

**Table 3.13:** Trade Weights, continued 1

| | India | Indonesia | Ireland | Italy | Japan | Malaysia | Mexico | Netherlands | New Zealand | Norway | Philippines |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 2.8% | 3.4% | 0.8% | 2.7% | 19.4% | 0.8% | 0.6% | 1.4% | 6.1% | 0.2% | 3.6% |
| Austria | 0.3% | 0.2% | 0.5% | 10.2% | 1.5% | 0.1% | 0.2% | 4.0% | 0.1% | 0.4% | 0.2% |
| Belgium | 1.5% | 0.3% | 3.0% | 5.1% | 2.1% | 0.1% | 0.3% | 17.0% | 0.1% | 0.8% | 0.2% |
| Brazil | 1.5% | 0.8% | 0.4% | 5.3% | 6.6% | 0.4% | 3.6% | 5.1% | 0.1% | 0.6% | 1.1% |
| Canada | 0.4% | 0.2% | 0.3% | 0.9% | 3.4% | 0.2% | 2.3% | 0.5% | 0.1% | 0.9% | 0.4% |
| China | 2.0% | 1.8% | 0.4% | 2.1% | 19.8% | 1.6% | 0.9% | 2.9% | 0.3% | 0.3% | 3.1% |
| Denmark | 0.5% | 0.2% | 1.4% | 4.5% | 2.3% | 0.1% | 0.2% | 6.8% | 0.2% | 6.6% | 0.3% |
| Finland | 0.6% | 0.4% | 0.9% | 4.5% | 3.1% | 0.3% | 0.3% | 7.1% | 0.1% | 3.8% | 0.5% |
| France | 0.6% | 0.3% | 1.4% | 11.2% | 2.2% | 0.2% | 0.4% | 6.9% | 0.1% | 1.2% | 0.4% |
| Germany | 0.7% | 0.4% | 1.4% | 8.8% | 3.3% | 0.3% | 0.7% | 10.3% | 0.1% | 1.8% | 0.6% |
| Hong Kong | 1.3% | 0.7% | 0.2% | 1.4% | 9.7% | 1.3% | 0.3% | 1.3% | 0.2% | 0.1% | 1.9% |
| India | 0.0% | 3.6% | 0.7% | 1.6% | 7.7% | 2.2% | 1.1% | 2.1% | 0.3% | 3.4% | 3.7% |
| Indonesia | 3.4% | 0.0% | 0.2% | 1.7% | 24.1% | 1.4% | 0.3% | 2.7% | 0.5% | 0.1% | 5.4% |
| Ireland | 0.2% | 0.1% | 0.0% | 3.5% | 3.2% | 0.4% | 0.4% | 5.0% | 0.1% | 1.2% | 1.0% |
| Italy | 0.9% | 0.4% | 1.1% | 0.0% | 2.3% | 0.1% | 0.6% | 5.7% | 0.1% | 0.7% | 0.4% |
| Japan | 12.3% | 3.1% | 0.3% | 3.5% | 0.0% | 0.1% | 0.7% | 2.3% | 4.4% | 0.2% | 3.4% |
| Malaysia | 2.3% | 3.5% | 0.7% | 0.9% | 16.6% | 0.0% | 0.6% | 3.0% | 0.5% | 0.1% | 2.2% |

Table 3.13 continues on Next Page.

| | India | Indonesia | Ireland | Italy | Japan | Malaysia | Mexico | Netherlands | New Zealand | Norway | Philippines |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mexico | 0.3% | 0.2% | 0.2% | 0.9% | 3.3% | 0.3% | 0.0% | 0.5% | 0.1% | 0.1% | 0.8% |
| Netherlands | 0.5% | 0.5% | 1.3% | 5.0% | 2.6% | 0.5% | 0.3% | 0.0% | 0.1% | 1.7% | 1.1% |
| New Zealand | 0.8% | 2.0% | 0.4% | 2.3% | 13.5% | 1.1% | 1.0% | 1.2% | 0.0% | 0.2% | 2.9% |
| Norward | 0.3% | 0.1% | 1.5% | 3.4% | 2.2% | 0.1% | 0.1% | 9.0% | 0.0% | 0.0% | 0.2% |
| Philippines | 0.7% | 1.9% | 0.9% | 0.6% | 21.4% | 5.2% | 0.3% | 5.6% | 0.5% | 0.0% | 0.0% |
| Singapore | 2.7% | 6.5% | 0.8% | 0.9% | 11.6% | 2.8% | 0.5% | 2.4% | 0.4% | 0.2% | 19.1% |
| South Africa | 1.2% | 0.3% | 0.5% | 1.7% | 4.7% | 0.1% | 0.2% | 1.8% | 0.1% | 0.1% | 0.6% |
| Spain | 0.6% | 0.6% | 1.4% | 11.7% | 2.1% | 0.1% | 1.6% | 5.6% | 0.1% | 0.8% | 0.3% |
| Sweden | 0.6% | 0.3% | 1.1% | 4.0% | 2.5% | 0.1% | 0.4% | 6.9% | 0.1% | 10.0% | 0.4% |
| Switzerland | 0.7% | 0.2% | 1.8% | 10.7% | 3.4% | 0.1% | 0.4% | 4.5% | 0.1% | 0.4% | 0.3% |
| Turkey | 1.3% | 0.7% | 1.0% | 11.5% | 2.9% | 0.1% | 0.3% | 4.0% | 0.1% | 0.6% | 0.8% |
| United Kingdom | 1.3% | 0.4% | 6.1% | 5.2% | 3.5% | 0.3% | 0.3% | 8.2% | 0.3% | 3.1% | 0.8% |
| United States | 1.2% | 0.9% | 1.6% | 2.2% | 11.1% | 1.0% | 14.2% | 2.1% | 0.3% | 0.4% | 2.1% |

End of Table 3.13

**Table 3.14:** Trade Weights, continued 2

| | Singapore | South Africa | Spain | Sweden | Switzerland | Turkey | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|
| Australia | 5.3% | 1.3% | 0.9% | 1.1% | 1.0% | 0.3% | 5.8% | 15.6% |
| Austria | 0.2% | 0.4% | 2.4% | 1.5% | 6.1% | 1.1% | 4.0% | 5.0% |
| Belgium | 0.3% | 0.5% | 3.2% | 2.1% | 1.3% | 0.9% | 9.1% | 6.9% |
| Brazil | 1.2% | 1.1% | 3.0% | 1.4% | 1.7% | 0.5% | 3.5% | 30.6% |
| Canada | 0.3% | 0.2% | 0.3% | 0.3% | 0.4% | 0.1% | 2.5% | 77.2% |
| China | 3.3% | 0.8% | 1.2% | 0.7% | 0.6% | 0.6% | 2.7% | 21.8% |
| Denmark | 0.4% | 0.3% | 2.6% | 15.3% | 1.3% | 0.7% | 9.1% | 5.6% |
| Finland | 0.4% | 0.6% | 2.7% | 15.6% | 1.4% | 0.9% | 9.0% | 7.6% |
| France | 0.9% | 0.4% | 10.1% | 1.7% | 3.6% | 1.2% | 10.1% | 8.2% |
| Germany | 0.7% | 0.8% | 5.0% | 2.6% | 5.1% | 1.8% | 9.2% | 10.0% |
| Hong Kong | 4.5% | 0.3% | 0.5% | 0.3% | 1.0% | 0.1% | 2.8% | 13.8% |
| India | 0.6% | 18.4% | 0.7% | 0.9% | 2.9% | 0.3% | 27.4% | 1.0% |
| Indonesia | 14.5% | 0.5% | 1.4% | 0.6% | 0.5% | 0.6% | 2.2% | 13.9% |
| Ireland | 1.5% | 0.4% | 2.6% | 1.3% | 2.4% | 0.4% | 29.3% | 17.6% |
| Italy | 0.5% | 0.8% | 7.6% | 1.6% | 4.9% | 2.1% | 7.6% | 8.2% |
| Japan | 0.3% | 18.7% | 1.5% | 6.1% | 1.0% | 0.8% | 3.0% | 6.7% |
| Malaysia | 19.1% | 0.4% | 0.4% | 0.5% | 0.7% | 0.3% | 2.6% | 20.3% |

Table 3.14 continues on Next Page.

| | Singapore | South Africa | Spain | Sweden | Switzerland | Turkey | United Kingdom | United States |
|---|---|---|---|---|---|---|---|---|
| Mexico | 0.5% | 0.0% | 1.3% | 0.2% | 0.4% | 0.1% | 0.7% | 78.4% |
| Netherlands | 1.0% | 0.6% | 3.4% | 2.4% | 1.4% | 0.9% | 10.3% | 7.6% |
| New Zealand | 2.9% | 0.5% | 0.7% | 0.8% | 0.7% | 0.2% | 5.1% | 15.8% |
| Norward | 0.6% | 0.2% | 2.3% | 11.0% | 0.8% | 0.5% | 19.5% | 7.1% |
| Philippines | 9.3% | 0.1% | 0.3% | 0.3% | 0.4% | 0.1% | 2.2% | 26.1% |
| Singapore | 0.0% | 0.3% | 0.3% | 0.3% | 1.0% | 0.2% | 3.1% | 17.4% |
| South Africa | 0.5% | 0.0% | 1.5% | 0.6% | 1.0% | 0.3% | 4.5% | 5.9% |
| Spain | 0.3% | 0.6% | 0.0% | 1.6% | 1.7% | 1.6% | 9.4% | 5.3% |
| Sweden | 0.5% | 0.5% | 2.6% | 0.0% | 1.4% | 0.9% | 9.5% | 8.3% |
| Switzerland | 0.8% | 0.5% | 3.1% | 1.3% | 0.0% | 0.9% | 5.8% | 9.9% |
| Turkey | 0.5% | 1.2% | 5.0% | 1.9% | 3.8% | 0.0% | 9.0% | 10.0% |
| United Kingdom | 1.3% | 1.3% | 4.3% | 2.5% | 2.3% | 1.2% | 0.0% | 15.0% |
| United States | 2.1% | 0.5% | 0.8% | 0.8% | 1.3% | 0.5% | 4.8% | 0.0% |

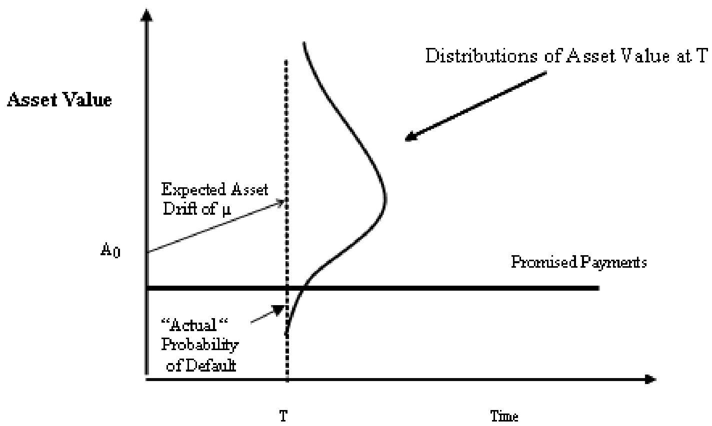
End of Table 3.14

## 3.6 Appendix 3.2. Contingent Claims Analysis and Estimating Default Probabilities for Corporates and Banks

The contingent claims analysis (CCA) is based on the Merton Model and it provides a methodology to combine balance sheet information with widely used finance and risk management tools to construct marked-to-market balance sheets that better reflect underlying risk (see Merton 1973, 1974 and Gray, Merton, and Bodie 2008). It can be used to derive a set of risk indicators for individual firms, financial institutions that can serve as risk indicators and barometers of vulnerability and calculate default probabilities. An estimate of the market value of assets and asset volatility is needed, but market value of assets is not directly observable because many of the assets on the balance sheet of a financial institution are not traded. CCA imputes the value and volatility of assets indirectly using the market value of equity from stock price data, equity volatility (from equity data and/or equity options), and the book value of short- and long-term obligations. This is then used to calculate risk indicators such as the probability of default, credit spreads, or other risk indicators.

The value of assets of a corporate or bank at time t is $A(t)$. Assets are uncertain (stochastic), and the evolution of the asset is given by $dA/A = \mu_A dt + \sigma_A \varepsilon \sqrt{t}$, where $\mu_A$ is the drift rate or asset return, $\sigma_A$is equal to the standard deviation of the asset return, and$\varepsilon$ is normally distributed, with zero mean and unit variance. The probability distribution of the asset at time T is shown below in (a)

**Figure 3.14:** The Probility Distribution of the Asset Value at time T



Default occurs when assets fall to or below the promised payments on debt which define the default barrier,$B_t$. The probability of default is the probability that $A_t \leq B_t$ which is:

$$\text{Prob}(A_t \leq B_t) = \text{Prob}\left(A_0 \exp\left[\left(\mu_A - \sigma_A^2/2\right)t + \sigma_A \varepsilon \sqrt{t}\right] \leq B_t\right) = \text{Prob}\left(\varepsilon \leq -d_{2,\mu}\right) \quad (3.13)$$

Since$\varepsilon \sim N(0,1)$, the "actual" probability of default is$N(-d_{2,\mu})$, where $d_{2,\mu} = \frac{\ln(A_0/B_t)+\left(\mu_A - \sigma_A^2/2\right)t}{\sigma_A\sqrt{t}}$, this term is called the distance to default. $N(\bullet)$is the cumulative standard normal distribution.

**Merton Model.** We can use this basic idea to construct risk-adjusted balance sheets, i.e. CCA balance sheets where the total market value of assets, $A$, at any time, $t$, is equal to the sum of its equity market value, $E$, and its risky debt, $D$, maturing at time $T$. The asset value is stochastic and may fall below the value of outstanding liabilities. Equity and debt derive their value from the uncertain assets. As pointed out by Merton (1973) equity value is the value of an implicit call option on the assets, with an exercise price equal to default barrier, $B$. The value of risky debt is equal to default-free debt minus the present value of expected loss due to default. The firm's outstanding liabilities constitute the bankruptcy level. The expected potential loss due to default can be calculated as the value of a put option on the assets, A, with an exercise price equal to $B$, $t$ is the time horizon, $r$ is the risk free rate, and $\sigma_A$, asset volatility.

Risky Debt = Default-free Debt - Potential Loss due to Default

$$D(t) = Be^{-rT} - P_E(t)$$

$$d_1 = \frac{\ln\left(\frac{A}{B}\right) + \left(r + \frac{\sigma_A^2}{2}\right)T}{\sigma_A\sqrt{T}} \quad \text{and} \quad d_2 = \frac{\ln\left(\frac{A}{B}\right) + \left(r - \frac{\sigma_A^2}{2}\right)T}{\sigma_A\sqrt{T}}$$

The calibration of the model uses the value of equity, the volatility of equity, the distress barrier as inputs into two equations in order to calculate the implied asset value and implied asset volatility.[1] Equity and equity volatility are consensus forecasts of market participants and this provide forward-looking information. The value of assets is unobservable, but it can be implied using CCA. In the Merton Model for firms, banks and non-bank financials with traded equity use equity, $E$, and equity volatility, $\sigma_E$, and the distress barrier in the following

[1] See Merton (1974,1977, and 1992), Gray, Merton, and Bodie (2008), and Gray and Malone (2008).

two equations to solve for the two unknowns $A$, asset value, and $\sigma_A$, asset volatility.

$$E = A_0 N(d_1) - Be^{-rT} N(d_2)$$

$$E\sigma_E = A\sigma_A N(d_1)$$

Now we have all the parameters which can be used to estimate credit risk indicators. The present value of expected losses associated with outstanding liabilities can be valued as an implicit put option. This implicit put option is calculated with the default threshold as strike price on the current asset value of each institution. Thus, the present value of expected loss can be computed as

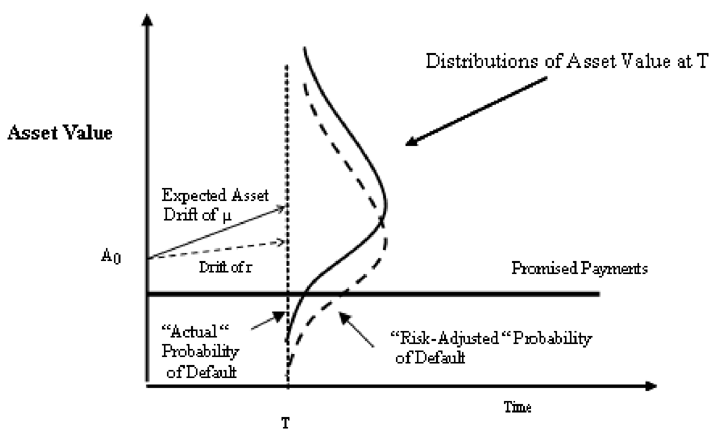
$$P_E = Be^{-rT} N(-d_2) - A_0 N(-d_1)$$

Once the asset value, asset volatility are known, together with the default barrier, time horizon, and r, the values of the implicit put option, $P_E(t)$, can be calculated. Note that by rearranging the formula for $P_E(t)$ we distinguish between default probability and loss given default (LGD), such that

$$P_E = N(-d_2) \underbrace{\left(1 - \frac{N(-d_1)}{N(-d_2)} \frac{A}{Be^{-rT}}\right)}_{LGD} Be^{-rT}$$

Shown in (b) below is the probability distribution (dashed line) with drift of the risk-free interest rate, $r$. Risk adjusted (or risk-neutral) probability of default is $N(-d_2)$, where $d_2 = \frac{\ln(A_0/B_t) + \left(r - \sigma_A^2/2\right)t}{\sigma_A \sqrt{t}}$. The actual probability of default from (a) is shown too.

**Figure 3.15:** The Actual Probility Distribution of Default at time T



**Moody's KMV Model**. In the 1990s a company called KMV adapted Merton's approach for commercial applications. They used information from the equity market for firms, along with book value information of liabilities to get estimates of distance-to-distress, which were used with a large database of actual defaults to estimate Expected Default Probabilities ($EDF^{TM}$). KMV was purchased by Moody's in 2002 and is now Moody's-KMV, or MKMV, for short. The exact methodology is confidential, but general descriptions can be found on the MKMV website (www.mkmv.com), and in KMV (2001) and MKMV (2003). MKMV's EDF credit measure is calculated using an iterative procedure to solve for the asset volatility. It uses and initial guess of volatility to determine asset value and de-lever the equity returns (according to MKMV 2003). The volatility of the asset returns are used as an input into the next iteration of asset values and asset returns until a convergence is obtained. In essence, the model used equity return volatility, equity values, distress barrier from book value of liabilities, and time horizon to get a distance-to-distress. This distance-to-distress was then mapped to actual default probabilities, called expected default probabilities (EDFs), using a database of detailed real world default probabilities for many firms. The distance-to-distress and the CEDF are calculated as follows:

$$DD_{KMV} = f\left(\frac{\ln\left(A_0/B_t\right) + \left(\mu_A - \sigma_A^2/2\right)t}{\sigma_A\sqrt{t}}\right)$$

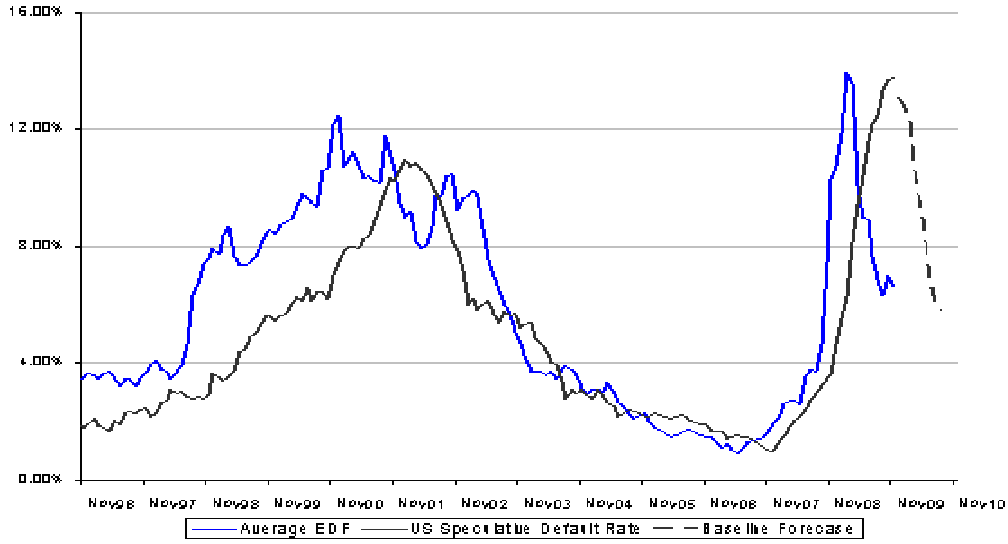
$$EDF_t = f\left(DD_{KMV}(t)\right)$$

MKMV estimates the "actual" default probabilities. The EDF credit measure is calculated daily for 35,000 corporations and financial institutions in 55 countries (see MKMV 2001 and 2003). Robustness checks confirm that the model to be quite accurate and is a leading indicator for default. MKMV lead actual defaults, for example high yield default forecasts, according to MKMV EDFs, lead actual default rates by about a year.

Source: MKMV

For sectors (groups of firms or banks) the time series of median (50th percentile) EDFs for corporate sectors and banking sectors is one candidate for a sector credit risk measure, but this would be biased by small firms in the sample. To get a single aggregate measure which is linked to the size of the firms and size of default risk in the sector, the EDFs are weighted by the market value of assets of the firms and banks in the sector for the analysis

**Figure 3.16:** MKMV estimated aveage EDF, US Speculate Default Rate and Baseline Forecast




in this paper. Extensions and more details of CCA models can be found in Gray and Malone (2008).

# Chapter 4

# Monetary Policy and the Interest Rate Channel in China

## 4.1 Introduction

In ordinary times, when interest rates bounded away from zero, central banks in advanced economies typically implement monetary policy by steering short-term interbank rates. While the exact ways in which this is done differs between countries, the focus is squarely on the price of liquidity. Thus, given the policy interest rate, other variables contain no information about the stance of monetary policy. In the case of China, however, it is generally felt that interbank rates are not good measures of the stance of monetary policy.[1]

Indeed, empirical evidence suggests that the interest rate channel of monetary policy transmission is week or non-existent in China. Geiger (2006) shows that retail lending rates and money market rates do not have a tight and predictable relationship with loan and money growth, and Laurens and Maino (2007) find that GDP and price does not react to short-term interest rates, although they react significantly to M2 growth. Green and Chang (2006) show that the People's Bank of China (PBoC) controls reserve money well but not M2, since there is no close relationship between reserve money and M2. This evidence suggests that the relationship between the monetary policy instruments, short-term interest rates, loan growth and money growth differs from what we observe in advanced economies.

In thinking about the transmission mechanism of monetary policy in China, it is useful to

[1] He and Pauwel (2006), Shu and Ng (2010) construct the indicator of the stance of monetary policy using PBoC statements or data on the policy instruments instead.

distinguish between the link, first, between the policy instruments and interbank rates, and, second, that between interbank rates and the cost and availability of bank loans. Explanations put forward in the literature of the ineffectiveness of monetary policy in China has typically focused on how structural impediments in financial markets have weakened the second link.[2] In this paper, by contrast, we also study the first link since understanding it is a prerequisite for understanding the overall transmission of monetary policy to the real economy.

The PBoC conducts monetary policy using an array of instruments. These include required reserve ratios (RR hereafter), the rate of remuneration on reserves, open market operations (that is, the issuance of central bank bills) and, crucially, regulated deposit and retail lending rates.[3] The two regulated rates are important for the implementation of monetary policy in China in contrast to in advanced economies. This raises the question of what the coexistence of such regulation and market forces implies for PBoC's policy to influence.

To study this mechanism, we present a model of bank behavior in China, which is an extension of the model of Porter and Xu (2009a), which in turn is an extension of Freixas and Rochet (2008). The model illustrates how the interbank rate and the quantity and price of retail loans are determined in an environment where banks compete, given regulations concerning the interest rates they can pay on deposits and charge for loans. The model suggests that the presence of regulated rates have a large impact on the transmission mechanism of monetary policy. In particular, the effect of monetary policy on interbank rates and retail bank lending depends on how the regulated interest rates deviate from their equilibrium levels, defined as the rates we would observe in the absence of regulation. Two corollaries flow from this conclusion.

First, in this regulated framework, the interbank rate is not a sufficient, and potentially misleading, indicator of the central bank's policy intentions. To characterize the stance of monetary policy, all policy instruments, including the benchmark deposit rate, benchmark lending rate, RR, open market operations and the rate of remunerations on reserves, must be considered.

Second, to the extent that the central bank does not observe the equilibrium rates, it may not know if a change of its policy instruments is expansionary or contractionary. Liberalizing the regulated rates eliminates this uncertainty and improves the effectiveness of the monetary

[2] See Liu and Zhang (2007), Larence and Maino (2007) and Podpiera (2006).

[3] Window guidance, which pressures or impose rules on banks to follow PBC's instructions about retail lending, is also an important tool.

policy transmission.

The rest of the paper is organized as follows: Section 4.2 provides an overview of the implementation of monetary policy in China. Section 4.3 presents the model and some policy implications. Section 4.4 considers a few recent monetary policy episodes in order to explore the model's empirical predictions. Section 4.5 concludes and provides suggestions for future research.

## 4.2 Implementing Monetary Policy in China

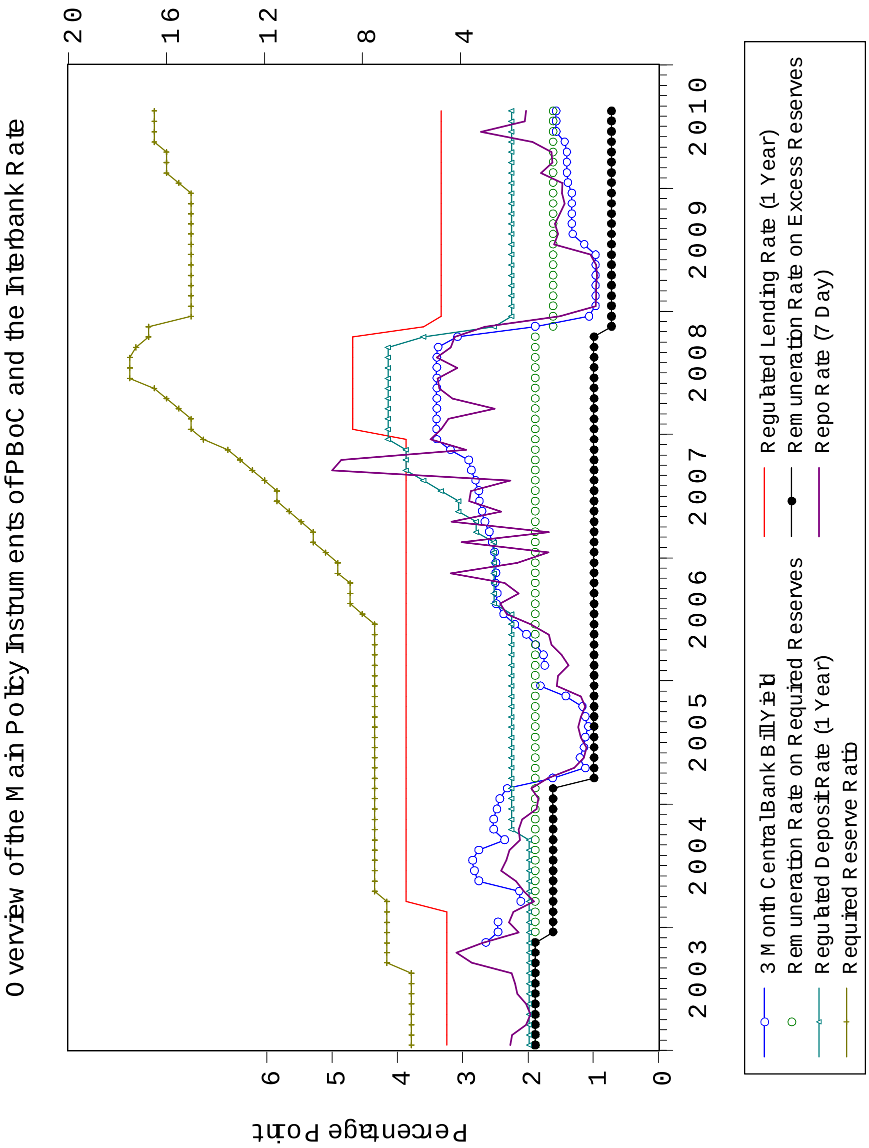
Since the PBoC uses a large number of policy instruments in setting monetary policy, it is useful to start by briefly reviewing how these have evolved over time. Figure 4.1 contains data on the interest rate on central bank bills, which are used in open market operations to steer interest rates more broadly, and interbank rates as captured by the 7-day repo rate. We also plot the rates paid on required and on excess reserves, and the regulated rates on deposits and loans.

The regulation of deposit and lending rates has a long history in China. The deposit rates and lending rates were historically set by the PBoC. From 1997 onwards, the PBoC gradually relaxed these regulations. In October 2004, PBoC retained a regulated rate (the benchmark lending rate) as a ceiling for the deposit rate and another (the benchmark deposit rate) as a floor for lending rates. The regulation of (the ceiling on) the deposit rate is generally seen as binding; the regulated floors on lending rates is perhaps less closely adhered to.

Since financial markets in China have developed rapidly over time, as has the conduct and implementation of monetary policy, the figure focuses on the period starting in 2004.[4] Several observations are warranted. First, the yield on central bank bills and the repo rate are closely correlated, indicating the important role played by open market operations in the PBoC's conduct of policy. Second, the benchmark deposit rate evolves over time in much the same way as the repo rate. This is compatible with the idea that when changing the stance of policy, the PBoC seeks to raise banks's costs of funds both in inter bank and deposit markets. Third, changes in the benchmark lending rate tend to coincide with changes in the repo rate and in the benchmark deposit rates. Overall, the figure is compatible with a "belts and suspenders" approach to monetary policy in which many, if not all, policy levers are used

[4] See Feyzioglu et al. (2009), Porter and Xu (2009a,b) and He and Pauwels (2008) for summaries of recent changes in Chinese financial markets and their implication for monetary policy.

**Figure 4.1:** Overview of the Main Policy Instruments of PBoC and the Interbank Rate



simultaneously to achieve the desired change in monetary conditions. Again, this contrasts with the approach in advanced economies in which typically only the interbank interest rate is used to change policy.

One not always understood the consequence of this approach in that the change of an instrument which would clearly have expansionary or contractionary effect in a liberalized market might have perverse effects in a quasi-liberalized market system such as that in China. It is therefore important to study the effects of changes in individual policy instruments in a model in which market forces and regulations coexist.

Finally, the figure also shows the RR, which was gradually increased in from 2006 onwards. This may reflect the desire of the PBoC to sterilize the effects of its foreign exchange markets interventions on monetary conditions.

In terms of the stance of monetary policy, the figure indicates that monetary policy was progressively tightened from 2004 onwards in response to robust economic growth, in particular to very strong investment spending, and a rise in inflation in 2004 and from 2007 onwards, in both cases largely due to rapidly increasing food prices. In the fall of 2008, monetary policy was relaxed sharply to mitigate the effects on the mainland economy of the rapid worsening of global economic and financial conditions to limit their effects on the Mainland economy.

## 4.3 The Theoretical Model

### 4.3.1 Model Framework

To study the effect of the monetary policy instruments on aggregate bank loans, we present a stylized model that integrates regulation of banks' deposit and lending rates with a competitive interbank market. The model is based on that of Porter and Xu (2009a), which is in turn an extended version of the model of Freixas and Rochet (2008). We assume that each bank chooses the amount of the deposits, excess reserves, central bank bills, and loans in order to maximize profits, given the RR, the reserve remuneration ratio, central bank bill yield and the regulated interest rates for deposit and lending. Thus, each bank's profit maximization problem is given as:

$$\pi_i = \max_{L_i, E_i, D_i, B_i} \{ r_L L_i + r_E E_i + r_R \alpha D_i + r_B B_i + r M_i - r_D D_i - c(D_i, L_i) - \frac{\beta}{2}\left(E_i - E^T\right)^2 - \frac{\kappa}{2}\left( L_i - L_i^T\right)^2 \} \tag{4.1}$$

where $L_i$ denotes the level of loans, $E_i$ is the level of excess reserves, $\alpha D_i$ is the amount of required reserves (with $\alpha$ being the RR and $D_i$ the deposit level), $B_i$ is the quantity of central bank bill holdings and changes as a consequence of open market operations,[5] and $M_i$, is the net position in interbank market. The relevant interest rates are denoted $r_L$, $r_E$, $r_R$, $r_D$, and $r_B$.

Equation 4.1 states that the profits of bank is the sum of revenues minus the costs. Revenues come from retail lending, $r_L L_i$; holdings of excess reserves[6], $r_E E_i$;[7] holdings of required reserves, $r_R \alpha D$;revenues on holdings of central bank bills, $r_B B_i$; and lending in the interbank market, $rM_i$.[8] The costs arise from interest payments on deposits, $r_D D_i$; the management of central bank bill holdings, deposits and loans, $c(\cdot)$;[9] and the cost of deviations of reserves from their target level $E_i^T$, $\frac{\beta}{2}\left(E_i - E_i^T\right)^2$.[10] The last term captures window guidance, that is, the fact that the PBoC on occasion sets a target loan level $L_i^T$for banks. In this section we disregard this cost by setting $\kappa = 0$.

The net position on the interbank market is given by $M_i$:

$$M_i = D_i - L_i - E_i - \alpha D_i - B_i \tag{4.2}$$

[5] Corporate bonds and repo transaction is modelled as interbank lending.

[6] The main difference between our model and that of Porter and Xu (2009a) is that we make a distintion between required and excess reserves. Since the PBoC sometimes changes the spread between the interest rate it pays on these two types of reserves, this seems appropriate.

[7] The PBC pays interest for required and excess reserve.

[8] We assume there is only one interbank market and thus one interbank rate. Although there is segmentation of the Chinese interbank, it does not affect our result qualitatively.

[9] Costs include implicit source costs to attract depositors, i.e.labor, physical capital, material cost to produce service to depositors (Sealey and Lindley 1977, p. 1254); costs to attract lenders and costs to manage bond investment portfolio.

[10] Reserve plays a role as liquidity, banks typically set a target level of reserve to finance unexpected inflow or outflow from banks' reserve account (Campbell 1987 p. 61). "The target level is determined by banks' relationship with its non-bank customers, its role in teh payment system, and the need to secure positive balances to avoid end-of-day overdraft penalties" (Bartolini et al 2001 p. 1295).

The management costs are given by:

$$C(D_i, L_i) = \frac{c_{Di}D_i^2 + c_{Li}L_i^2}{2} \tag{4.3}$$

with $c_{Di}$, $c_{Li} > 0$.

Following Bartolini et al. (2001) and Campbell (1987), we assume that banks are concerned about their access to liquidity. The cost is modelled as a quadratic function of the deviation of actual excess reserve holding from the target level. Using equation (4.2), the profit maximization problem becomes:

$$\begin{aligned} \pi_i \quad = \quad & \max_{L_i,E_i,D_i,B_i} \{(r_L - r) L_i + (r_E - r) E_i + [r - r_D + \alpha (r_R - r)] D_i \\ & + (r_B - r) B_i - \frac{c_{Di}D_i^2 + c_{Li}L_i^2}{2} - \frac{\beta}{2} \left[E_i - E_i^T\right]^2\} \end{aligned} \tag{4.4}$$

Rearranging the first-order conditions with respect to $L_i$, we obtain:

$$r_L = r + c_{Li}L_i. \tag{4.5}$$

Equation (4.5) indicates that the optimal amount of loans is given by the point where the marginal benefit of loans equals the marginal cost of loans. The marginal benefit is the interest rate in retail lending and the marginal cost depends on two components: the interbank rate and the cost of managing the loans.

Similarly, the first-order condition for excess reserves can be rearranged to yield:

$$r_E = r + \beta \left[E_i - E_i^T\right] \tag{4.6}$$

Thus, the optimal level of excess reserves is selected such that remuneration equals the cost of holding them. These costs are given by the sum of the interbank rate and cost of deviation from target reserve level.

Turning to deposits, we obtain:

$$\alpha r_R + (1 - \alpha)r = r_D + c_{Di}D_i \tag{4.7}$$

The bank should thus attract deposits to the point where their marginal benefit and marginal cost are equal. The benefit of holding reserves is the sum of the interest earned on required reserves, $\alpha r_R$, and the interbank lending return from the part of deposits that do not serve as required reserves, $(1-\alpha)r$. The cost composes of the interest rate on deposits, $r_D$, and management costs.

Finally, the optimal quantity of central bank bills to hold is given by the level that equates the central bank bill yield with opportunity cost of holding central bank bills, $r$:

$$r_B = r \tag{4.8}$$

Holding central bank bills is therefore a perfect substitute for lending the same amount of funds in interbank market.

Furthermore, the supply for loans can be written as a function of the spread between the lending rate and the interbank rate:

$$L_i = \frac{r_L - r}{c_{Li}} \tag{4.9}$$

and optimal excess reserve as:

$$E_i = \frac{1}{\beta}\left(r_E - r\right) + E_i^T \tag{4.10}$$

The deposit demand function is:

$$D_i = \frac{1}{c_{Di}}\left(r - r_D + \alpha\left(r_R - r\right)\right) \tag{4.11}$$

Assuming there are $N$ banks in the interbank market, the market clearing condition is:

$$\sum_{i=1}^{N} M_i = 0 \tag{4.12}$$

The supply of central bank bills is exogenous and set through OMOs. $r_B$ and $r$ are jointly determined by the interbank market clearing condition (equation 4.12). In practice, the PBoC announces the reference rate for the central bank bills in order to influence the interbank rate.

So far we have assumed that banks maximize profits by choosing the amount of deposits, loans, excess reserves and central bank bill holdings, given interest rates and their cost functions. The net position $M_i$ of each firm can be positive, zero, or negative, while the sum of $M_i$ equals zero, as shown in equation (4.12). Equations (4.12) have three unknowns we need to determine: the interbank market rate, $r$, the deposit rate, $r_D$, and the retail lending rate, $r_L$. In the next section, we study the model solution and the impact of changes in policy instruments on interbank rate and lending.

### 4.3.2 The Impact on Interbank Rate and Loans

We first discuss the solution for the standard case in which the interest rates for lending and deposits are market determined.

*Case 1: $r_L$ and $r_D$ are market determined.*

In the standard case, the retail lending rate, $r_L$, and deposit rate, $r_D$, are endogenously determined in the loan and deposit markets. To capture the demand side of the loan market, we simply assume that aggregate loan demand is negatively related to the lending rate and positively related to real GDP and the price level:

$$L^d = L^d\left(\overset{-}{r}_L, \overset{+}{Y}, \overset{+}{P}\right) \tag{4.13}$$

Loan supply is the sum of banks' loan supply so that the equilibrium lending rate, $r_L^*$, is implicitly determined by:

$$L^d\left(\overset{-}{r}_L, \overset{+}{Y}, \overset{+}{P}\right) = L^s = \sum_{i=1}^{N} L_i = \sum_{i=1}^{N} \frac{r_L - r}{c_{Li}} \tag{4.14}$$

which we can solve for $r_L^*$:

$$r_L^* = h\left(\overset{+}{r}, \overset{+}{Y}, \overset{+}{P}\right) \tag{4.15}$$

Thus, $r_L^*$ positively related to the interbank rate, $r$, real GDP, $Y$, the price level, $P$, and loan management costs, as captured by $c_{Li}$. Furthermore, we assume that the supply of deposits is a linear function of the deposit rate, real GDP and the price level:

$$D^s = D^s\left(\overset{+}{r}_D, \overset{+}{Y}, \overset{+}{P}\right). \tag{4.16}$$

In equilibrium we have that:

$$D^s\left(\overset{+}{r}_D, \overset{+}{Y}, \overset{+}{P}\right) = D^d = \sum_{i=1}^{N} D_i = \sum_{i=1}^{N} \frac{1}{c_{Di}} \left(r - r_D + \alpha\left(r_R - r\right)\right) \tag{4.17}$$

By solving equation (4.17), the equilibrium deposit rate, $r_D^*$, is obtained:

$$r_D^* = f\left(\overset{+}{r}, \overset{+}{r}_R, \overset{+}{\alpha}, \overset{-}{Y}, \overset{-}{P}\right). \tag{4.18}$$

Thus $r_D^*$ is positively related to the interbank rate, $r$; the remuneration rate on required reserves, $r_R$; the required reserve ratio, $\alpha$; the price level, P; and negatively related to real GDP, $Y$. Substituting $r_L$ and $r_D$ in (4.9) and (4.11) with $r_L^*$ and $r_D^*$ respectively, and substituting $M_i$ with $D_i$, $L_i$, $E_i$, and $B$, the sum of aggregate net position, i.e. equation (4.12) can be expressed as:

$$\begin{aligned} F(\cdot) &= \sum_{i=1}^{N} M_i = \sum_{i=1}^{N} \left[(1-\ \alpha) D_i - L_i - E_i\right] - B \\ &= \sum_{i=1}^{N} (1-\ \alpha) D_i - \sum_{i=1}^{N} L_i - \sum_{i=1}^{N} E_i - B \end{aligned} \tag{4.19}$$

The aggregate net position $F(\cdot)$ depends on four factors: the fraction of aggregate deposits that is not held as required reserves, $\sum_{i=1}^{N} (1-\ \alpha) D_i$; aggregate loans, $\sum_{i=1}^{N} L_i$; aggregate excess reserves, $\sum_{i=1}^{N} E_i$; and the aggregate amount of central bank bills, $B$, which is determined by the central bank's open market operations and is exogenous. The equilibrium interbank rate, $r^*$, clears the interbank market, and is given by:

$$r^* = g\left(\ \alpha, r_R, r_E, B, Y, P\right). \tag{4.20}$$

The solution of $r^*$ equations (4.13) or (4.14), implies that:

$$L = L^d = L^s = \sum_{i=1}^{N} \frac{h\left(\overset{+}{r^*}, \overset{+}{Y}, \overset{+}{P}\right) - r^*}{c_{Li}} \tag{4.21}$$

The partial effects of adjusting monetary policy instruments on this equilibrium loan level is

**Table 4.1:** Impact of Changes in Policy Instruments on Interbank Rate

| **Instrument** | **Case 1** | **Case 2.1** | **case 2.2** | **case 2.3** |
|---|---|---|---|---|
| | **No Intervention** | $r_L^B < r_L^*$ | $\mathbf{r}_L^B \geq \mathbf{r}_L^*$ | |
| | | $\mathbf{r}_D^B < \mathbf{r}_D^*$ | $\mathbf{r}_D^B < \mathbf{r}_D^*$ | $\mathbf{r}_D^B \geq \mathbf{r}_D^*$ |
| $\mathbf{r}_L^B$ | / | 0 | $-$ | $-$ |
| $\mathbf{r}_D^B$ | / | $-$ | $-$ | 0 |
| $\boldsymbol{\alpha}$ | $\mp$ | $+$ | $+$ | $\mp$ |
| $\mathbf{r}_R$ | $-$ | 0 | 0 | $-$ |
| $\mathbf{r}_E$ | $+$ | $+$ | $+$ | $+$ |
| $\mathbf{B}$ | $+$ | $+$ | $+$ | $+$ |

given by Proposition 1:

**Proposition 1.** *When the deposit rate, $r_D$, and lending rate, $r_L$, are market determined, the impact of increasing the rate of remuneration on excess reserves and sales of central bank bill on loans, i.e. $\frac{\partial L}{\partial r_E}$ and $\frac{\partial L}{\partial B}$, are both negative. The impact of increasing remuneration rate on required reserve on loans, $\frac{\partial L}{\partial r_R}$, is positive, and the impact of increasing RR on loans, $\frac{\partial L}{\partial \alpha}$, is ambiguous.*

The proof of Proposition 1 is in Appendix 4.1. The intuition is as follows: increasing the remuneration on excess reserve leads banks to hold more excess reserves, which results in a negative aggregate position in the interbank market, $F(\cdot) < 0$, given the original equilibrium interbank rate. Hence the equilibrium rate must rise to clear the interbank market. In turn, that results in a higher lending rate and a lower loan level.

Sales of bills by the central bank has the same effect on loans by making the aggregate net position negative. By contrast, a higher remuneration rate on required reserves lead banks to attract more deposits. The resulting rise in aggregate deposits causes the aggregate net position in the interbank market to become positive, thus resulting in a lower interbank rate and hence more lending.

The impact of a change in RR depends on two factors. First, higher RR reduces the funds banks have available to lend, purchase central bank bills, and to hold excess reserves. Moreover, a higher RR also increases the demand for deposits by banks. The overall impact on the aggregate net position in the interbank market and on loans is ambiguous. Table 4.1 and 4.2 summarize the policy effects on interbank rate and loans respectively.

So far, we have discussed a model in which banks maximize profits, under the assumption

**Table 4.2:** Impact of Changes in Policy Instruments on Loans

| **Instrument** | **Case 1** | **Case 2.1** | **case 2.2** | **case 2.3** |
|---|---|---|---|---|
| | **No** | $r_L^B < r_L^*$ | $\mathbf{r}_L^B \geq \mathbf{r}_L^*$ | |
| | **Intervention** | $\mathbf{r}_D^B < \mathbf{r}_D^*$ | $\mathbf{r}_D^B \geq \mathbf{r}_D^*$ | $\mathbf{r}_D^B < \mathbf{r}_D^*$ |
| $\mathbf{r}_L^B$ | / | 0 | $-$ | $-$ |
| $\mathbf{r}_D^B$ | / | + | 0 | 0 |
| $\boldsymbol{\alpha}$ | $\pm$ | $-$ | 0 | 0 |
| $\mathbf{r}_R$ | + | 0 | 0 | 0 |
| $\mathbf{r}_E$ | $-$ | $-$ | 0 | 0 |
| $\mathbf{B}$ | $-$ | $-$ | 0 | 0 |

that the interest rates on deposits and retail lending are market determined. This case considered above is relevant for central banks that conduct monetary policy principally by influencing interest rates in interbank markets. While this is the standard procedure in advanced economies, the PBoC continues to rely on regulation of the interest rates that banks pay on deposits and charge for loans.

We therefore next consider how the introduction of regulated interest rates modifies the conclusions from the above analysis assuming market determined deposit and lending rates. This complicates the analysis considerably because such regulation could apply to either or both deposit and lending rates. Moreover, it can force the actual rate below or above the equilibrium level. To limit the number of cases that we must consider, we therefore focus on the sub-cases that we believe best capture the present situation in China.

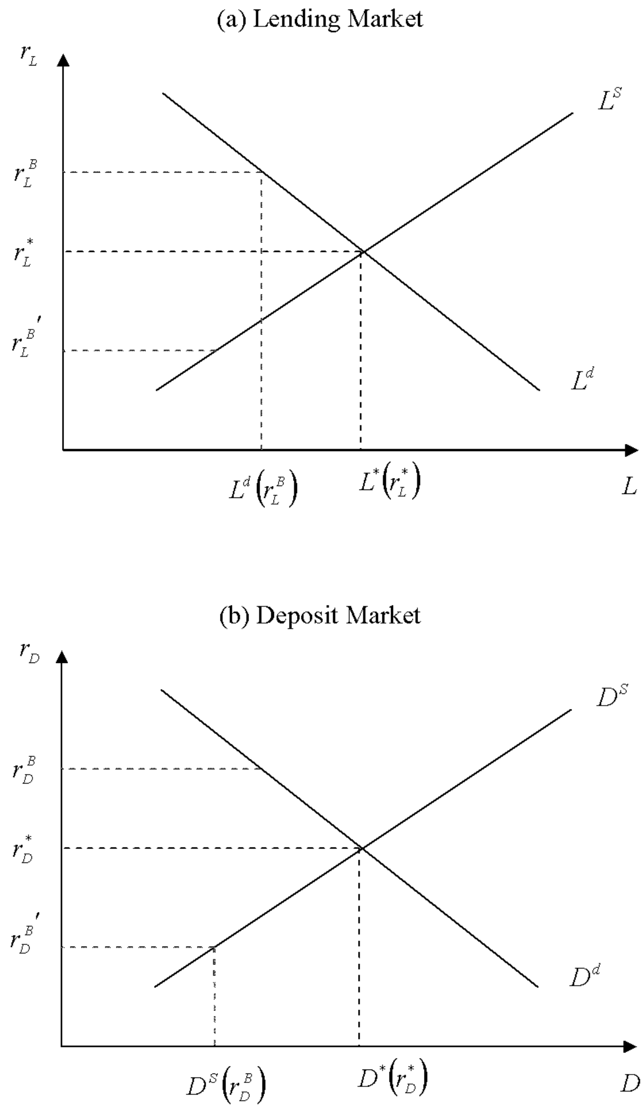
*Case 2 The floor of $r_L$ and the cap of $r_D$ are set by the central bank*

Figure 4.2 illustrates the determination of loan and deposit when the regulated rates provide a floor for the lending rate and a ceiling for the deposit rate.[11] The level of loans and the lending rate are equilibrium outcomes, when the regulated lending rate is below the equilibrium level. However, when the regulated lending rate is above the equilibrium rate, the loan level is determined by the loan demand, which is exogenous to the banks. The opposite holds true in the case of deposits. If the regulated deposit rate is above the equilibrium level, the amount of deposits is determined as if there was no such regulation. In contrast, if the regulated rate is below the equilibrium rate, deposits are determined by supply function.

Whether the regulated interest rates are above or below their equilibrium levels is crucial

[11] In practice, the lower bound of the lending rate is 90% of the regulated lending rate (also named benchmark lending rate). We do not model this detail since it does not change our result qualitatively.

**Figure 4.2:** Regulated Lending and Deposit Market



because it determines whether the quantity of deposits and loans will rise, fall or remain the same following a change in some instruments. Since it may be difficult for policy makers to determine the equilibrium rate, one consequence is that they may not know whether a change in the regulated interest rate will be expansionary or contractionary.

In order to explore the consequences of changing monetary policy instruments when the interest rates are regulated, below we discuss the sub-cases in which the regulated rates deviate from the equilibrium rates in different directions. Since the regulated rates only affect the equilibrium when they are binding (that is, the lending rate is below equilibrium and the regulated deposit rate is above equilibrium), we solely discuss cases in which either or both regulated rates are binding.

*Case 2.1* $r_L^B < r_L^*$ *and* $r_D^B < r_D^*$

Here we examine the effect of policy changes when both regulated rates are below their equilibrium levels. The fact that regulated lending rate is below the equilibrium level means the volume of bank loans are market determined and not affected by the regulation. In this case, we can solve for $r_L^*$ using (4.15) and the loan level is then given by equation (4.21). In contrast, as the regulated deposit rate is below the equilibrium level, deposits are determined by supply factors. The aggregate net position in the interbank market is therefore given by:

$$\begin{aligned} F(\cdot) &= (1-\alpha) D^s \left( r_D^B \right) - L^d \left( \overset{-}{h\left( \overset{+}{r}, \overset{+}{Y}, \overset{+}{P} \right)}, \overset{+}{Y}, \overset{+}{P} \right) \\ &\quad - \sum_{i=1}^{N} \left( \frac{1}{\beta} (r_E - r) + E_i^T \right) - B \end{aligned} \tag{4.22}$$

The effect of policy instruments are presented in Proposition 2.

**Proposition 2.** *When* $r_L^B$ *provides a floor for the retail lending rate and* $r_D^B$ *a ceiling for deposit rate, and these two rates are both below their equilibrium rates respectively, increasing the benchmark deposit rate is expansionary. Increasing the RR, remuneration rate on excess reserve and sales of securities to banking system are contractionary. Changes in the regulated lending rate and on remuneration on required reserve do not influence the level of loans.*

The proof of Proposition 2 is in Appendix 4.1. In this case, the increase of the benchmark deposit rate attracts more deposits from the public and thus attracts funds to the interbank market, which implies this is an expansionary policy. Higher RR, higher remuneration on excess reserves and sales of central bank bills reduce liquidity in the interbank market, thus are all contractionary. Thus these three policy actions are all contractionary. Since the regulated lending rate is not binding, raising it does not change the level of loans and lending rate. A change in the remuneration on required reserves also does not have effect on interbank liquidity and loans. The reason is that it only influences interbank liquidity through banks' demand for deposit, while in this case, the interbank liquidity is not determined by this bank demand.

*Case 2.2* $r_L^B \geq r_L^*$ *and* $r_D^B < r_D^*$

When the regulated lending rate exceeds the equilibrium level, it is binding and the level of loans is demand driven. As in Case 2.1, the deposit level is determined by supply function. The aggregate net position in the interbank market is given by:

$$F(\cdot) = (1 - \alpha) D^s \left( r_D^B \right) - L^d \left( r_L^B \right) - \sum_{i=1}^{N} \left( \frac{1}{\beta} (r_E - r) + E_i^T \right) - B \tag{4.23}$$

The only instrument that matters for the determination of loans is the regulated lending rate, a rise in which leads to a lower demand for loans, and thus lower level to loans. Moreover, raising benchmark lending rate lowers interbank rates by leading the banks to demand less liquidity from the interbank.

This partial effect of raising regulated lending rate on loans is given by:

$$\frac{\partial L}{\partial r_L^B} = \frac{\partial}{\partial r_L^B} L^D \left( \overset{-}{r_L^B}, \overset{+}{Y}, \overset{+}{P} \right) < 0. \tag{4.24}$$

And the effect on interbank rate is:

$$\frac{\partial r}{\partial r_L^B} = -\frac{\partial F / \partial r_L^B}{\partial F / \partial r} = -\frac{-\partial L^d \left( r_L^B \right) / \partial r_L^B}{\partial F / \partial r} < 0 \tag{4.25}$$

However, changes in other instruments influence the interbank market rate in the same way as in Case 2.1. Thus, a rise in benchmark deposit lowers the interbank rate, while raising RR, increasing remuneration on excess reserve and sales on central bank bills pushes up the interbank rate. There is no effect of a change in the remuneration on required reserves on the interbank rate.

In this case the central bank can directly control the loan level by changing the regulated lending rate, so that the interbank market plays no role for the transmission of monetary policy. Furthermore, there exist a disconnect between the interbank rate and bank loans. In particular, when the central bank raises RR, increase the remuneration on excess reserves, and conduct sales of central bank bills, the interbank rate increases but bank loans does not change.

*Case 2.3* $r_L^B \geq r_L^*$ *and* $r_D^B \geq r_D^*$

When both regulated rates are above the equilibrium rates, bank loans are determined by demand while deposit is determined by the equilibrium rate. The aggregate net position thus is:

$$\begin{aligned} F(\cdot) &= (1-\alpha) D^s \left( f \left( \overset{+}{r}, \overset{+}{r_R}, \overset{+}{\alpha}, \overset{-}{Y}, \overset{-}{P} \right) \right) - L^d \left( r_L^B \right) \\ &\quad - \sum_{i=1}^{N} \left( \frac{1}{\beta} (r_E - r) + E_i^T \right) - B \end{aligned} \tag{4.26}$$

As in Case 2.2, raising benchmark lending rate lowers loans by reducing loan demand. Changes of other instrument do not have any effect on it. Raising benchmark lending rate lowers interbank rates by reducing the bank demand for funds from the interbank market. However, other instruments influence the interbank liquidity either directly, or through changing the equilibrium level of deposits and excess reserves. Their effects on the interbank rate are therefore the same as in Case 1. To be specific, higher remuneration on required reserves lowers the interbank rate, higher remuneration on excess reserves and sales of central bank bills increase the interbank rate, and the effect of raising required reserve on interbank rate is ambiguous.

The main implication from the theoretical model is thus that the effect of policy instruments on the interbank rate and bank loans differs from the standard case if the interest rates on deposit and lending are regulated. Furthermore, the effect depends on whether the regulated interest rate is above or below the equilibrium rate. The disconnect between the changes in interbank rate and loans can thus be explained by the presence of regulated rates in the policy framework.

Before proceeding, we emphasize that from the view point of the central bank, knowledge about the relationship between the benchmark rates and equilibrium rates is crucial for knowing the effect of changes in policy instruments.

This section provides a theoretical model to show the transmission of monetary policy to bank loans in an monetary policy framework with regulations of deposit and retail lending market. In the next section, we provide some empirical evidence showing that the effects of some previous policy actions from PBoC are consistent with the predictions of the model.

## 4.4 Selected Monetary Policy Episodes

In lieu of undertaking a formal econometric study, in this section we interpret recent Chinese monetary policy development from the perspective of the model. In doing so it should be noted that the model traces out the responses of the banking system to monetary stimulus under the assumption that output and prices are exogenously given. While this is, of course, not a good characterization of the real world, the time spans that we consider below are short and it seems not unreasonable to assume that they are approximately constant.

With that caveat in mind, we study three episodes from 2004 onwards in which intensive policy actions were taken. The purpose of this analysis is to illustrate the potential for perverse changes in interbank rates and lending to changes in policy. Within each period, we list the dates and magnitudes of the changes in the PBoC's policy instruments, the resulting change in interbank market rate and the in bank lending. We focus on two episodes as shown in Table 4.3 and 4.4 respectively.

**Table 4.3:** Episode 1 : September - October 2006

| Period | Policy Actions | | Interbank Rate Change bps | New Increased Loan Growth% |
|---|---|---|---|---|
| Sept. 15 | Increase of RR by 0.5% | Withdrawal of liquidity by 73billion | 19 | -0.19 |
| Sept. 19 | Increase of the regulated *deposit* and *lending* rate by 27 bps | | | |
| Sept. 30 | | | | |
| October | Withdrawal of liquidity by 97.25 billion | | 22 | -2.56 |

Source: CEIC and author's calculation

**Table 4.4:** Episode 2: May 2007

| Period | Policy Actions | | Interbank Rate Change bps | New Increased Loan Growth% |
|---|---|---|---|---|
| May 5th | Increase of RR by 0.5% | Injection of liquidity by 212 billion | -27 | 5.4 |
| May 19th | Increase of the regulated *deposit* and *lending* rate by 27 bps | | | |
| June 5th | Increase of RR by 0.5% | | | |

Source: CEIC and author's calculation

In all episodes, the PBoC appears to have taken policy actions to tighten monetary conditions.[12] In particular, they raised the regulated rates for both deposits and lending simultaneously, raised RR, and withdrew liquidity. However, surprisingly, the resulting interbank rate fell and new loans increased on all three occasions, suggesting that these measures were expansionary. Indeed, this is suggested by the model.

To explain the different episodes with the model, we first need to identify in which regime or case the economy is. This is difficult since it requires us to know whether the regulated deposit and lending rates are above or below their underlying equilibrium levels. As already noted, the equilibrium deposit rates are in general believed to be above the benchmark rate, since there is little evidence that market deposit rates below the regulated rate. Thus we assume this is the case in our analysis. For the lending rate, it is less clear whether the regulated rate is binding. Table 4.5 shows the fraction of bank loans that are lent at rates above the regulated rate. In particular, for some periods, the largest four state-owned banks and joint-stock commercial banks had more than one third of their loans prices above the regulated rate, while the city commercial banks had more than two thirds. We therefore assume that either Case 2.1 or 2.2 best characterizes the economy.

Episode 1 shows the policy actions and the corresponding changes in interbank market and new loans between September 15th and October 31st, 2006. On September 15th, the PBoC raised RR by 0.5%, which the model suggests would push up the interbank rate. Four days later, PBoC increased the regulated rates for both deposit and lending simultaneously by 27 basis points. The model suggests that the combination of these two actions would reduce the interbank rate. At the same time, the withdrawal of 73 billion RMB of interbank liquidity was – according to the model – also expected to raise the interbank rate. The overall effect on the interbank rate thus depends on whether the increase in the regulated rates (which attracts deposits and tends to reduce interbank rates) was greater than the contractionary effects on interbank liquidity arising from the increase in the RR and the withdrawal of liquidity. The data shows that the interbank rate fell by 19 basis points, indicating the effect arising from the increase in the regulated rates, which attracts liquidity into the interbank markets, dominates. The resulting increase of new loans suggests that the economy is in Case 2.1.

In the next month, PBoC withdrew liquidity by 97 billion RMB without altering its other

[12] This is consistent with what the monetary policy indicator imply in Shu and Ng (2010).

**Table 4.5:** Proportions of Lending Rates Higher than the Regulated Lending Rate

| Period | Big Four | Commercial Banks | |
|---|---|---|---|
| | | Joint-stock | City |
| **2004Q3** | 35.70 | 33.20 | 66.30 |
| **2004Q4** | 44.33 | 36.00 | 60.23 |
| **2005Q1** | 39.80 | 34.60 | 66.80 |
| **2005Q2** | 39.96 | 32.37 | 57.79 |
| **2005Q3** | 41.08 | 35.62 | 68.10 |
| **2005Q4** | 41.09 | 35.07 | 51.94 |
| **2006Q1** | 39.92 | 35.07 | 57.01 |
| **2006Q2** | 39.41 | 34.70 | 58.32 |
| **2006Q3** | 35.70 | 31.02 | 62.82 |
| **2006Q4** | 38.52 | 29.03 | 56.93 |
| **2007Q1** | 36.01 | 28.43 | 54.67 |
| **2007Q2** | 36.48 | 27.41 | 49.82 |
| **2007Q3** | 36.88 | 26.19 | 44.12 |
| **2007Q4** | 35.54 | 29.35 | 46.30 |
| **2008Q1** | 36.47 | 35.57 | NA |

Source: CEIC

policy instruments. In contrast to the previous month, this time the interbank rate increased by 22 basis points and new loans fell by about 2.6%. The result is again consistent with the predictions of the model Thus, the model suggests that increasing the two regulated rates is probably the main reason leading to an opposite overall effect.

The second episode considers the policy actions from May 15th to June 5th, 2007. The sequence of adjustments in the instruments is the same as the first case, except that the PBoC increased the RR a second time after the adjustment of the regulated interest rates rates. Furthermore, it injected, rather than withdrew, a large amount of interbank liquidity. The impact on the interbank rate and new loans were similar to in the first episode. The explanation of the model is that although the second rise of the RR reduced liquidity in the interbank market, the large liquidity injection and the increase of the regulated deposit rate were more important. Hence the interbank rate dropped by more, and new loans grew faster, then in the earlier case.

## 4.5 Conclusion

In this paper we have studied the implementation of monetary policy and the interest-rate transmission mechanism in China. This is an interesting area of inquiry because the coexistence of regulation regarding what interest rates banks can charge for loans and offer on deposits with a market determined interbank rate make the transmission mechanism much more complicated than in a system in which all interest rates are fully flexible. Perhaps because of these complications and the resulting limited controllability of the degree to which monetary conditions are expansionary, the PBoC uses an array of policy instruments – including required reserve ratios, the rate of remuneration on reserves, open market operations – which further complicates the transmission mechanism.

To understand these issues better, we extend the model of bank behavior in China proposed by Porter and Xu (2009a). The model illustrates how the interbank rate and the quantity and price of retail loans are determined in an environment where banks compete, given regulations concerning the interest rates they can pay on deposits and charge for loans. The analysis suggests to several conclusions.

First, the presence of regulated rates has a large impact on the interest rate transmission mechanism. In particular, the net effect of changes in the policy instruments depends on whether and how the regulated interest rates deviate from their equilibrium levels. For instance, an increase in deposit rates will attract more deposits – and therefore depress interbank rates and expand bank lending – if the deposit rate is below the equilibrium level, but may do the opposite if the deposit rate is above the equilibrium level, given macroeconomic conditions.

Second and as a consequence, the interbank rate does not fully reflect the stance of monetary policy. Indeed, it can even be a potentially misleading indicator of the central bank's policy intentions. For instance, an increase in the regulated lending rate above the equilibrium level will tend to depress interbank rates – suggesting a more expansionary policy – since banks may react to the resulting decline in bank lending rates by reducing their demand for funds in the interbank market.

Third, to characterize properly the central bank's policy stance, information from all policy instruments – including the remuneration on required and excess reserves, RR and open market operations – needs to be taken into account. Doing so is not an easy exercise, neither for outside analysts nor the PBoC's staff.

Fourth, since the PBoC does not observe the equilibrium rates, there is a risk that it may not know at all times whether a change of its policy instruments would be expansionary or contractionary. This raises the risk that policy changes do not always have their intended effects, which may lead to policy errors.

Fifth, liberalizing the regulated rates would eliminate much of this uncertainty and is therefore likely to improve the PBoC's ability to control the degree to which monetary policy is stimulatory. The system of regulated rates is also likely to lead banks and borrowers to avoid the regulation by operating in grey markets. An additional benefit of lifting the regulations is that it would transfer this activity to the regulated sector.

While the focus of this paper has been to better understand the transmission mechanism by investigating theoretically how profit maximizing banks are likely to behave in the presence of regulation, a number of important empirical questions are readily apparent.

One set of questions concerns the behavior of interbank rates. For instance, to what extent do they respond to the policy instruments reviewed above? Have the responses become stronger over time, as one would expect given the gradual liberalization of the Chinese financial system over time? How do answers to these questions depend on the maturity of the interbank rate considered? What is the role of macroeconomic conditions in determining their evolution over time?

A second set of questions pertains to the behaviour of effective bank lending rates. How do they respond to the different policy instruments of the PBoC? Have these responses varied over time? What is the role of fluctuation in the demand for bank loans coming from movements in real GDP?

Finally, questions regarding the interconnectedness of Chinese interest rates with interest rates in the rest of the world arise. If the exchange rate is fixed or heavily managed, economic forces will tend to equalize interest rates across currencies. Of course, regulation to thwart these forces may be effective, at least for some time. Over time and as financial integration proceeds, one would expect international interest rate linkages to become stronger. Is this true for China?

While admittedly the available data set is limited, it would be fruitful to address these issues in a future paper. We hope to do so.

## 4.6 Appendix 4.1: Proof of Propositions

### 4.6.1 Proof of Proposition 1

**Proof. :** ■

The aggregate net position is given by:

$$\begin{aligned} F(\cdot) &= (1-\ \alpha) D^s - L^D - \sum_{i=1}^{N} E_i - B \\ &= (1-\ \alpha) D^s \left( f \left( \overset{+}{r}, \overset{+}{r_R}, \overset{\overset{+}{}}{\overset{+}{\alpha}} \overset{-}{Y}, \overset{+}{P} \right), \overset{+}{Y}, \overset{-}{P} \right). - L^D \left( h \left( \overset{+}{r}, \overset{\overset{-}{+}}{Y}, \overset{+}{P} \right), \overset{+}{Y}, \overset{+}{P} \right) \\ &\quad - \sum_{i=1}^{N} \left( \frac{1}{\beta} (r_E - r) + E_i^T \right) - B \end{aligned} \tag{4.27}$$

The partial effect of a change in interbank market rate on the aggregate net position is:

$$\begin{aligned} \partial F(\cdot)/\partial r &= (1-\ \alpha) \frac{\partial}{\partial\, r} D^s - \frac{\partial L}{\partial\, r} - \frac{\partial}{\partial\, r} \sum_{i=1}^{N} E_i - \frac{\partial B}{\partial\, r} \\ &= \underbrace{(1-\ \alpha) \frac{\partial}{\partial\, r} D^s \left( f \left( \overset{+}{r}, \overset{+}{r_R}, \overset{\overset{+}{}}{\overset{+}{\alpha}} \overset{-}{Y}, \overset{+}{P} \right), \overset{+}{Y}, \overset{-}{P} \right)}_{>0} \\ &\quad \underbrace{- \frac{\partial}{\partial\, r} L^D \left( h \left( \overset{+}{r}, \overset{\overset{-}{+}}{Y}, \overset{+}{P} \right), \overset{+}{Y}, \overset{+}{P} \right)}_{<0} + \underbrace{\frac{N}{\beta}}_{>0} \end{aligned} \tag{4.28}$$

which implies

$$\partial F(\cdot)/\partial r > 0 \tag{4.29}$$

The partial effects of raising remuneration on excess reserves on aggregate position is given by:

$$\partial F(\cdot)/\partial r_E = -\frac{\partial}{\partial r_E} \sum_{i=1}^{N} E_i = -\frac{N}{\beta} < 0, \tag{4.30}$$

Using the implicit function theorem, we therefore obtain the partial effect of remuneration on excess reserves on interbank rate is given as the following:

$$\frac{\partial\ r}{\partial r_E} = -\frac{\partial F\left(\cdot\right)/\partial r_E}{\partial F\left(\cdot\right)/\partial r} > 0 \tag{4.31}$$

in turn, the impact on loans is:

$$\frac{\partial L}{\partial r_E} = \frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial\ r}{\partial r_E} = -\frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial F\left(\cdot\right)/\partial r_E}{\partial F\left(\cdot\right)/\partial r} < 0 \tag{4.32}$$

Similarly, the partial effect of changes in remuneration on required reserves on the interbank rate and loans are:

$$\partial F\left(\cdot\right)/\partial r_R = \left(1 -\ \alpha\right)\frac{\partial}{\partial r_R}D^s > 0, \tag{4.33}$$

$$\frac{\partial\ r}{\partial r_R} = -\frac{\partial F\left(\cdot\right)/\partial r_R}{\partial F\left(\cdot\right)/\partial r} < 0 \tag{4.34}$$

$$\frac{\partial L}{\partial r_R} = \frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial\ r}{\partial r_R} = -\frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial F\left(\cdot\right)/\partial r_R}{\partial F\left(\cdot\right)/\partial r} > 0 \tag{4.35}$$

The same impact of RR is:

$$\partial F\left(\cdot\right)/\partial\alpha = \underbrace{-D^s}_{<0} + \underbrace{\left(1 -\ \alpha\right)\frac{\partial}{\partial\alpha}D^s}_{>0} \gtrless 0 \tag{4.36}$$

$$\frac{\partial\ r}{\partial\alpha} = -\frac{\partial F\left(\cdot\right)/\partial\alpha}{\partial F\left(\cdot\right)/\partial r} \lesseqgtr 0 \tag{4.37}$$

$$\frac{\partial L}{\partial\alpha} = \frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial\ r}{\partial\alpha} = -\frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial F\left(\cdot\right)/\partial\alpha}{\partial F\left(\cdot\right)/\partial r} \gtrless 0 \tag{4.38}$$

The impact of sales of central bank bills is thus:

$$\partial F\left(\cdot\right)/\partial B = -1 \tag{4.39}$$

$$\frac{\partial\ r}{\partial B} = -\frac{\partial F\left(\cdot\right)/\partial B}{\partial F\left(\cdot\right)/\partial r} > 0$$

$$\frac{\partial L}{\partial B} = \frac{\partial L^D}{\partial\, h}\frac{\partial\, h}{\partial\, r}\frac{\partial\, r}{\partial B} = -\frac{\partial L^D}{\partial\, h}\frac{\partial\, h}{\partial\, r}\frac{\partial F\left(\cdot\right)/\partial B}{\partial F\left(\cdot\right)/\partial r} < 0 \tag{4.40}$$

Q.E.D

### 4.6.2 Proof of proposition 2

**Proof.**

**In this case, the aggregate net position is given by:**

$$\begin{aligned} \partial F\left(\cdot\right)/\partial r &= \frac{\partial}{\partial r}\left(1-\alpha\right)D^s\left(r_D^B\right) - \frac{\partial}{\partial r}L^D\left(h\left(\overset{+}{r},\overset{\overset{-}{+}}{Y},\overset{+}{P}\right),\overset{+}{Y},\overset{+}{P}\right) \qquad (4.41)\\ &\quad -\frac{\partial}{\partial r}\sum_{i=1}^{N}E_i - \frac{\partial}{\partial r}B \\ &= \underbrace{-\frac{\partial L^D}{\partial h}\frac{\partial h}{\partial r}}_{>0} + \frac{N}{\beta} > 0 \qquad (4.42)\end{aligned}$$

■

The impact of a change in regulated lending rates on aggregate net position is given by:

$$\partial F\left(\cdot\right)/\partial\, r_L^B = 0 \tag{4.43}$$

Applying the implicit function theorem, this impact on interbank rate becomes:

$$\frac{\partial\, r}{\partial\, r_L^B} = -\frac{\partial F\left(\cdot\right)/\partial\, r_L^B}{\partial F\left(\cdot\right)/\partial r} = 0 \tag{4.44}$$

and the impact on loans is therefore:

$$\frac{\partial L}{\partial\, r_L^B} = \frac{\partial L^D}{\partial\, h}\frac{\partial\, h}{\partial\, r}\frac{\partial\, r}{\partial\, r_L^B} = -\frac{\partial L^D}{\partial\, h}\frac{\partial\, h}{\partial\, r}\frac{\partial F\left(\cdot\right)/\partial\, r_L^B}{\partial F\left(\cdot\right)/\partial r} = 0 \tag{4.45}$$

Similarly, the impact of a change in regulated deposit rate on net aggregate position, interbank rate, and loans are given by:

$$\partial F\left(\cdot\right)/\partial\, r_D^B = \left(1-\ \alpha\right)\frac{\partial}{\partial\, r_D^B}D^s\left(\ r_D^B\right) > 0 \tag{4.46}$$

$$\frac{\partial\ r}{\partial\ r_D^B} = -\frac{\partial F\left(\cdot\right)/\partial\ r_D^B}{\partial F\left(\cdot\right)/\partial r} < 0 \tag{4.47}$$

$$\frac{\partial L}{\partial\ r_D^B} = \frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial\ r}{\partial\ r_D^B} = -\frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial F\left(\cdot\right)/\partial\ r_D^B}{\partial F\left(\cdot\right)/\partial r} > 0 \tag{4.48}$$

The effects of raising remuneration on excess reserves is:

$$\partial F\left(\cdot\right)/\partial r_E = -\frac{\partial}{\partial\ r}\sum_{i=1}^{N} E_i = -\frac{N}{\beta} < 0 \tag{4.49}$$

$$\frac{\partial\ r}{\partial\ r_E} = -\frac{\partial F\left(\cdot\right)/\partial\ r_E}{\partial F\left(\cdot\right)/\partial r} > 0 \tag{4.50}$$

$$\frac{\partial L}{\partial\ r_E} = \frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial\ r}{\partial\ r_E} = -\frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial F\left(\cdot\right)/\partial\ r_E}{\partial F\left(\cdot\right)/\partial r} < 0 \tag{4.51}$$

and the effects of raising remuneration on required reserves is:

$$\partial F\left(\cdot\right)/\partial r_R = 0 \tag{4.52}$$

$$\frac{\partial\ r}{\partial\ r_R} = -\frac{\partial F\left(\cdot\right)/\partial\ r_R}{\partial F\left(\cdot\right)/\partial r} = 0 \tag{4.53}$$

$$\frac{\partial L}{\partial\ r_R} = -\frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial F\left(\cdot\right)/\partial\ r_R}{\partial F\left(\cdot\right)/\partial r} = 0 \tag{4.54}$$

and the impact of a higher RR is given by:

$$\partial F\left(\cdot\right)/\partial\alpha = -D^s\left(\ r_D^B\right) < 0 \tag{4.55}$$

$$\frac{\partial\ r}{\partial\alpha} = -\frac{\partial F\left(\cdot\right)/\partial\alpha}{\partial F\left(\cdot\right)/\partial r} > 0$$

$$\frac{\partial L}{\partial\alpha} = -\frac{\partial L^D}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial F\left(\cdot\right)/\partial\alpha}{\partial F\left(\cdot\right)/\partial r} < 0 \tag{4.56}$$

The impact of sales of central bank bill is:

$$\partial F\left(\cdot\right)/\partial\ B = -1 < 0 \tag{4.57}$$

$$\frac{\partial\ r}{\partial B} = -\frac{\partial F\left(\cdot\right)/\partial B}{\partial F\left(\cdot\right)/\partial r} > 0$$

$$\frac{\partial L}{\partial B} = \frac{\partial L^{D}}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial\ r}{\partial B} = -\frac{\partial L^{D}}{\partial\ h}\frac{\partial\ h}{\partial\ r}\frac{\partial F\left(\cdot\right)/\partial B}{\partial F\left(\cdot\right)/\partial r} < 0$$

Q.E.D.

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**Ehrenwoertliche Erklaerung**

Ich habe die vorgelegte Dissertation selbst verfasst und dabei nur die von mir angegebenen Quellen und Hilfsmittel benutzt. Alle Textstellen, die woertlich oder sinngemäss aus veröffentlichten oder nicht veroeffentlichten Schriften entnommen sind, sowie alle Angaben, die auf muendlichen Auskuenften beruhen, sind als solche kenntlich gemacht.

Hong Kong, den 23. October 2010

# Deutsche Zusammenfassung

**Einleitung** Die vorliegende Dissertation umfasst vier Kapitel, von denen sich jedes mit einem anderen Themengebiet aus der internationalen Makroökonomik und Geldpolitik befasst. Das erste Kapitel analysiert den Einfluss unerwarteter geldpolitischer Schocks auf die Wechselkurse in einem empirischen Mehrländermodell. Das dritte Kapitel untersucht den internationalen Einfluss fiskalpolitischer Schocks. Das zweite Kapitel untersucht den Zusammenhang zwischen makroökonomischen Faktoren und Wechselkursen über den Erwartungskanal der Geldpolitik. Im vierten Kapitel wird die internationale Transmission wirtschaftlicher Schieflagen im Unternehmens- und Bankensektor analysiert. Das letzte Kapitel untersucht den Zinskanal der monetären Transmission in einer aufstrebenden Volkswirtschaft, China, in der sowohl Marktkräfte als auch Regulierung Einfluss auf den Transmissionsprozess entfalten.

**Kapitel 1** untersucht Effekt unerwarteter gelpolitischer Schocks auf den Wechselkurs im Rahmen eines ökonometrischen Mehrländermodell.

Sowohl in der theoretischen wie auch in der empirischen Makroökonomik hat die Frage, wie eine Änderung in der Geldpolitik einer Volkswirtschaft den Außenwert seiner Währung beeinflusst, eine lange Tradition. Rüdiger Dornbuschs (1978) Artikel über das Überschießen des Wechselkurses ist in diesem Zusammenhang als einer der wichtigsten Beiträge zu betrachten. In Dornbuschs Modell wertet der reale Wechselkurs nach einem kontraktionären geldpolitischen Schritt zunächst auf, und verliert erst graduell im weiteren Verlauf an Wert. Dieses Ergebnis wird von mehreren neueren Beiträgen aus der Literatur, die sich mit dynamisch-stochastischen Gleichgewichtsmodellen befasst, bestätigt.

Im Gegensatz zu diesen theoretischen Arbeiten dokumentiert der überwiegende Teil der empirischen Literatur allerdings, dass der Höhepunkt der Aufwertung des nominalen und des realen Wechselkurses infolge eines kontraktionären geldpolitischen Schritts erst nach einer erheblichen Zeitverzögerung erreicht wird: dieses Ergebnis wird auch als das "delayed exchange rate overshooting puzzle" bezeichnet. Des weiteren scheinen die Ergebnisse in der empirischen Literatur darauf hinzudeuten, dass es nach einem kontraktionären US-amerikanischen geldpolitischen Schritt beträchtliche und langwierige Arbitragegelegenheiten zugunsten US-amerikanischer Anleihen gibt, die gegen die Gültigkeit der bedingten ungedeckten Zinsparität sprechen: dieses Ergebnis wird auch als das "forward premium/discount puzzle" bezeichnet. Die empirische Evidenz wurde bislang in solch einem Maße als stichhaltig angesehen, dass mehrere Mechanismen vorgeschlagen wurden, um die Puzzles mit fundierten Erklärungen zu unterlegen, so z.B. die lediglich eingeschränkte Verarbeitung von Informationen, verzerrte Wahrnehmungen oder zustandsabhängige Preisbestimmung.

Der übliche Ansatz zur Analyse von Geldpolitik und Wechselkursen in der bestehenden empirischen Literatur ist die (zwei-Länder) Vektorautoregression (VARs), in der die relevanten makroökonomischen Variablen sowohl für die in- wie auch für die ausländische Volkswirtschaft aufgenommen werden. Die Identifikation geldpolitischer Schocks erfolgt überwiegend auf Basis der Choleski-Zerlegung. Jüngere Arbeiten nutzen weniger restriktive, auf die kurzfristigen Effekte zielende Identifikationsschemata wie z.B. Vorzeichenrestriktionen (Scholl und Uhlig, 2008).

Im ersten Kapitel dieser Dissertation wird untersucht, ob die Erklärung des oben beschriebenen Puzzles in der empirischen Literatur durch die Wahl eines konzeptionell restriktiven, empirischen Ansatzes begründet sein könnte. Insbesondere werden zwei mögliche Ursachen für das Entstehen der Puzzles untersucht: (i) im Rahmen bilateraler VARs wird von den infolge geldpolitischer Schocks zeitgleich in mehr als nur zwei Ländern stattfindenden makoökonomischen Anpassungsmechanismen abstrahiert; (ii) die Identifikation geldpolitischer Schocks durch die Auferlegung von Kurzfristrestriktionen basierend auf der Choleski-Zerlegung ist zum einen nicht durch eine makroökonomische Theorie gestützt, und lässt zum anderen empirisch dokumentierte Langfristbeziehungen zwischen den makroökonomischen Variablen im VAR ungenutzt.

Im esten Kapitel dieser Dissertation wird daher zur Untersuchung der Wechselkurseffekte eines geldpolitischen Schocks unter besonderer Berücksichtigung dieser zwei Aspekte ein Mehrländer-VAR Modell für ein Panel von neun Industrieländern aufgestellt. Die geldpolitischen Schocks werden unter Ausnutzung empirisch dokumentierter Langfristbeziehungen zwischen den Variablen identifiziert. Die empirischen Ergebnisse implizieren, dass sowohl der effektive wie auch der bilaterale US-amerikanische Wechselkurs zeitgleich mit dem kontraktionären US-amerikanischen geldpolitischen Schock aufwerten, und dass der Wechselkurs nicht verzögert überschießt. Des Weiteren entsteht nach einem kontraktionären geldpolitischen Schock keine nennenswerte, persistente Abweichung von der ungedeckten Zinsparität und daher auch kein "forward premium". Die Ergebnisse dieses Kapitels sind konsistent mit den Implikationen aus theoretischen Modellen der offenen Volkswirtschaft mit unvollkommen flexiblen Preisen. Zudem deuten die empirischen Ergebnisse in diesem Kapitel darauf hin, dass es aufschlussreich sein könnte, existierende Modelle der offenen Volkswirtschaft - z.B. das von Benigno (2004), Bergin (2006) oder Steinsson (2008) - zu erweitern, um simultane Anpassungsdynamiken in einem Mehrländerkontext mit abzubilden.

**Kapitel 2** analysiert den Effekt makroökonomischer und für die Zinsentscheidung von Zentralbanken relevanter Variablen auf Wechselkursrenditen.

Seit der Studie von Meese und Rogoff (1983) ist allgemein anerkannt, dass zwischen makroökonomischen Faktoren und der Wechselkursdynamik kein Zusammenhang besteht. Neuere Studien belegen jedoch, dass Zinsentscheidungen von Zentralbanken Änderungen der makroökonomischen Faktoren berücksichtigen. Dieses Ergebnis legt nahe, dass makroökonomische Faktoren die Wechselkurse beeinflussen könnten, indem sie Erwartungen über die künftige Geldpolitik verändern. Des Weiteren sollten Faktoren, auf die Zentralbanken reagieren (geldpolitische Faktoren), gemeinsam als Erklärungsgröße für die Wechselkursentwicklung berücksichtigt werden.

Neuere Studien zu Wechselkursmodellen, in denen Geldpolitik in Abhängigkeit von makroökonomischen Faktoren modelliert wird und die Erklärungskraft und Vorhersagegüte geldpolitischer Faktoren beurteilen, weisen unterschiedliche Resultate auf. In diesen Arbeiten gelten restriktive Annahmen bezüglich der Bildung von Markterwartungen über die zukünftige Geldpolitik, was Schlussfolgerungen erschwert. Weil Markterwartungen über die zukünftige Geldpolitik notwendig sind, um über geldpolitische Faktoren Wechselkurse zu beeinflussen, ist die Modellierung dieser Erwartungen von entscheidender Bedeutung.

In Kapitel 2 wird die Wechselkursrendite in drei Komponenten zerlegt: Markterwartungen über die kurzfristigen Zinsen, Markterwartungen über Währungsrisikoprämien und Fehler in den Wechselkursprognosen. Darauffolgend wird untersucht, ob und inwiefern Faktoren, die in Zinsentscheidungen von Zentralbanken einfließen, über die erste Komponente den Wechselkurs beeinflussen. Insbesondere wird der Erwartungsbildungsprozess der kurzfristigen Zinsen auf Basis von Prognosen befragter Marktteilnehmer sowie alternativer Lernprozesse modelliert. Dabei wird der Mechanismus, dessen Zinsvorhersagen den Prognosen der befragten Marktteilnehmer am nächsten kommen, als Markterwartungsprozess definiert und dazu benutzt, die von Marktteilnehmern erwarteten Zinsen zu berechnen.

Die Analyse der Preisnotierung des U.S. Dollars gegenüber der Deutschen Mark und des Euro von 1979 bis 2008 bestätigt, dass geldpolitische Faktoren die Wechselkursrenditen über die geldpolitischen Erwartungen beeinflussen. Im Vergleich zur bestehenden Literatur verbessert das Einbinden von Markterwartungen bezüglich der Geldpolitik über Prognosen von Marktteilnehmern sowohl die Erklärungskraft als auch die Vorhersagegüte geldpolitischer Faktoren. Des Weiteren ist die erwartete Summe der zukünftigen Zinsunterschiede ein guter Ansatz um die Wechselkursrendite "out-of sample" vorherzusagen. Daraus lassen sich zwei Schlussfolgerungen ableiten.

Erstens nehmen die Outputlücke und die Inflationsrate eine zentrale Rolle bei der Bildung von geldpolitischen Erwartungen von deutschen und US-amerikanischen Marktteilnehmern ein. Die funktionale Form dieses Prozesses ändert sich jedoch über die Zeit und ist von Land zu Land unterschiedlich. Zweitens gilt die ungedeckte Zinsparität in der Eurozone nicht, und für die Zukunft erwartete höhere Zinsen führen zu einer Aufwertung der Währung.

**Kapitel 3** untersucht die internationale Transmission finanzieller Schieflagen von Banken und Unternehmen. Die Finanzkrise hat deutlich gezeigt, wie schnell finanzielle Schieflagen sich innerhalb einer Volkswirtschaft und über ihre Grenzen hinaus in die Weltwirtschaft verbreiten können. Die US-amerikanische Subprime-Krise hat Bankbilanzen geschwächt, Haushalte und Unternehmen haben Finanzmarktinstitutionen so nahe an den Bankrott getrieben, dass Regierungen mit umfangreichen Rettungspaketen eingreifen mussten. Die Verschlechterung der globalen Finanzsituation hat die Verfügbarkeit von finanziellen Ressourcen für Unternehmen aus der Realwirtschaft weltweit reduziert und dadurch ihre Produktions- und Investitionstätigkeit beeinträchtigt. Auch der private Konsum wurde in Mitleidenschaft gezogen.

Der Kreditkanal wird gemeinhin als der wesentliche Transmissionskanal für die Effekte finanzieller Schieflagen auf die Realwirtschaft gesehen. Die Stärke der Effekte hängt dabei von der Prevalenz des "financial accelerator" ab (Gilchrist et al, 2009). Die empirische Evidenz bezüglich der Transmission finanzieller Schieflagen beschränkt sich bislang beinahe ausschließlich auf entwickelte Volkswirtschaften, und nutzt nur in wenigen Fällen einen Ansatz, der sowohl makroökonomische wie auch finanz- und realwirtschaftliche Unternehmensvariablen berücksichtigt. In den Arbeiten von Cartensen et al. (2008), Pesaran et al. (2006) und Dees et al. (2007) wird die finanzielle Schieflage durch Bankeigenkapital oder das Ausfallrisiko von Schuldnern gemessen, und durch Spreads in Unternehmensanleihen bzw. Credit Default Swaps oder tatsächlichen Kreditausfalldaten approximiert. Die begrenzte Verfügbarkeit der Daten beschränkt die Untersuchung auf entwickelte Volkswirtschaften.

Die Untersuchung in Kapitel vier schließt durch eine umfassende Analyse der Verbindungen zwischen dem Banken- und dem (realwirtschaftlichen) Unternehmenssektor in der Weltwirtschaft eine Lücke in der Literatur. Dies erfolgt durch die Einführung eines vorausschauenden Ausfallrisikomaßes für Banken und Unternehmen in das von Pesaran et al. (2004) vorgeschlagene globale vektorautoregressive Modell (GVAR). Die Ausfallrisiken für Banken und Unternehmen werden durch die entsprechenden "Expected Default Frequencies" (EDFs) aus Moody's KMV Credit Edge approximiert. Die EDFs nutzen Informationen aus Aktienmarktdaten, Bank- und Unternehmensbilanzen, und werden daher auch oft als aktienmarktimplizierte Ausfallrisiken (Vassalou und Xing, 2004) bezeichnet, die für eine große Zahl von Schwellenländern verfügbar sind. Zusätzlich zu den EDFs werden in das GVAR makroökonomische und finanzwirtschaftliche Variablen aufgenommen.

Ähnlich den früheren Studien, belegen auch die Ergebnisse in Kapitel vier Verbindungen zwischen dem Finanzsektor und der Realwirtschaft durch einen signifikanten Effekt finanzieller Schieflagen im Banken- und Unternehmenssektor auf die inländische Wirtschaftsaktivität. Weiterhin sind finanzielle Schieflagen im Banken- und Unternehmenssektor auch mit statistisch signifikanten globalen Rückkopplungen - mit deutlichen Unterschieden zwischen entwickelten Volkswirtschaften und Schwellenländern - verbunden. Internationale Spillovers sind stärker ausgeprägt, wenn finanzielle Schieflagen in großen, entwickelten Volkswirtschaften ihren Ursprung haben (insbesondere in den USA). Die Effekte finanzieller Schieflagen von Unternehmen mit Ursprung in entwickelten Volkswirtschaften auf das Wachstum in Schwellenländern scheinen größer als die Effekte finanzieller Schieflagen im Bankensektor entwickelter Volkswirtschaften zu sein. Internationaler Handel scheint demnach eine bedeutende Rolle bei der Transmission von Schocks aus entwickelten Volkswirtschaften in Schwellenländern zu spielen. Wegen der wichtigeren Rolle des Bankensektors für die inländische Wirtschaft scheinen im Gegensatz dazu entwickelte Volkswirtschaften stärker auf finanzielle Schieflagen im Banken- als im Unternehmenssektor zu reagieren. Des Weiteren scheinen - im Einklang mit der Theorie des "financial accelerator" - Bank- und Unternehmensbilanzkanäle wichtige

Verstärkungsmechanismen für die internationale Transmission von Schocks zu sein.

**Kapitel 4** analysiert den Zinskanal im Rahmen des monetären Transmissionsprozess in China.

Zentralbanken entwickelter Volkswirtschaften setzen ihre Geldpolitik normalerweise um, indem sie die kurzfristigen Zinsen am Interbankenmarkt steuern. Aus diesem Grunde liefern kurzfristige Zinssätze Informationen über die gegenwärtige geldpolitische Ausrichtung. Für China geht man jedoch weitgehend davon aus, dass Interbankenzinsen kein ausreichendes Maß für die geldpolitische Ausrichtung sind.

Tatsächlich deutet die empirische Evidenz in der Literatur, wie z.B. Geiger (2006) sowie Laurens und Maino (2007), darauf hin, dass der Zinskanal im monetären Transmissionsprozess in China nur schwach ausgeprägt bzw. gar nicht existent ist. Wenn man den monetären Transmissionsprozess in China betrachtet, bietet es sich an (i) die Verbindung zwischen Politikinstrumenten und Interbankenzinsen sowie (ii) die Verbindung zwischen Interbankenzinsen und Kosten sowie Verfügbarkeit von Einzelhandelskrediten zu unterscheiden. Ansätze, die in der Literatur häufig zur Erklärung der Wirkungslosigkeit der Geldpolitik in China herangezogen werden, konzentrieren sich im Allgemeinen darauf, dass strukturelle Hindernisse an den Finanzmärkten die zweite Verbindung geschwächt haben.

Im Gegensatz dazu untersucht das fünfte Kapitel auch die erste Verbindung, da diese entscheidend dazu beiträgt, den gesamten Transmissionsmechanismus der Geldpolitik auf die Realwirtschaft zu verstehen.

Die chinesische Zentralbank greift in ihrer geldpolitischen Strategie auf eine Vielzahl von Instrumenten zurück. Diese bestehen aus auch in entwickelten Volkswirtschaften verwendeten geldpolitischen Instrumenten und zusätzlich - was von entscheidender Bedeutung ist - aus Einlage- und Kreditzinsen für Nichtbanken. Im Gegensatz zu entwickelten Volkswirtschaften sind diese beiden regulierten Zinssätze wichtig für die Umsetzung der Geldpolitik in China. Aus diesem Grunde stellt sich die Frage, welchen Einfluss das Zusammenspiel dieses erweiterten Instrumentariums mit verschiedenen Marktkräften auf die Effektivität der Geldpolitik der chinesischen Zentralbank hat.

Um diese Fragestellung zu analysieren, wird im fünften Kapitel ein an das chinesische System angepasstes Bankenmodell aufgestellt, das eine Erweiterung des Modells von Porter und Xu (2009a) ist, die ihrerseits auf das Modell von Freixas und Rochet (2008) zurückgegriffen haben. Das Modell zeigt, wie Interbankenzinsen sowie Menge und Preis von Einzelhandelskrediten in einem Umfeld bestimmt werden, in dem Banken untereinander im Wettbewerb stehen und derselben Regulierung in Bezug auf Einlage- und Kreditzinsen für Nichtbanken unterliegen. Die Ergebnisse des Modells deuten darauf hin, dass die Regulierung dieser Zinssätze einen entscheidenden Einfluss auf den Transmissionsprozess der Geldpolitik ausübt. Insbesondere hängt der Einfluss der Geldpolitik auf Interbankenzinsen und Einzelhandelskredite davon ab, wie stark die regulierten Zinssätze von den Gleichgewichtszinsen abweichen, die sich ohne Regulierung am Markt bilden würden. Aus diesem Ergebnis lassen sich zwei Schlussfolgerungen ziehen.

Erstens sind Interbankenzinsen in diesem regulierten Umfeld kein ausreichender - möglicherweise sogar ein irreführender - Indikator für die geldpolitischen Absichten der Zentralbank. Um deren gelpolitische Haltung zu beschreiben, müssen alle verwendeten geldpolitischen Instrumente in Betracht gezogen werden, darunter die Einlage- und Kreditzinsen für Nichtbanken, die Mindestreserveanforderungen und deren Vergütung sowie Offenmarktgeschäfte.

Zweitens, entsprechend dem Ausmaß, in dem die Zentralbank die Gleichgewichtszinsen nicht beobachten kann, kann sie nicht wissen, ob eine Änderung in ihren Instrumenten geldpolitisch expansiv oder restriktiv wirkt. Die Freigabe dieser regulierten Zinssätze behebt diese Unsicherheit und verbessert die Effektivität des monetären Transmissionsprozesses.