Why do floating exchange rates float? Evidence from capital flows in a structural VAR model

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Abstract

Most of past empirical research based on the single equation monetary models of exchange rates found poor fit for data beyond the 1980s. Recent research of exchange rates determination has documented impacts of monetary policies on exchange rates. While focusing on traditional macroeconomic fundamentals, existing literature has produced little understanding of what roles various types of capital flows play in the dynamics of exchange rates. This paper develops a unifying framework that takes into account macroeconomic fundamentals as well as various kinds of capital flows in explaining fluctuations of floating exchange rates. We apply a structural VAR model with non-recursive contemporaneous restrictions on quarterly data of Australian dollar, Canadian dollar and US dollar over the period of 1980 to 2004. Our main findings are as follows: 1) for small open economies such as Australia and Canada, portfolio investment explains a major portion of exchange rate fluctuations over the short-to-medium run; 2) for a large and relatively closed economy such as the US, traditional macroeconomic fundamentals are more important in explaining exchange rate fluctuations while capital flows have far less influence; and 3) for all countries, interest rate differentials play an important role in exchange rate determination, as predicted by the traditional monetary models. Our research contributes to the understanding of determination of floating exchange rates in an increasingly financially integrated world economy.

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1. Introduction

The collapse of the Bretton Woods System led major currencies in the industrial countries to float. In the subsequent decades, volumes of research on the determination of floating exchange rates have been produced. Major theoretical contributions are the monetary approach and the portfolio balance approach to exchange rates, with both based upon the building blocks of interest rate parity (IP) and purchasing power parity (PPP) in international finance theory. In the empirical research, typical explanatory variables of exchange rates are economic growth, inflation, interest rate, and money supply. These traditional macroeconomic fundamentals are believed to determine the equilibrium exchange rates in the long run (MacDonald, 1999).

The exchange rate of a floating currency is determined jointly by the demand and supply conditions of the currency in the foreign exchange market, with these conditions closely related to the country's transactions with the rest of the world. International merchandise trade is an important exchange rate determinant in a world with little international financial activity. However, with highly liberalized financial accounts, capital flows across borders could overwhelm merchandise trade both in volume and in their impact on exchange rate fluctuations. Several currency crises that hit both emerging markets and industrialized countries during the 1990s were largely the result of problems with the financial markets associated with voluminous and unbridled international capital flows.

The Mundell-Fleming model provides an integrated framework for studying the internal and external balances of an open economy with flexible exchange rate and perfect capital mobility. However, different kinds of capital flows, such as direct investment, portfolio investment, bank loans, etc., are treated equally. In today's diverse capital market, different types of capital flows are not only driven by different forces, they may have different impacts on the equilibrium exchange rates as well. Brooks, Edison, Kumar, and Slok (2004) argue that the impacts of debt flows on exchange rates may be limited because such flows are usually hedged; however, equity flows are usually not hedged and therefore their impacts on the currency markets may be greater. Surprisingly, the existing literature – empirical or theoretical – has generated little understanding of the roles of different kinds of capital flows in determining the exchange rate of a floating currency. This paper attempts to fill this void in the literature.

In this paper, we develop a structural vector autoregressive model (SVAR) to examine the dynamics of the exchange rates of the Australian dollar, the Canadian dollar, and the US dollar over 1980-2004. Our model incorporates not only traditional macroeconomic fundamentals such as national income, the interest rate, the money supply, the price level, and the balance of trade, but also various kinds of capital flows, such as direct investment, portfolio investment, and other capital flows.

Our main findings are: 1) traditional macroeconomic fundamentals except the interest rate do not explain much of the fluctuations in the Australian dollar or the Canadian dollar exchange rates, for which, portfolio investment plays a major role in the short-to-medium term exchange rate determination; 2) for the US dollar, the interest rate dwarfs capital flows as the most important factor in explaining exchange rate fluctuations over the short-to-medium term. Delayed overshooting is found with the US dollar exchange rate in response to an increase in the relative interest rate of the US to the rest of the world. However, when the US economy is assumed to be unaffected by most of its smaller trading partners, the delayed overshooting is mitigated and the response pattern becomes similar to the Dornbusch (1976) overshooting[2]. Most findings are consistent with the standard wisdom of exchange rate theories, such as uncovered interest parity, purchasing power parity, and various predictions of the monetary theories of exchange rates.

The contributions of this paper are several: 1) this paper provides fresh evidence to the literature of how different types of capital flows differ in their impacts on the exchange rates of floating currencies; 2) this paper distinguishes factors that may directly

[2] The "delayed overshooting" is used in comparison to the Dornbusch (1976) overshooting, both of which describe the responses of exchange rates to shocks to the interest rate. With the Dornbusch (1976) overshooting, the nominal exchange rate appreciates to some maximum level upon impact of an increase in the interest rate and then depreciates gradually towards a new equilibrium. With the "delayed overshooting", the nominal exchange rate will keep appreciating and reach the maximum several periods later before turning to depreciate towards the new equilibrium after an increase in the interest rate. The "delayed overshooting" puzzle has been observed by Eichenbaum and Evans (1995) and Grilli and Roubini (1996). The puzzle has not been fully resolved yet.

change the exchange rates, such as the capital flows and the balance of trade, from those that only influence the exchange rates in their long run equilibrium via other channels, such as the relative income, the money supply, and the interest rate; and 3) the model outperforms the single equation monetary model of exchange rate determination by giving appropriate attention to the impacts of the capital account and the balance of trade on the exchange rates in a highly financially integrated world.

The rest of the paper is organized as follows. Section 2 reviews selected current literature on the determination of floating exchange rates. Section 3 presents the empirical methodology. Section 4 discusses the empirical results. Section 5 concludes.

2. Selected Review of the Literature

Among the early theories of the determination of floating exchange rates are the monetary model with flexible prices, the monetary model with sticky prices and exchange rate overshooting, and the portfolio balance model. Comprehensive surveys of related theoretical and empirical research are provided by MacDonald and Taylor (1994) and Taylor (1995). A critical discussion of the econometric approaches to the early empirical models of exchange rate determination can be found in Pentecost (1991). In the empirical research of monetary models to exchange rates, it is believed that the relative income, the relative price level, the relative interest rate, and the relative money supply jointly influence the expected future path of exchange rate movements (Pentecost, 1991).

The monetary class of models assumes that money is an asset, the price of which – the exchange rate – is jointly determined by the supply and demand of money. Purchasing power parity is assumed to hold continuously. In the flexible-price version of the monetary model, it is assumed that prices adjust instantaneously to their new equilibrium after a shock and thus the exchange rate does not deviate from its equilibrium. In the sticky-price version of the monetary model, prices can be sticky to a shock in the short run and thus nominal and real exchange rates are allowed to overshoot in the short and medium run before they reach their long run PPP equilibrium. (Dornbusch, 1976)

Testing of the monetary models generates supportive evidence for these models using data over the 1970s (Bilson 1979; Frenkel, 1976), while poor fit to the data beyond the late 1970s; at best, there is conflicting empirical evidence (Frankel, 1993; Backus, 1984; and etc). Among the explanations for the breakdown of the single equation monetary models to data beyond late 70s are the following: either simple monetary models do not incorporate the effects of large current account deficits or surpluses (Frankel, 1984, 1993) or macroeconomic fundamentals are not sufficient to explain the effects of speculative behavior in the foreign exchange market (Baxter and Stockman, 1989; Flood and Rose, 1995; and etc). These suggestions point to the direction that the effects of the balance of payments components should be considered as well as the macroeconomic fundamentals in exchange rate determination models.

A recent extension of the monetary approach to exchange rate determination is the research on the interactions between monetary policies and exchange rates in an open economy, represented by Clarida and Gali (1994), Eichenbaum and Evans (1995), Grilli and Roubini (1996), Kim (2000), and Kim and Roubini (2000). Most of these works adopt structural VAR modeling and are able to trace out responses of nominal or real exchange rates to various types of structural macroeconomic shocks. For example, Eichenbaum and Evans (1995) find persistent and significant appreciation in the US nominal and real exchange rates following a contractionary monetary policy shock. Kim (2003) investigates the impacts of foreign exchange intervention and conventional monetary policy on the exchange rate and the interactions between the two policies based on the US data. He finds that there exist many interactions among the two types of monetary policies and the exchange rate, and that foreign exchange intervention not only influences the exchange rate substantially, but it reacts to the exchange rate significantly as well. Kim and Roubini (2000) have solved several empirical anomalies such as the "liquidity" bias, the "price" bias, the "exchange rate" bias, and the "forward discount" bias by estimating a structural VAR model using non-US G-7 data. They also find that the impacts of monetary policy shocks on exchange rates are consistent with the predictions of a broad set of theoretical models. However, these models focus only on the impacts of monetary or foreign exchange policies and may omit important information, suggesting the need for further exploration.

There is much less empirical research on the portfolio balance model and hence much less evidence for the empirical success of the model in explaining exchange rates (MacDonald and Taylor, 1994; Taylor, 1995). In fact, Frankel (1984) tests the portfolio balance model using the mark/dollar exchange rate over 1974:1 to 1978:10 and obtains poor results. One problem researchers usually encounter is the lack of concrete definition of non-money assets. This question is especially relevant when the financial markets today have developed so fully both in breadth, as there are a wide variety of financial instruments and enormous volumes of financial assets are traded every day; and in depth as financial markets are closely linked across borders, from Frankfort to Tokyo, from New York to Sao Paulo. In this context, the data of capital flows on a bilateral basis may be hard to obtain if not impossible.

Two new directions have emerged: 1) exchange rates need to be treated on a trade-weighted basis rather than on a bilateral basis in order to take advantage of the financial data which are aggregated capital flows from all over the world; and 2) different kinds of capital flows may need to be treated separately in order to examine their differences, if any, in influencing exchange rates. Indeed, a bilateral exchange rate such as the exchange rate of the euro in terms of the dollar does not determine the general competitiveness of European goods and assets in the world. Some exchange rate index that aggregates bilateral exchange rates of the euro against all other currencies, weighted by their relative importance in international transactions, is a more accurate indicator of the general competitiveness of the Euro area in the world. The nominal or real effective exchange rate of a currency is an ideal indicator which aggregates the country's bilateral exchange rates against its major trading partners weighted by the relative importance of each trading partner in trade.

Recently, researchers have started to pay attention to the possible influences that different kinds of capital flows may have on the exchange rates. (Brooks et al., 2004; Athukorala and Rajapatirana, 2003) Brooks, Edison, Kumar and Slok (2004) explore the ability of portfolio and foreign direct investment flows to track movements in the euro/dollar and the yen/dollar exchange rates. They argue that the low explanatory power of traditional variables, such as the long-term interest rate differential, the inflation differential, and the relative current account positions, calls for refocusing of the existing exchange rate model to take into account various capital flows variables. According to them, various kinds of capital flows, such as debt flows, portfolio flows, and direct investment flows, are driven by different forces and hence would have different influences on exchange rates. They further point out that hedged debt flows should have less influence on the exchange rates than unhedged portfolio flows. Using quarterly data over 1988:1 to 2000:3, they find that the euro/dollar exchange rate is closely tied to net portfolio flows between the Euro area and the United States, while net direct investment flows seem to be less important in accounting for exchange rate volatility. The yen/dollar exchange rate can be explained more by conventional variables such as the current account and the interest rate differential.

Brooks, Edison, Kumar and Slok (2004) made a successful pioneering attempt in accounting for movements in exchange rates by incorporating the possible different impacts of different types of capital flows. However, their single equation estimation method is subject to two possible problems: 1) the endogeneity of major regressor variables, such as the interest rate differential and the capital flow variables; and 2) the serial correlation of estimated residuals. As Pentecost (1991) points out in a survey of the econometric approaches to empirical asset market model of exchange rates, simultaneous equations methods are more successful and are usually able to generate more favorable results.

3. Empirical Methodology

Our data vector for each country is $X_t = (yd, rd, md, pd, di, po, tb, oc, er)_t^{'}$, where yd_t represents the relative income, $(y_t - y_t^*)$; rd_t is the relative interest rate, $(i_t - i_t^*)$; md_t is the relative money aggregate, $(m_t - m_t^*)$; pd_t is the relative price level, $(p_t - p_t^*)$; di_t is the net direct investment; po_t is the net portfolio investment; tb_t is the balance of trade (or current account); oc_t represents the net balance of all other capital flows; er_t is the nominal exchange rate; and * refers to the largest trading partners in this study. The first four variables – yd_t , rd_t, md_t, and pd_t – are the conventional macroeconomic fundamentals in the traditional models. The following four variables – di_t, po_t, tb_t, and oc_t – are the balance of payments variables, the influences of which are yet to be examined.

It is assumed that the relationships among the nine variables can be described by the following structural VAR model:

(1) $$A_0 X_t = \sum_{i=1}^{n} A_i X_{t-i} + \varepsilon_t$$

where X_t*'s* are as defined above. A_0 is a nonsingular 9x9 matrix capturing the contemporaneous interactions among the variables. The $A_i\text{'}s$, *i = 1, 2,…n*, are also 9x9 and describe the lagged interactions among the variables. The ε_t's are the i.i.d structural disturbances and $Var(\varepsilon_t) = I$. $\varepsilon_t = (\varepsilon^{yd}, \varepsilon^{rd}, \varepsilon^{md}, \varepsilon^{pd}, \varepsilon^{di}, \varepsilon^{po}, \varepsilon^{tb}, \varepsilon^{oc}, \varepsilon^{er})_t^{'}$, where ε^{yd} is the relative income shock, ε^{rd} is the relative money supply shock[3], ε^{md} is the relative money demand shock, ε^{pd} is the relative price shock, ε^{di} is the direct investment shock, ε^{po} is the portfolio investment shock, ε^{tb} is the trade balance shock[4], ε^{oc} is the shock to all other capital flows, and ε^{er} is the exchange rate shock.

A_0 is considered to have the non-recursive structure with contemporaneous restrictions as proposed by Sims (1986) and Bernanke (1986). Contemporaneous restrictions on structural VAR models are used extensively by researchers in studying the interactions among monetary policies and exchange rates. Among them are Eichenbaum and Evans (1995), Cushman and Zha (1997), Grilli and Roubini (1996), Kim and Roubini (2000), Kim (2003), Kim (2005), etc.

There are several benefits from using the contemporaneous restrictions: 1) the long run relationships among macroeconomic fundamental variables and various balance of payments variables remain unclear and elusive, while short run relationships tend to be more easily identified from standard wisdom; 2) the impacts of some of the balance of payments shocks on the exchange rate can be transitory, making contemporaneous restrictions more appropriate; and 3) using contemporaneous restrictions, we do not need to impose any restrictions on the lagged variables and thus let the data reveal the lagged interactions among the variables.

[3] In Kim and Roubini (2000), the shock to the short-term interest rate is considered the supply shock in the money market, while the shock to the money supply is taken as the money demand shock. In this study, it is the relative interest rate and the relative money supply, defined to be the differentials between the variables of the home country and those of the country's largest trading partners. Hence, the two shocks are defined as the relative money supply shock, and the relative money demand shock, respectively.

[4] ε^{ca} is also considered instead of the balance of trade shock in robustness analysis.

The following matrix form of (1) shows the restrictions on the contemporaneous interactions in matrix A_0:

$$\textbf{(2)}\quad \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & a_{17} & 0 & 0 \\ a_{21} & 1 & a_{23} & a_{24} & 0 & 0 & 0 & 0 & a_{29} \\ a_{31} & a_{32} & 1 & a_{34} & 0 & 0 & 0 & 0 & 0 \\ a_{41} & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & 0 & 0 & 1 & 0 & 0 & a_{69} \\ a_{71} & 0 & 0 & a_{74} & 0 & 0 & 1 & 0 & 0 \\ a_{81} & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & 1 & a_{89} \\ a_{91} & a_{92} & a_{93} & a_{94} & a_{95} & a_{96} & a_{97} & a_{98} & 1 \end{pmatrix} \begin{pmatrix} yd \\ rd \\ md \\ pd \\ di \\ po \\ tb \\ oc \\ er \end{pmatrix}_t = \sum_{i=1}^{p} A_i \begin{pmatrix} yd \\ rd \\ md \\ pd \\ di \\ po \\ tb \\ oc \\ er \end{pmatrix}_{t-i} + \begin{pmatrix} \varepsilon^{yd} \\ \varepsilon^{rd} \\ \varepsilon^{md} \\ \varepsilon^{pd} \\ \varepsilon^{di} \\ \varepsilon^{po} \\ \varepsilon^{tb} \\ \varepsilon^{oc} \\ \varepsilon^{er} \end{pmatrix}_t$$

3.1 Identification assumptions

Relative income

Equation (2.1) captures the dynamics of the relative income between home country and the rest of the world. For any country, national income (real GDP) may respond to changes in the interest rate, the money supply, the capital flows, and the nominal exchange rate only with a lag. Thus, $a_{12} = \dots = a_{16} = a_{18} = a_{19} = 0$. Trade balance may be an exception. Net exports are a component of GDP, as such, contemporaneous trade shocks influence current total output. That is, $a_{17} \neq 0$[5].

Equations (2.2) and (2.3) represent the monetary policy sector, the reaction functions of the interest rate and the money stock. Following Kim and Roubini (2000) and Kim (2003), equations (2.2) and (2.3) are defined as the relative money supply and the relative money demand equations, respectively.

Relative money supply

Equation (2.2) is assumed to be the relative monetary policy reaction function, following Kim and Roubini (2000). For any economy, the monetary policy reaction

[5] However, if we assume that the majority of trade takes longer than a quarter to be completed so that the rest only has trivial contemporaneous impact on current GDP that can be ignored, we could assume $a_{17} = 0$. We examine the robustness of the results by making this assumption, the results are available upon request.

function is supposed to show how the monetary authority responds to shocks to both the internal and the external sectors via interest rate targeting. Standard monetary theory implies that real money supply is influenced by shocks to the national income and the price level[6] contemporaneously – within a quarter in this study. Thus, we assume that the relative money supply be affected contemporaneously by the relative income shock and the relative price level shock. Since the monetary authority is also able to react to the value of money over a quarter, we assume that the relative money demand shock also affects the relative money supply contemporaneously. Following Kim (2003), we assume that the relative money supply is also affected by the shock to the nominal exchange rate contemporaneously since the monetary authority may respond to such shocks by adjusting the interest rate.

It is assumed that the monetary authority needs longer than a quarter to evaluate the true impacts of changes in the balance of payments before making any policy adjustment. Direct investments are the foreign funds injected into domestic production projects, such as building new plants, forming joint ventures, etc. The impact of such investments on an economy can only be felt with a lag, so $a_{25} = 0$. The impacts of portfolio investments, mainly short-term foreign investments in domestic stock and bond markets, and international bank loans and deposits, are more unpredictable due to their volatile nature. Hence it is very unlikely that domestic monetary authority would respond to these shocks within a short period of time before understanding their true impacts on the economy. Thus, $a_{26} = a_{28} = 0$.

It is also assumed that the monetary authority may not respond to shocks to the balance of trade (or the current account) contemporaneously for at least two reasons. First, if the shock is more persistent, such as a change in taste, such a shock may usually influence the economy with a lag, at least longer than a quarter. For example, a sudden change in tastes leads to increased demand for domestic goods by foreign consumers. New orders will be placed by foreign importers. In practice, the process of sourcing and

[6] In Kim (2005), the interest rate is assumed not to respond to shocks to the real output or the price level contemporaneously because the monthly data will not be available for the monetary authority to respond in time. In this study, quarterly data are used. We believe that within a quarter, there can be sufficient information available for the monetary authority to peruse.

placing new orders usually takes time – at least a few months. Newly placed foreign orders for domestic goods will then influence home output (income) gradually via multiplier effects. However, the direct result of this shock – a change in foreign consumers' tastes – will only be recorded in the balance of payments with an even longer lag, when the new orders are completed and the goods delivered. Hence, the monetary authority will only be able to identify such shocks several periods later. Second, if the shocks are more temporary in nature, such as a temporary increase in orders the production of which is already underway, the impacts of such shocks may be transitory too. It may not be worth it for the monetary authority to respond. Hence, $a_{27} = 0$.

Relative money demand

Equation (2.3), md_t, is the equation for the relative money demand. Standard monetary theory implies that real money demand is affected by income and the interest rate. Thus, the relative money demand is assumed to be affected by shocks to the relative income, the interest rate, and the relative price level, contemporaneously – over a quarter in this study. For similar reasons discussed above with the relative money supply equation, we assume that shocks to the capital flows or the balance of trade do not influence the relative money demand contemporaneously, so $a_{35} = a_{36} = a_{37} = a_{38} = 0$. Following Kim and Roubini (2000), we assume that the relative money demand does not change contemporaneously to shocks to the nominal exchange rate, so $a_{39} = 0$[7]. This holds better if countries use sterilized intervention to influence the nominal exchange rate. For example, in order to tackle the appreciation in the dollar, the US Fed may buy foreign currencies in the foreign exchange market, and at the same time, sell government securities at home to offset the increase in the monetary aggregate as a result of the foreign exchange intervention. By selling government securities at home, the interest rate at home is boosted up.

[7] In Kim and Roubini (2000), exchange rate is assumed to enter the interest rate function contemporaneously but not the function of the money stock.

Relative price[8]

Equation (2.4) describes the dynamics of the relative price. We believe that prices are sticky in the short run so that contemporaneously, the relative price is exogenous to all variables except the relative income. Thus, $a_{42} = a_{43} = a_{45} = ... = a_{49} = 0$.

Equations (3.5) to (3.8) capture the dynamics of the balance of payments variables.

Direct investment

Decisions on direct investments, represented by equation (3.5), are usually deliberated long before the foreign funds are applied to the designated projects. This indicates that, contemporaneously, direct investments are exogenous to all shocks so that $a_{51} = ... = a_{54} = a_{56} = ... = a_{59} = 0$.

Portfolio investment

Portfolio (equity and debt) investments, described by equation (3.6), can be more volatile and sensitive than direct investments to shocks in the current relative income, relative money supply, relative money demand, and nominal exchange rates[9]. We assume that, contemporaneously, shocks to the relative price level, direct investment, other capital flows, and balance of trade do not influence the portfolio investment. That is, $a_{64} = a_{65} = a_{67} = a_{68} = 0$.

Balance of trade

The balance of trade – equation (2.7) – is assumed to be independent of all shocks contemporaneously except the relative income shock and the relative price level shock.

[8] In Kim and Roubini (2000), the supply (productivity) shock is allowed to influence the price level within a month. We doubt this assumption would be too strong given price stickiness. However, within a quarter, this should hold better. We have also tried the alternative of having $a_{41} = 0$ and get very similar results.

[9] Kant (2005) has found that while portfolio equity and debt investments are responsive to interest rates, direct investments are not.

This implies $a_{72} = a_{73} = a_{75} = a_{76} = a_{78} = a_{79} = 0$. We assume that a change in the nominal exchange rate may only influence the trade balance with a lag[10].

Other capital flows

We assume that other capital flows – the "catch-all" type of foreign investment other than the direct investment and the portfolio investment – respond to all shocks contemporaneously. These capital flows are mainly composed of bank loans and deposits. For example, positive expectations as a result of a higher income at home may attract foreign funds to flow into the country initially in the form of banking deposits which may be invested in the home economy in other forms later. A positive shock to direct investment can mean a decrease in the other capital flows because the funds can be transferred from a foreign-owned bank account to fund the domestic project. For the same reason, current portfolio investment shocks and current shocks to the balance of trade can mean a change to the total bank deposits. Given their sensitive and volatile nature, short-term bank deposits and portfolio investments are usually considered "hot

[10] This assumption implies that trade is relatively inelastic to exchange rates at least within a few months. In international trade, the exchange rate risk is usually hedged especially for large trade orders so that any shock to the exchange rate may not influence such orders, at least within a few months. Even if we assume that the exchange rate risk is not hedged, the impact of exchange rate changes on trade can still be limited within a short notice of time (a quarter in our study) because of the inertia of consumption and the fact that it takes time for buyers to switch to suppliers from other countries. Trade can become more elastic to exchange rates in the long run. For example, home currency is hit by a depreciation shock. This makes imports more expensive and exports cheaper for the home country. Foreign exchange risk is usually well hedged for existing large orders so that they may not be influenced by the depreciation. Small home importers may want to find even cheaper sources or press the foreign suppliers to cut down prices, but contemporaneously may continue to import at a similar level to maintain their business and market. Small home exporters may expect more orders from abroad, but it takes time for it to have an impact on the actual trade balance. In one word, it takes time for a real sector such as the international merchandise and service trade to respond and adjust to an exchange rate shock since decisions are made by managers on every ring of a whole supply chain. Another argument is that if pricing to market dominates in trade of the industrialized countries studied here, exchange rate changes should have little impact on trade, at least contemporaneously. We have also examined the robustness of the results by assuming $a_{79} \neq 0$. The results are not reported by can be available upon request.

money”. It is almost uncontroversial that flows of “hot money” are sensitive to exchange rate changes even within a very short period of time.

Nominal exchange rate

Finally, nominal exchange rates are assumed to be subject to all shocks contemporaneously.

3.2 Estimation

Structural VAR models are usually not directly estimated. We first estimate the reduced-form VAR as the following:

(3) $$X_t = \sum_{i=1}^{n} G_i X_{t-i} + e_t$$

where G_i*'s*, $i=1, 2, \ldots, n$, are the 9x9 estimated lagged coefficient matrices of X_t*'s*. The e_t is a 9x1 vector of estimated white-noise residuals of all nine equations in system (3) and $Var(e_t) = \Sigma$ is the symmetric 9x9 covariance matrix of residuals. The following relations hold between the structural model in (2) and the reduced-form model in (3):

(4) $G_i = A_0^{-1} A_i$, $i = 1, 2, \ldots, n$, and

(5) $$e_t = A_0^{-1} \varepsilon_t$$

which implies

(6) $$A_0^{-1}(A_0^{-1})' = \Sigma$$

The 31 free parameters in A_0 can be obtained only through the sample estimate of Σ. The model is over-identified, since there are 31 free parameters to be estimated in A_0, while Σ. gives 45 restrictions. That is, we will solve for 31 unknowns in 45 equations. A_0 can be estimated with the maximum likelihood method.

4. Empirical Results

4.1 The data

In this study, we examine three floating currencies: the Australian dollar, the Canadian dollar, and the US dollar. Quarterly data over 1980-2004 are used for empirical estimation. By selecting this period, we avoid the oil shocks during the early 1970s and can take advantage of the increasingly integrated and developed world capital markets. These currencies are not only representative of floating currencies, but the financial markets of their host countries are relatively open and well developed. In addition, none of them has experienced any major currency crisis for the period of time that is examined.

The data are obtained from the *International Financial Statistics* of the IMF. The income is real GDP. The interest rate is the three-month treasury-bill rate. The money stock is the M1, following the existing studies of monetary models of exchange rate determination[11]. The price level is the CPI. The balance of trade is the balance of goods and services (or the balance of the current account). The balance of trade (or current account), the net direct investment, the net portfolio investment, and the net other capital flows are all expressed as percentages of the trended nominal GDP[12]. The nominal exchange rate is nominal effective exchange rate[13], where an increase indicates appreciation of the home currency. All variables are seasonally adjusted when necessary.

4.2 Estimated contemporaneous parameters of A_0

The baseline model is estimated with two lags. For monthly data, either six or twelve lags are commonly used in the literature. For example, Eichenbaum and Evans (1995), Kim and Roubini (2000), Kim (2003 and 2005) use six lags; Cushman and Zha (1997) use twelve lags. We have tested for the lag length using the Akaike Information Criterion and the Schwarz Bayesian Criterion. For all three countries, the AIC test favors longer lags, while the SBC test favors shorter lags[14]. In our selection of the lag length, we prefer the shorter lags by the SBC for the concern of preserving degrees of freedom.

[11] Refer to Frankel (1984, 1993) and Kim and Roubini (2000) for the use of M1 money aggregate in empirical studies. We examine the robustness of our results to the use of the M2 money aggregate. The results are qualitatively similar and are available upon request.
[12] The trended real GDP is first computed and then converted back to trended nominal GDP using GDP deflator. We also use the original GDP data and get similar results.
[13] The nominal effective exchange rate data are from the IMF IFS. It is an index number calculated as the trade-weighted average of the bilateral nominal exchange rates against major trading partners. An increase in the index number indicates appreciation of the home currency.
[14] Evidence suggests that minimizing the Akaike Information Criterion may lead to over-parameterization. (Sawa, 1978)

Furthermore, for simplicity, we assume two lags for all three countries. Meanwhile, we test the robustness of the results using four lags in section 4.5 and get comparable results.

Income, the money aggregate, the price level, and the nominal exchange rate are all in log levels. All other variables are in levels[15]. Table 1 shows the estimated contemporaneous parameters of A_0.

[Table 1 about here]

Most of the parameters are estimated to have the right sign according to standard theories. For example, a_{92} is negative for all three countries, indicating that an increase in the relative interest rate in favor of the home country leads to appreciation of the home currency upon impact, consistent with the expected performance of the nominal exchange rate with sticky prices in the short run. The parameters of all three capital flows are negative, indicating that upon impact, a net inflow of capital flows, regardless of type, causes appreciation in the home currency. The balance of trade also has a negative sign, indicating that an increase in net export causes the home currency to appreciate upon impact. However, the contemporaneous parameters only tell about the interactions among the variables upon impact of shocks. In the following sections, we also examine the impulse responses and the variance decompositions to see how the entire model works.

4.3 Impulse responses

In Figure 1 we show the impulse responses of nominal exchange rates to the nine shocks over 20 quarters for the three currencies. The upper and lower lines are the one-standard-deviation error bands[16].

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[15] All series enter the estimation without differencing. According to Fuller (1976, Theorem 8.5.1), differencing produces no gain in asymptotic efficiency in an autoregression, even if it is appropriate (See RATS 6 User's Guide, p331, Should I difference?). In a VAR, differencing throws information away while produces no gain. Also see Tiao and Box (1981) and Tiao and Tsay (1983). The estimation is done with the Bayesian method using Monte Carlo Integration of 10,000 draws by applying the Gaussian approximation of the posterior of A_0. The Bayesian method does not require differencing. (see Sims, 1988; Sims and Uhlig, 1991)

[16] Intervals between the upper and lower dashed lines contain two standard errors, which correspond to the 16% and 84% fractiles, respectively. The one- standard-deviation error bands are used extensively in the literature, such as Cushman and Zha (1997), Eichenbaum and Evans (1995), Kim and Roubini (2000), etc.

[Figure 1] [17]

A. Responses to the macroeconomic fundamental shocks

According to the single equation monetary model to exchange rates, an increase in the relative income causes the home currency to appreciate; an increase in the relative monetary aggregate causes the home currency to depreciate; and an increase in the relative interest rate causes the home currency to depreciate in the long run equilibrium. Purchasing power parity implies that an increase in the relative price level causes the home currency to depreciate in the long run.

Our results confirm these predictions in most cases. A positive shock to the relative income causes statistically significant appreciation in the Canadian dollar over time. However, the responses of the Australian dollar and the US dollar are insignificant. A positive shock to the relative money demand causes statistically significant depreciation in the Australian dollar and the US dollar over time, while the responses of the Canadian dollar are insignificant. The responses of the three currencies to a positive shock to the relative price level are insignificant, even though all currencies show depreciating responses. A trade surplus causes the home currency to appreciate over time. However, the responses are not significant.

Responses to positive shocks to the relative money supply are interesting. For the Australian dollar and the Canadian dollar, results are consistent with the Dornbusch (1976) overshooting with sticky prices. That is, nominal exchange rates almost appreciate to their maximum levels upon impact of the shocks – with approximately one or two quarters lags – then depreciate. For the US dollar, a positive shock to the relative interest rate causes the so-called delayed overshooting, as found by Eichenbaum and Evans (1995) on US data and Grilli and Roubini (1996) on the non-US G-7 data. That is, nominal exchange rate appreciates gradually for about 10 quarters (2.5 years) before reaching its maximum and turning to depreciate.

This delayed overshooting puzzle has not yet been fully resolved in the literature. Cushman and Zha (1997) argue that the puzzle of delayed overshooting is generated by

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[17] The error bands of impulse responses are generated from 10,000 draws by Monte Carlo Integration following Sims and Zha (1999). This is a Bayesian method which employs a Gaussian approximation of the posterior of A_0. The scale shows the percentage deviation from an underlying growth path.

inappropriate monetary policy identification restrictions. By assuming block exogeneity of the US economy relative to the Canadian economy in a structural VAR model, they find that the delayed overshooting disappears for the Canadian dollar exchange rate in response to a contractionary monetary policy shock. Kim (2005) offers an explanation by introducing the interactions between the foreign exchange policy and the conventional monetary policy. He argues that the "leaning-against-the-wind" foreign exchange intervention may have delayed the overshooting of nominal exchange rates upon impact of conventional contractionary monetary policy shocks. When the foreign exchange intervention effects fade out over time, the more prolonged monetary policy effects show up as the exchange rate keeps appreciating to its maximum. His conjecture is formally confirmed using Canada data over 1975:1 – 2002:2.

In general, our results of the responses of nominal exchange rates to macroeconomic fundamental shocks are consistent with traditional theories of exchange rate determination.

B. Responses to the capital flows shocks

One focus of this paper is to identify the difference, if any, in the influence of various types of capital flows on nominal exchange rates. In the Mundell-Fleming model, different types of capital flows are all lumped under the same category, when, indeed, different types of capital flows, while driven by different forces, may have different impacts on the nominal exchange rates.

A net inflow of direct investments causes statistically significant appreciation in the Australian dollar over time, in the Canadian dollar over the first few quarters upon impact of the shock, and in the US dollar over the 3rd to the 5th quarters.

A net inflow of portfolio investments causes statistically significant appreciation in the Australian dollar and the Canadian dollar over a long time. However, the US dollar exchange rate hardly responds to a shock to the portfolio investment, implying that shocks to portfolio investments play a far less important role in determining the exchange rate of a relatively large and closed economy as the US.

Responses of exchange rates to other capital flows are negligible for the Australian dollar and the US dollar. For the Canadian dollar, there is only a very small significant appreciation upon impact of the net inflow of other capital flows.

Finally, a positive shock to the nominal exchange rate causes statistically significant appreciation in all three currencies over time.

In sum, the Australian dollar and the Canadian dollar exchange rates have similar impulse responses to shocks in the various types of capital flows. Their exchange rates are most responsive to changes in the portfolio investments. The US dollar is almost unresponsive to changes in the capital flows[18].

4.4 Variance decompositions

In Table 2, we present the forecast error variance decompositions of nominal exchange rates to various shocks. This helps us understand the relative importance of different structural shocks to exchange rate fluctuations over time. We report the results at the 1st, 4th, 8th, 12th, and 20th quarters. The numbers in parentheses are the standard errors at 95% level of significance.

[Table 2 about here][19]

For the Australian dollar, the portfolio investment shocks, the relative money supply shocks, and the direct investment shocks are the three most important factors that explain the exchange rate fluctuations. Portfolio investment shocks contribute 42%-48% of total exchange rate changes over time. The relative money supply shocks contribute 15%-23% of total exchange rate fluctuations. And direct investment shocks contribute 11%-12% of total exchange rate variances.

For the Canadian dollar, the nominal exchange rate shocks, the portfolio investment shocks, and the relative money supply shocks are the three most important factors explaining exchange rate fluctuations in the Canadian dollar in the short run. Contribution of the nominal exchange rate shocks to the total variance of the Canadian dollar exchange rates range from 17% to 38%. The portfolio investment shocks explain around 18%-32% of total exchange rate changes. The relative money supply shocks contribute around 15%-22% of total exchange rate fluctuations. An interesting finding is that the contribution of the relative income shock is rapidly increasing over time. In 20

[18] We provide an explanation in section 5 by assuming exogeneity of the US economy.

[19] The standard errors are generated using the same method as the error bands of the impulse responses at the 95% level of significance.

quarters, the relative income shock explains the most of exchange rate fluctuations among all shocks, contributing 25% of total variances.

For the US dollar, the three most important factors that explain the US dollar exchange rates are the nominal exchange rate shocks, the relative money supply shocks, and the portfolio investment shocks, respectively. The nominal exchange rate shocks account for around 21%-66% of total US dollar fluctuations. The relative money supply shocks account for around 8%-32% of total exchange rate changes. The portfolio investment shocks account for only about 7%-12% of total US dollar variances.

The relative money supply shocks are among the three most important factors for the exchange rates of all three currencies on average, indicating that among the traditional macroeconomic fundamentals, it plays the most important role in determining floating exchange rates. Other macroeconomic fundamentals, such as the relative money demand shocks, the relative price level shocks, and the balance of trade shocks, only explain a small portion of total exchange rate fluctuations. They jointly account for around 20%-30% of total exchange rate fluctuations.

Among the capital flows, portfolio investments influence the exchange rates the most for the Australian dollar and the Canadian dollar, while direct investments and other capital flows are much less important. However, influences of capital flows are much smaller for the US dollar. These findings may indicate that influences of capital flows, especially portfolio investments, on exchange rates, may depend on the relative size and openness of the country. This is worth more research in the future.

We have found the following differences in impulse responses and variance decompositions among the US dollar, the Australian dollar, and the Canadian dollar exchange rates: 1) both the Australian dollar and the Canadian dollar appreciate by a larger magnitude to shocks in portfolio investments, to which the US dollar hardly responds; 2) both the Australian dollar and the Canadian dollar appreciate to the maximum possible level almost upon impact of a positive shock to the relative interest rate, while the overshooting delays for the US dollar; 3) for the Australian dollar and the Canadian dollar exchange rates, portfolio investment shocks contribute a lot to their fluctuations, while capital flows account for very little of the US dollar fluctuations; and

4) relative money supply shocks seem to contribute more to the US dollar fluctuations than to the Australian dollar or the Canadian dollar fluctuations.

Some explanations may be offered. First, Australia and Canada are relatively small and open, while the US is relatively large and closed. Any external shock, such as shocks to capital flows or the balance of trade, can be absorbed more easily and quickly by the US economy. Thus they will have less impact on the US dollar exchange rates. Second, the US dollar is more a global currency, while the Australian dollar and the Canadian dollar are used mainly nationally or regionally (at best). Being the global vehicle currency makes it easier to have the impacts of capital flows to and from the US offset by demand and supply of the dollar elsewhere in the world. On the other hand, the Australian dollar or the Canadian dollar are used within more restricted regions, thus capital flows, especially the more speculative and volatile portfolio investment flows, may have long-lasting impacts that can only be digested gradually by the currencies over time. Third, the US economy is much larger than most of its major trading partners, implying that the US may be exogenous to shocks of its smaller trading partners. Thus, it may be inappropriate to compute the relative variables for the US against its trading partners. In the next section, we consider this possibility of exogeneity to address the delayed overshooting puzzle of the US dollar exchange rate.

4.5 Explaining delayed overshooting in the US dollar exchange rate

Kim (2005) provides a formal explanation for the delayed overshooting found with the Canadian dollar exchange rate by incorporating foreign exchange intervention. He argues that in response to contractionary monetary policies, the “lean-against-the-wind” foreign exchange intervention may offset the impacts of the higher interest rates on the exchange rates at earlier stages. However, as the foreign exchange intervention effects fade away, the more persistent monetary policy effects will surface, showing the true responses of exchange rates to conventional monetary policy shocks.

[Table 3 about here]

Our approach to address the delayed overshooting of the US dollar is to assume exogeneity of the US economy. We assume that Japan represents the rest of the world for the US and that the relative variables, *yd, md, rd*, and *pd*, are all computed against the

Japanese macroeconomic indicators. In Table 3, we provide a comparison of the estimated contemporaneous parameters between the benchmark model and the exogeneity model. In Figures 2, we report the impulse responses of nominal exchange rates to all nine shocks in the exogeneity model.

[Figure 2 about here]

As can be seen, most coefficients are highly comparable to the benchmark results. When excluding the smaller trading partners and assuming Japan to represent the rest of the world for the US, results look more refined. The US dollar exchange rate now responds by a statistically significant appreciation to a positive shock to the portfolio investment, the direct investment, or the balance of trade. Responses to other factors remain basically unchanged. One gain from this modification is that the delayed overshooting of the exchange rate in response to a positive relative money supply shock has been largely altered. The exchange rate appreciates to its maximum level in about 2-3 quarters after the initial impact of the shock, flattens out for about 4-5 quarters, and depreciates quickly afterwards. The impulse responses are more consistent with those of the Dornbusch (1976) overshooting.

[Table 4 about here]

Table 4 reports the variance decompositions. As can be seen, they do not deviate much from the benchmark. Our findings suggest that exogeneity does matter for a large and relatively closed economy like the US in our VAR modeling[20].

5. Conclusion

This paper develops a structural VAR model to explain the determination of exchange rates of floating currencies, incorporating both traditional macroeconomic fundamentals and various capital flows. In the model, nominal exchange rates are assumed to be subject to nine structural shocks: the relative income shock, the relative

[20] Robustness of the benchmark results are examined in four ways: 1) estimating the benchmark model with four lags instead of two lags; 2) replacing the balance of trade with the balance of the current account in the benchmark model; 3) ignoring the contemporaneous impacts of the trade shocks to the relative income by assuming $a_{17}=0$; and 4) allowing contemporaneous effects of the nominal exchange rate on the balance of trade by relaxing the restriction on a_{79}. The results are similar to the benchmark results. The results are not reported but are available upon request.

interest rate shock, the relative money stock shock, the relative price level shock, the direct investment shock, the portfolio investment shock, the balance of trade shock, the other capital flows shock, and the exchange rate shock. The model is then applied to the Australian dollar, the Canadian dollar, and the US dollar exchange rates over 1980-2004.

We find that for small open economies like Australia and Canada, portfolio investment is an important determinant of exchange rates as well as the relative interest rate. Other traditional macroeconomic fundamentals do not explain much of the exchange rate fluctuations. For relatively large and closed economies like the US, capital flows are much less important than expected. The relative interest rate and shocks to the exchange rates are among the most important factors. Other traditional macroeconomic fundamentals do not seem as important as expected. Most of our findings are consistent with the standard wisdom of exchange rate determinations in the existing literature. Our model is quite successful in capturing the interactions between capital flows and exchange rates for small open economies. However, for relatively large and closed economies, like the US, more research needs to be done for a more complete understanding of exchange rate determination.

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Table 1: Estimated Contemporaneous Parameters of A_0

	Australia		Canada		US	
	Coefficient	**Std. error**	**Coefficient**	**Std. error**	**Coefficient**	**Std. error**
A17	-0.002	0.007	0.001	0.003	0.007	0.011
A21	-5.022	16.858	19.589	9.149	-4.584	8.781
A23	1.335	7.429	4.944	5.049	4.394	6.295
A24	-2.922	19.046	20.676	14.786	3.735	15.586
A29	13.716	5.875	7.044	7.173	1.132	4.394
A31	-1.479	0.374	0.223	0.398	-0.170	0.319
A32	0.006	0.007	0.007	0.007	0.004	0.006
A34	-0.609	0.449	0.677	0.630	0.629	0.565
A41	0.007	0.089	0.043	0.069	-0.114	0.066
A61	-7.491	17.315	-9.675	11.603	6.279	3.584
A62	-0.243	0.198	-0.078	0.170	-0.079	0.049
A63	6.961	6.067	-2.300	3.300	-1.794	1.501
A69	14.756	5.171	13.522	8.053	1.462	2.017
A71	-2.436	6.395	1.738	2.226	1.380	3.171
A74	-1.771	3.650	13.707	6.793	5.163	2.702
A81	-1.484	6.380	-29.798	8.050	-3.396	4.055
A82	0.034	0.059	-0.030	0.101	-0.035	0.049
A83	2.684	1.904	-0.741	2.543	0.006	1.412
A84	-0.700	7.119	9.472	13.748	-11.574	7.267
A85	0.469	0.149	0.830	0.148	0.442	0.143
A86	0.658	0.134	0.919	0.128	0.641	0.112
A87	0.467	0.254	1.023	0.223	0.160	0.264
A89	-0.904	1.749	-2.421	5.694	0.012	1.756
A91	0.442	0.813	0.064	0.394	-0.472	0.596
A92	-0.015	0.009	-0.002	0.006	-0.001	0.011
A93	0.283	0.274	-0.040	0.099	0.218	0.197
A94	1.122	0.861	-0.694	0.584	0.619	0.999
A95	-0.068	0.020	-0.015	0.008	-0.009	0.024
A96	-0.070	0.021	-0.018	0.010	-0.004	0.036
A97	-0.073	0.030	-0.011	0.012	-0.007	0.034
A98	-0.012	0.025	-0.003	0.007	0.000	0.025

Note: The model is estimated with two lags.

Table 2: Variance Decomposition

The percentage of the k-step ahead forecast error variance of the nominal exchange rates explained by the shock of									
k	ε^{yd}	ε^{rd}	ε^{md}	ε^{pd}	ε^{di}	ε^{po}	ε^{tb}	ε^{oc}	ε^{er}
Australian dollar									
1	1.2 (1.6)	23.2 (16.0)	4.5 (3.6)	1.4 (1.3)	11.2 (4.0)	43.0 (14.8)	1.4 (1.1)	1.5 (1.4)	12.7 (5.1)
4	3.4 (2.9)	20.3 (13.8)	4.5 (3.4)	2.1 (1.8)	10.7 (6.8)	47.5 (13.8)	2.2 (2.7)	1.9 (1.5)	7.4 (4.3)
8	4.0 (3.2)	16.7 (10.7)	5.3 (4.4)	3.2 (3.0)	11.0 (7.7)	46.3 (14.0)	3.4 (4.0)	2.4 (2.3)	7.8 (4.7)
12	4.7 (3.6)	15.6 (10.3)	5.8 (5.2)	3.4 (3.1)	11.4 (8.0)	44.7 (13.0)	4.3 (4.1)	2.5 (2.2)	7.7 (4.8)
20	6.6 (5.0)	14.8 (10.2)	6.2 (5.4)	3.5 (3.0)	11.7 (8.2)	42.3 (12.6)	5.1 (4.5)	2.5 (2.2)	7.5 (4.7)
Canadian dollar									
1	0.8 (1.0)	13.2 (10.2)	1.1 (1.5)	1.9 (1.3)	7.0 (3.2)	31.8 (12.4)	1.7 (1.2)	4.7 (4.7)	37.9 (12.6)
4	1.5 (1.6)	22.0 (17.2)	1.8 (2.1)	2.9 (2.0)	5.9 (4.1)	28.9 (13.7)	1.8 (1.8)	5.0 (4.0)	30.1 (15.9)
8	3.8 (2.7)	21.4 (15.8)	2.4 (2.7)	2.8 (2.3)	10.5 (9.6)	25.9 (15.8)	3.6 (3.6)	4.8 (4.1)	24.8 (14.8)
12	11.0 (6.8)	18.3 (12.3)	3.1 (3.8)	2.6 (2.1)	11.4 (10.4)	22.9 (14.9)	4.8 (4.7)	4.5 (3.9)	21.5 (13.4)
20	25.1 (11.3)	14.8 (8.4)	4.2 (6.0)	2.6 (2.1)	9.4 (8.1)	18.1 (13.1)	5.3 (4.5)	3.6 (3.1)	17.1 (10.0)
US dollar									
1	1.6 (1.8)	7.8 (7.6)	2.3 (2.3)	1.3 (1.4)	2.0 (2.1)	12.2 (11.7)	1.3 (1.3)	5.7 (5.4)	65.9 (14.8)
4	2.1 (2.1)	17.7 (12.4)	4.4 (4.4)	3.3 (3.0)	3.7 (3.7)	10.4 (10.8)	3.1 (2.8)	6.6 (6.4)	48.6 (16.0)
8	3.6 (3.2)	28.9 (15.5)	7.2 (6.1)	3.4 (3.3)	5.0 (4.9)	7.8 (7.6)	4.4 (4.0)	5.8 (4.9)	33.9 (14.6)
12	4.7 (4.4)	33.6 (15.1)	8.2 (6.8)	3.7 (3.6)	4.8 (4.3)	7.0 (5.5)	5.6 (5.1)	7.2 (5.2)	25.1 (11.9)
20	6.2 (5.8)	31.5 (14.4)	7.8 (6.5)	4.2 (4.0)	4.8 (4.2)	7.3 (5.3)	7.3 (6.7)	10.1 (7.5)	20.8 (10.1)

Notes: The model is estimated with 2 lags. The numbers in parentheses are the standard errors of the variance decompositions at 95% level of significance. * indicates the estimate is significant at 95% level. The standard errors are generated from 10,000 draws by Monte Carlo Integration following Sims and Zha (1994). This is a Bayesian method which employs a Gaussian approximation of the posterior of A_0.

Table 3: Contemporaneous Coefficients in Alternative Models for the US

	Exogeneity Model		Benchmark	
	Coefficient	**Std. error**	**Coefficient**	**Std. error**
A17	0.002	0.019	0.007	0.011
A21	-7.518	7.133	-4.584	8.781
A23	2.006	4.749	4.394	6.295
A24	9.715	13.474	3.735	15.586
A29	-0.436	4.571	1.132	4.394
A31	-0.297	0.319	-0.170	0.319
A32	0.004	0.009	0.004	0.006
A34	0.950	0.582	0.629	0.565
A41	0.111	0.053	-0.114	0.066
A61	2.064	3.016	6.279	3.584
A62	-0.085	0.049	-0.079	0.049
A63	-1.218	1.141	-1.794	1.501
A69	2.211	2.174	1.462	2.017
A71	0.340	2.153	1.380	3.171
A74	1.301	2.185	5.163	2.702
A81	-0.230	2.829	-3.396	4.055
A82	-0.026	0.041	-0.035	0.049
A83	0.633	1.089	0.006	1.412
A84	-3.568	5.052	-11.574	7.267
A85	0.442	0.143	0.442	0.143
A86	0.638	0.115	0.641	0.112
A87	0.303	0.241	0.160	0.264
A89	0.085	1.719	0.012	1.756
A91	-0.593	0.354	-0.472	0.596
A92	-0.004	0.009	-0.001	0.011
A93	0.283	0.126	0.218	0.197
A94	-0.380	0.656	0.619	0.999
A95	-0.023	0.023	-0.009	0.024
A96	-0.018	0.032	-0.004	0.036
A97	0.003	0.030	-0.007	0.034
A98	0.001	0.025	0.000	0.025

Note: The model is estimated with two lags.

Table 4: Variance Decomposition – A Comparison between the Benchmark Model and the Exogeneity Model for the US

The percentage of the k-step ahead forecast error variance of the nominal exchange rates explained by the shock of									
k	ε^{yd}	ε^{rd}	ε^{md}	ε^{pd}	ε^{di}	ε^{po}	ε^{tb}	ε^{oc}	ε^{er}
Benchmark Model									
1	1.6 (1.8)	7.8 (7.6)	2.3 (2.3)	1.3 (1.4)	2.0 (2.1)	12.2 (11.7)	1.3 (1.3)	5.7 (5.4)	65.9 (14.8)
4	2.1 (2.1)	17.7 (12.4)	4.4 (4.4)	3.3 (3.0)	3.7 (3.7)	10.4 (10.8)	3.1 (2.8)	6.6 (6.4)	48.6 (16.0)
8	3.6 (3.2)	28.9 (15.5)	7.2 (6.1)	3.4 (3.3)	5.0 (4.9)	7.8 (7.6)	4.4 (4.0)	5.8 (4.9)	33.9 (14.6)
12	4.7 (4.4)	33.6 (15.1)	8.2 (6.8)	3.7 (3.6)	4.8 (4.3)	7.0 (5.5)	5.6 (5.1)	7.2 (5.2)	25.1 (11.9)
20	6.2 (5.8)	31.5 (14.4)	7.8 (6.5)	4.2 (4.0)	4.8 (4.2)	7.3 (5.3)	7.3 (6.7)	10.1 (7.5)	20.8 (10.1)
Exogeneity Model									
1	2.9 (2.6)	7.0 (7.7)	6.6 (5.2)	1.5 (1.7)	3.6 (3.0)	13.3 (10.9)	0.8 (0.9)	5.5 (5.7)	58.7 (13.5)
4	7.8 (6.2)	12.9 (11.0)	7.0 (5.7)	1.3 (1.3)	7.3 (5.5)	14.0 (10.5)	3.3 (3.2)	5.5 (5.3)	41.0 (14.6)
8	9.7 (8.4)	16.1 (12.3)	7.2 (6.4)	1.3 (1.4)	10.9 (8.4)	11.2 (9.1)	7.1 (6.5)	5.2 (4.8)	31.3 (13.5)
12	12.2 (9.6)	16.1 (11.9)	6.8 (5.5)	1.6 (1.5)	11.6 (8.6)	9.7 (7.9)	11.5 (9.0)	5.0 (4.4)	25.4 (11.9)
20	15.5 (11.5)	14.0 (10.3)	6.6 (5.0)	1.8 (1.6)	11.2 (8.4)	9.0 (6.7)	15.6 (11.2)	5.2 (4.4)	21.2 (10.9)

Notes: The model is estimated with two lags. The numbers in parentheses are the standard errors of the variance decompositions at 95% level of significance. * indicates the estimate coefficient is significant at 90% level or above. The standard errors are generated from 10,000 draws by Monte Carlo Integration following Sims and Zha (1994). This is a Bayesian method which employs a Gaussian approximation to the posterior of A_0.

Figure 1: Impulse Responses – Benchmark Model

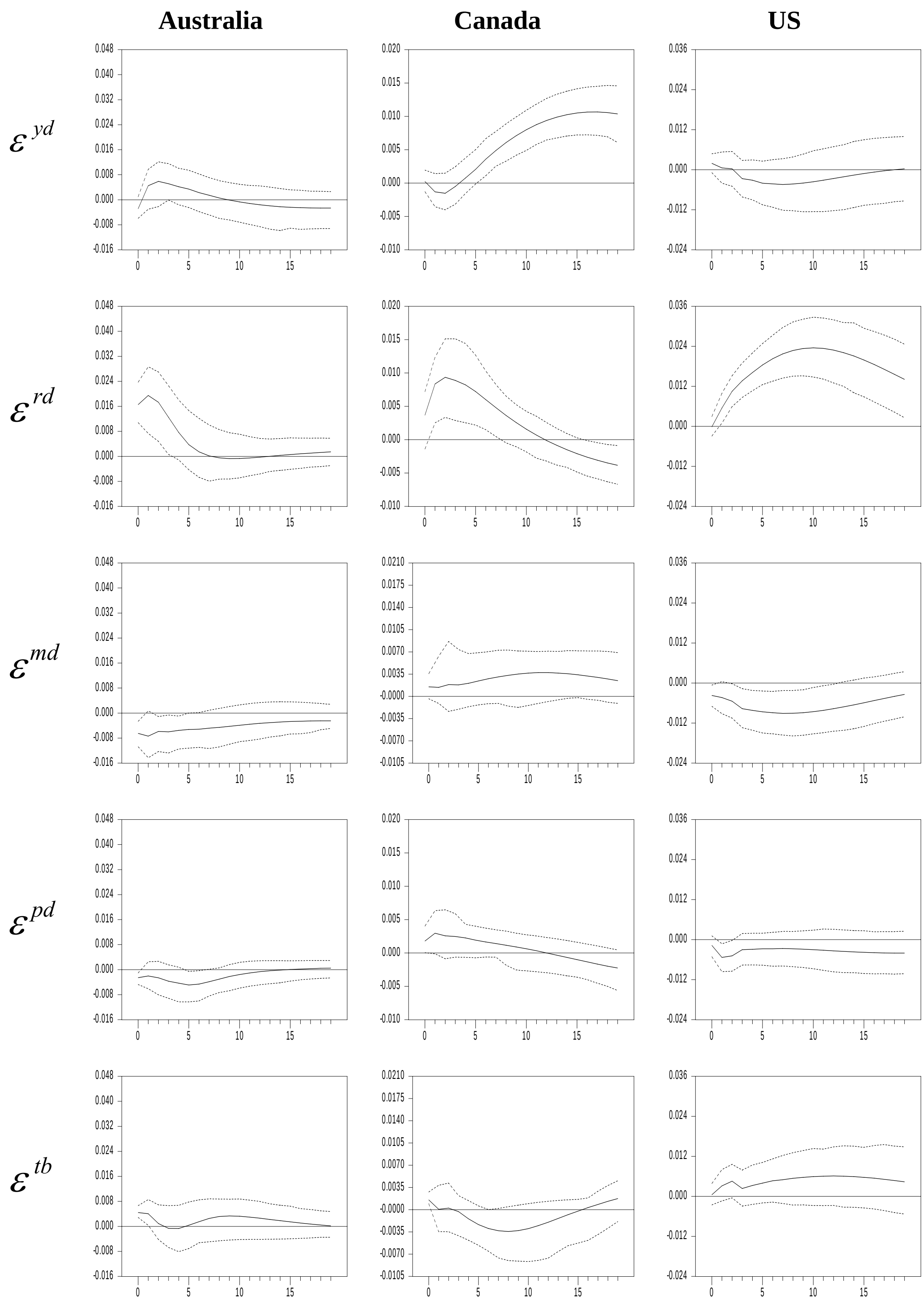
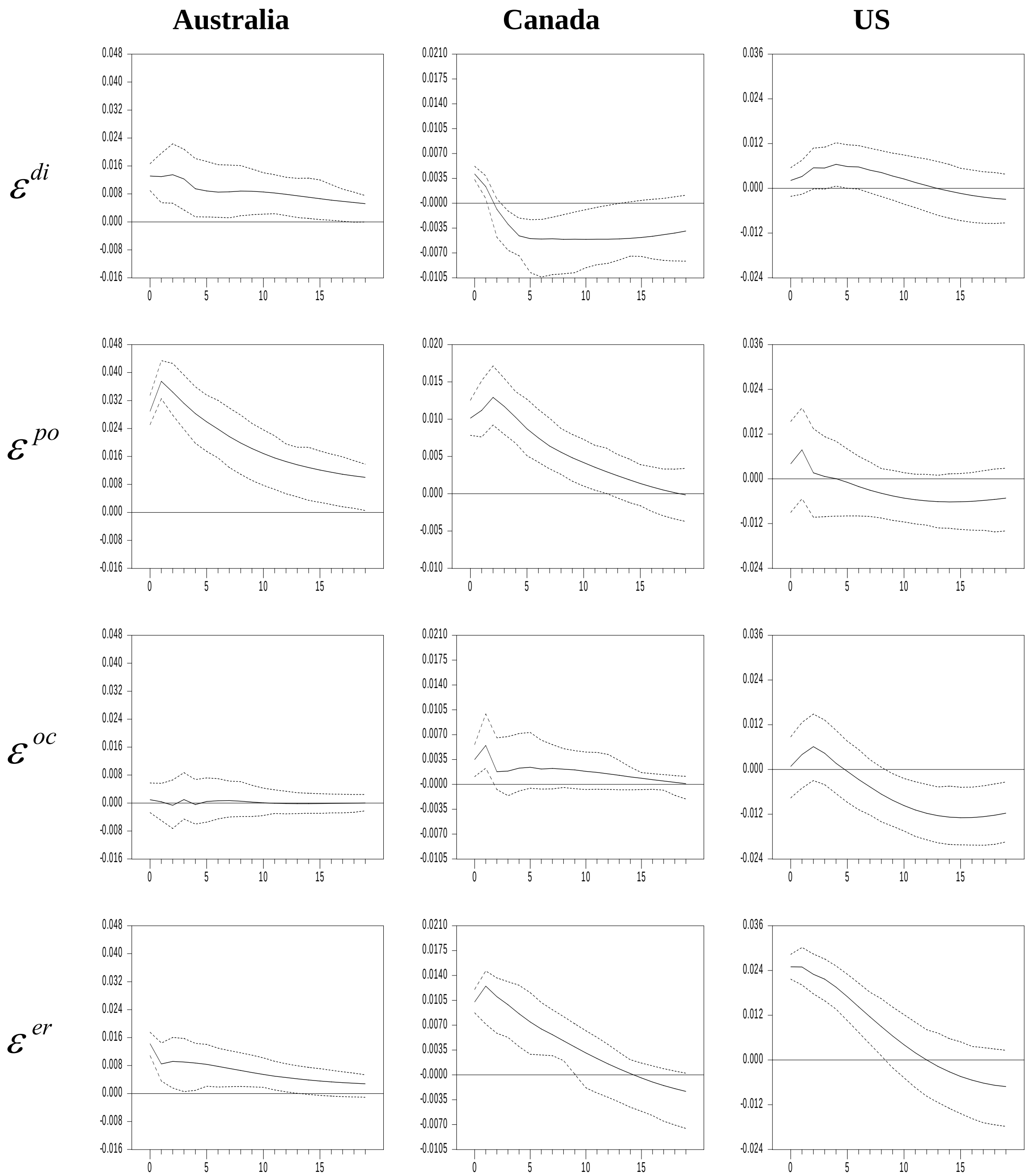
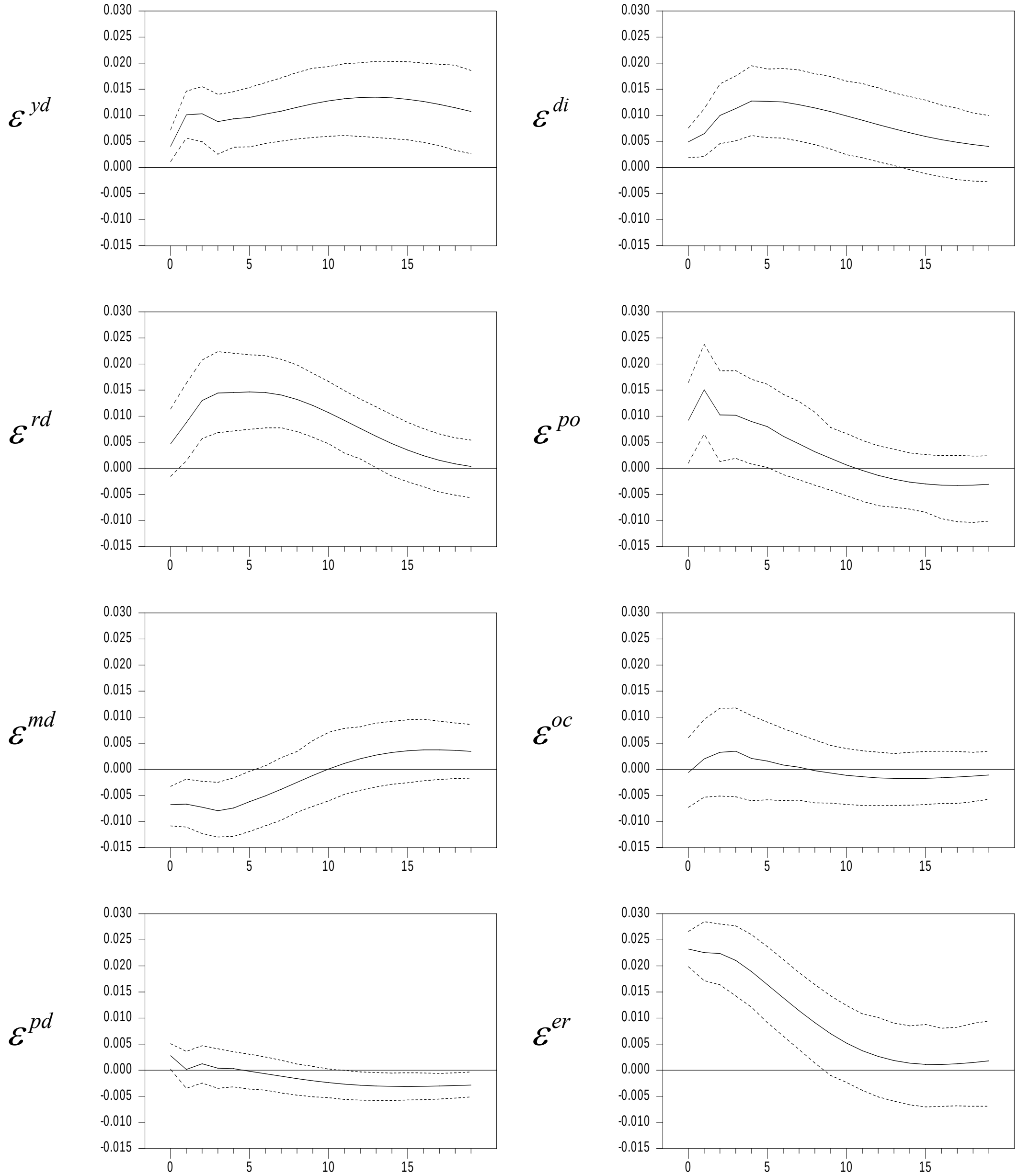


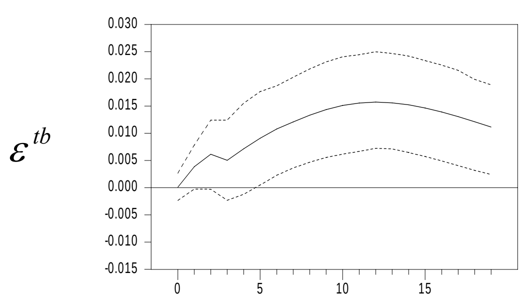
Figure 1 (continued)



Notes: The baseline model is estimated with two lags. Estimation is done by the Bayesian method using Monte Carlo Integration of 10,000 draws which employs the Gaussian approximation of the posterior of A_0. Error bands are the 16% and 84% fractiles.

Figure 2: Impulse Responses – US Exogeneity Model





Notes: This model assumes that Japan represents the rest of the world for the US economy. All relative variables are computed to be the difference between the US and the Japan macroeconomic indicators. The model is estimated with two lags.

Appendix

A1: Trade Weights

Australia		**Canada**		**US**	
Trade Partners	Weight	Trade Partners	Weight	Trade Partners	Weight
Japan	42%	US	85%	Canada	40%
US	32%	Japan	8%	Japan	33%
UK	9%	UK	3%	Germany	11%
New Zealand	9%	Germany	2%	UK	10%
Germany	8%	France	2%	France	6%

Notes: Only the five largest trading partners for each country are considered. In case when data for a large trading partner are not sufficient, that trading partner is replaced with the next largest trading partner. For example, for the years considered, China was the 5th largest trading partner for the US, but since data for China are not available, I replace China with France, which was the next largest in the list.

A2: Descriptions of Variables and Data

Variable	Description
yd	$yd = \log(y) - \sum_{i=1}^{5} \omega_i \log(y_i^*)$
rd	$rd = r - \sum_{i=1}^{5} \omega_i r_i^*$
md	$md = \log(m) - \sum_{i=1}^{5} \omega_i \log(m_i^*)$
pd	$pd = \log(p) - \sum_{i=1}^{5} \omega_i \log(p_i^*)$

Explanations:

- "*'s" refer to the trading partners, ω's are the trade weights. For trading partners and trade weights information, see Appendix I.
- For all countries, y, the real national income, is the real GDP volume (2000=100); m, the money demand, is M1 (or Money) index (2000=100); r, the nominal interest rate, is the three-month (or 13 weeks) treasury bill rate or other comparable short-term nominal interest rates, for Japan, the r used is discount rate; and p is the Consumer Price Index (2000=100).
- For New Zealand, y for 1980, 1981, 1982 is approximated from the annual (quarterly data not available) real GDP available from IMF IFS. For Germany and UK, m is interpolated based on the annual growth rate of money available from IMF IFS. For France, m beyond 1998 is interpolated based on the quarterly rate of money growth for the entire euro zone, data available from the website of the European Central Bank.
- All of y, m, r, and p are in levels. All original series are seasonally adjusted.

A2 (continued)

Variable	Description
di	Net direct investment inflow (+), expressed as a percentage of current year nominal GDP
po	Net portfolio investment inflow (+), expressed as a percentage of currency year nominal GDP
tb	Net balance of trade on goods and services (+: net export), expressed as a percentage of current year nominal GDP
oc	Net other inflows of capital (+), expressed as a percentage of currency year nominal GDP
Explanations: The original data for capital flows and trade balance for each country are in millions or billions of US dollars. The nominal GDP are in local currencies. The conversion of local-currency-denominated nominal GDP into US-dollar-denominated nominal GDP is based on the market exchange rate of each currency against the US dollar. All variables are in levels in estimation.	
er	Nominal effective exchange rate
Explanation: The nominal effective exchange rate for each country is constructed by the IMF in such a way that an increase in the index implies an appreciation of the currency.	
Source of data: 1. International Monetary Fund, International Financial Statistics 2. Website of European Central Bank: www.ecb.int 3. International Monetary Fund, Direction of Trade Statistics	