UNIVERSITÉ DU QUÉBEC À MONTRÉAL

# WHAT MOVES REAL EXCHANGE RATES? - DIFFERENCES BETWEEN INDUSTRIALIZED AND EMERGING COUNTRIES

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# RÉSUMÉ

Depuis la fin des accords de Bretton Woods, les taux de change réels ont affiché de grandes et persistantes fluctuations. Ces fluctuations se sont avérées difficiles à expliquer, tant de manière théorique qu'empirique. Ce mémoire utilise une approche d'autorégression structurelle de vecteurs pour (i) identifier les chocs fondamentaux qui expliquent la plus grande partie des fluctuations du taux de change réel; (ii) quantifier l'impact que ces chocs ont sur d'autres agrégats macroéconomiques prédominants; et (iii) documenter les différences de ces chocs pour les pays industrialisés et les pays émergents.

Nous analysons un échantillon de cinq pays: le Canada, le Mexique, l'Afrique du Sud, la Thaïlande et les États-Unis. Nos principaux résultats sont les suivants: (i) les fluctuations du taux de change sont menées par un seul choc majeur; (ii) ce choc ressemble le plus à un choc de demande; et (iii) le détachement du taux de change est plus fort dans les pays émergents que dans les pays industrialisés. En outre, notre analyse confirme que ni la parité du pouvoir d'achat, ni la parité du taux d'intérêt découvert ne tiennent.

## ABSTRACT

Since the end of the Bretton Woods agreement, real exchange rates have exhibited large and persistent fluctuations. Both theoretically and empirically, these fluctuations have proved hard to explain. This thesis uses a structural vector autoregression approach (i) to identify the fundamental shocks that explain the most of the fluctuations of the real exchange rate; (ii) to quantify the impact these shocks have on other prominent macroeconomic aggregates; and (iii) to document differences of these shocks for industrialized and emerging countries.

We analyze a panel of five countries: Canada, Mexico, South Africa, Thailand and the United States. Our main results are the following: (i) exchange rate fluctuations are primarily driven by one single shock; (ii) this shock resembles most a demand shock; and (iii) the exchange-rate disconnect is stronger in emerging than in industrialized countries. Furthermore, our analysis confirms that neither purchasing-power parity nor uncovered-interest-rate parity hold.

# INTRODUCTION

Exchange rate fluctuations are among the most studied phenomena in macroeconomics. Understanding their origins is important as they have an impact on economic stability, transnational investment, trade and exchange rate arrangements and monetary policy. Since the collapse of the Bretton Woods agreement, exchange rate volatility increased substantially (Mussa, 1986) and displays persistent deviations form standard theories as purchasing-power parity (Dornbusch, 1980) or uncovered-interest-rate parity (Campbell and Clarida, 1987). Furthermore, exchange rates do not share the common dynamics with core macroeconomic variables which is referred to as the exchange-rate-disconnect puzzle (Obstfeld and Rogoff, 2000).

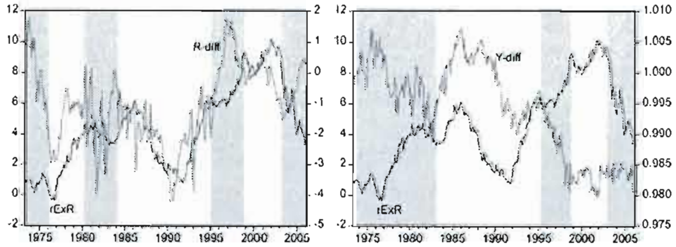


**Figure 0.1** Display of the Exchange Rate Disconnect

Figure 0.1 shows the log Canadian/U.S. real exchange rate (rExR) with three core macroeconomic variables: the log-differential (ratio) in price levels (P-diff), the differential of short-term interest rates (R-diff) and the log-differential of output (Y-diff). All variables are normalized to one. Our monthly data ranges from 1973m5 until 2006m2. The gray shades indicate periods when the disconnect is particularly visible.

This thesis attempts to identify sources and cross-country differences of real exchange rate volatility in the post-Bretton Woods era. Our three main objectives are to (i) determine the most influential economic shocks for the real exchange rate; to (ii) quantify the impact of these shocks on other macroeconomic variables; and to (iii) document the difference between industrialized and emerging countries.

Our methodological approach consists of a structural vector autoregression (SVAR) open macro model that contains six equations. We apply an econometric method which is based on the statistical identification procedure outlined by Uhlig (2003). Accordingly, we first determine the most influential –unlabeled– shocks and their impact on the forecast-error variance of the exchange rate. In a second step, we label these shocks according to the responses they provoke in our variables. The advantage of this sequence is that we are sure to find the shocks which drive the most of the real exchange rate. The challenge we face is to label the shocks correctly.

Earlier work on exchange rate volatility using SVARs applies theoretical identification procedures to first label shocks and determine their influence afterwards. The problem with this approach is that the choice of theoretical restrictions necessarily has an influence on the results; researchers identify the shocks by applying some information ordering and alter the restrictions until the impulse-response functions match with conventional wisdom. This problem is clearly pointed out in the literature (Cochrane, 1994; Uhlig, 2005) and we hope to avoid it by applying an atheoretical approach.

Our system of equations contains six variables in cross-country differentials: the real exchange rate, output, the interest-rate spread, the price level, the monetary-policy instrument and the stock-market index. We use monthly and quarterly data from Canada, Mexico, South Africa, Thailand and the USA for the data horizon 1973-2006.

Applying the statistical identification procedure, we generate the following results: (i) there is essentially one shock driving the real exchange rate to over 90% and its impact on the real exchange rate is strongest after a lag of three months; (ii) our impulse-response functions show that the effect of this shock on our SVAR resembles most a demand shock; (iii) the exchange-rate disconnect exists in all countries analyzed but appears to be greater in emerging countries; and (iv) neither purchasing-power parity nor uncovered-interest-rate parity hold.

The present work extends the existing SVAR literature on exchange rate fluctuations by proposing a new identification method and applying it to a new country panel. Earlier research was based on theoretical identification procedures and focused exclusively on industrialized countries. Our results support some earlier work and contradicts other. Clarida and Galí (1994) find evidence for demand shocks, Eichenbaum and Evans (1995) consider only monetary shocks and Gauthier and Tessier (2002) advocate supply shocks. Our work yields similar results to Clarida and Galí (1994) and we clearly rule out monetary and supply shocks.

The remainder of this thesis is structured as follows. Chapter 1 reviews the existing literature. Chapter 2 provides an overview of traditional econometric methods and explains different identification procedures. Chapter 3 presents our empirical specifications. Chapter 4 discusses results on the sources of the shocks and chapter 5 compares the difference to emerging countries. A conclusion completes this thesis.

# CHAPTER I

## LITERATURE REVIEW

Throughout the last three decades research on exchange rate volatility has been very active, resulting in a vast literature and five principal approaches (MacDonald, 1998). We follow the line of research applying structural vector autoregression models (SVARs) to untangle exogenous shocks from general equilibrium movements of macro variables. Advances in econometrics offer improved and promising tools to address particularly two key questions. Specifically, (i) what shocks cause fluctuations of exchange rates?; and (ii) can the data be reconciled with existing theories?
Three different sources are being advocated: Demand shocks (Clarida and Galí, 1994; Weber, 1997), monetary shocks (Eichenbaum and Evans, 1995; Faust and Rogers, 1999) and supply shocks (Alexius, 2000; Gauthier and Tessier, 2002). Here, we provide a short overview about the objectives, methods and results of these papers.

Clarida and Galí (1994) is the pioneer work in this line of research. They focus on nominal shocks to the exchange rate but take demand and supply shocks into consideration. Four industrialized countries are examined: Canada, Germany, Japan and the United Kingdom. The reference country is the USA. They use quarterly data for the horizon 1973q3 until 1992q1 to build a SVAR containing three variables in first-differences: the real exchange rate, the differential of price levels and the differential of output. The identification procedure to impose long-run restrictions follows Blanchard and Quah (1989): A monetary shock has no long-run effect on output nor the real exchange rate and a demand shock has no long-run effect on output. For the German and Japanese case, about 50% and 35% of forecast-error variance of the real exchange rate in the short-run (<one year) are caused by monetary shocks. For Canada and the United Kingdom monetary shocks seem to have no importance, as they explain less than 1% and 1,3% respectively. A second finding is that the time horizon may be an important factor: The German data reveals that in the late 1970s more than 50% of real exchange rate fluctuations were due to monetary shocks, whereas in the early 1980s the majority is due to demand shocks. They also find that the expected sum of future interest differentials does not explain much to real exchange rate fluctuations, meaning that uncovered-interest-rate parity (UIP) fails. Their main conclusion is: Demand shocks are the predominant factor behind real exchange rate volatility; over 90% for the Canadian case. Monetary shocks are important in some countries only. Supply shocks do not have a significant impact.

Weber (1997) refines Clarida and Galí's work. The main improvement is the splitting of supply shocks into labor supply shocks and productivity shocks and of monetary shocks into money demand and money supply shocks. This offers the ability to quantify the responses of the VAR variables to five instead of only three different shocks. Five variables are used to build a SVAR: the real exchange rate, the differential of output, the differential of real money, the differential of price levels and the differential of employment. The data set is extended to the sample 1972m8 until 1994m12 and the analysis is limited to three countries: Germany, Japan and the USA. There is no fixed reference country as rotating the countries results in three combinations: USA/GER, USA/JAP and GER/JAP. Long-run restrictions to identify the SVAR are chosen from Blanchard and Quah (1989) and Shapiro and Watson (1989): demand shocks, monetary demand shocks and money supply shocks have no effect on neither output nor employment. Both monetary shocks have no effect on the real exchange rate and monetary supply shocks have no impact on real money balances. Supply shocks have no impact on employment. The findings are that most of forecast-error variance of the real exchange rate (in short-run) can be attributed to demand shocks (60%-85%), much less to monetary shocks (10%-20%) and virtually none to supply shocks. This confirms the conclusion of

Clarida and Galí (1994). Interestingly, about 35% of the real exchange rate fluctuations in Japan in the long-run seem to be due to labor supply shocks.

Eichenbaum and Evans (1995) contribute the second fundamental work. They only address the question of how important monetary shocks are for real exchange rate fluctuations. Their analysis is based on the following five industrialized countries: France, Germany, Italy, Japan and the United Kingdom. The USA serves as the reference country. They use monthly data for the sample horizon 1974m1 until 1990m5 to construct a seven-variable SVAR. The variables are the real exchange rate, the U.S. output, the foreign output, the U.S. short-term interest rate, the foreign short-term interest rate, the U.S. price level and a U.S. monetary policy measurement.[1] The monetary policy measurement captures the nominal shock. It rotates, taking the form of three different sources: the log-differential of non-borrowed reserves over total reserves (NBRX), the Federal Funds Rate (FFR) and dummy variables capturing Federal Open Market Committee (FOMC) meetings that lead to large monetary interventions. [2] The identification procedure applied follows Christiano and Eichenbaum (1992) which isolates measures of exogenous shocks to monetary policy: they impose that a monetary shock has a contemporaneous impact only on the U.S. short-term interest rate and the real exchange rate but on other variable in their SVAR. The main results are that a contractionary monetary shock leads to persistent and significant appreciations of the real exchange rate. Monetary policy shocks explain between 10% and 40% of the forecast-error variance of the real exchange rate, depending on the policy instrument and the country analyzed. The impacts of the shocks are maximal after approximately three years. Furthermore, they find that UIP is violated for several periods after the shock.

Faust and Rogers (1999) extend Eichenbaum and Evans's work to a 14-variable

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[1] They use the real- as well as the nominal exchange rate, but show that this choice does not have a significant impact on the results. Their analysis is done with the real exchange rate.

[2] The FOMC measurement refers to observations inicially made by Friedman and Schwartz (1971) which were carried on by Romer and Romer (1990).

SVAR. Their SVAR consists of the real exchange rate, U.S. and foreign output, U.S. and foreign prices, commodity prices, U.S. and foreign money supplies, U.S. non-borrowed reserves, U.S. total reserves, U.S. and foreign short and long-term interest rates. They use the same setting as Eichenbaum and Evans, thus regarding only a monetary shock over the sample horizon 1974m1 until 1990m5, but limit themselves to the cases of Germany and the United Kingdom. Their method differs mainly in the restrictions as they argue that the proposed restrictions by Eichenbaum and Evans are not very creditable and instead follow Faust (1998) to employ sign restrictions: an appreciation of the real exchange rate goes along with an increase in interest rates and with a decrease in all other variables considered. According to their findings, the U.S. monetary shock accounts for less of the real exchange rate fluctuation in the 14-variable SVAR (2%-30%) than in the replicated seven-variable SVAR (8%-56%). A conclusion they draw from this is that the smaller model might omit important variables. Furthermore, they are able to reproduce the large deviations from UIP already found by Eichenbaum and Evans.

Alexius (2000) advocates supply shocks being the main driving force after studying four industrialized countries: Germany, Japan, United Kingdom and the USA. There is no fixed reference country but rotation results in six country combinations: USA/GER, USA/JAP, GER/JAP, UK/JAP, UK/GER and UK/USA. Alexius builds a four-variable SVAR with the nominal exchange rate, the differential of output, the differential of government consumption as a share of output and the differential of price levels. The data horizon is 1960q1 until 1998q4. Four shocks are being considered: monetary shocks, supply shocks, demand shocks and transitory shocks. They impose the following long-run restrictions: monetary shocks do not affect output nor government spending but exchange rates. Demand shocks do not affect output. Supply shocks do not affect government spending. The results reveal that in the short-run transitory shocks dominate (37%-76%), in the medium-run monetary shocks dominate (7%-40%) and in the long-run supply shocks dominate (6%-57%). Demand shocks never play a major role. Dependent on the model used, the researcher finds for five of six country combinations that about 60% until 90% of the long-run forecast-error variance are due to supply shocks.

Gauthier and Tessier (2002) propose work towards the supply-shock theory, too. They concentrate on the Canadian economy for the sample range 1961q1 until 1990q4 to construct a structural Vector Error Correction Model (SVECM) with six variables: the real exchange rate, real commodity prices, the differential of output per capita, the differential of government spending to output and the differential of interest rates. Their analysis considers four different shocks: monetary, demand, supply and transitory. They use the King-Plosser-Stock-Watson (1991) identification procedure which imposes long-run restrictions: output shocks and (government spending) demand shocks do not affect commodity prices. Only commodity price shocks and supply shocks have an impact on output. The main finding is that supply shocks are the dominant factor for real exchange rate volatility at all horizons; particularly in the long-run (>five years), when they account for over 60% of the forecast-error variance of the real exchange rate. In the short-run (one year) they explain 39% and in the medium-run (two to five years) still 34% on average. In contrast, monetary shocks contribute 27% in the short-run, 26% in the medium-run and zero percent in the long-run. Even demand shocks add more to real exchange rate volatility: 14% in short-run, 25% in medium-run and 39% in the long-run.

Without putting these papers in more direct competition, we would like to reconsider some facts. First, the SVAR approach has been proven useful but the identification procedure is a critical choice as results often depend on ad-hoc restrictions. Second, different results do as well stem from the country choice and the time horizon considered.

# CHAPTER II

# METHODOLOGY

The approach used by the papers cited above consists of building a VAR, applying some theoretical identification procedure and sorting out the effect of one or several shocks. Our objective is different. As there is reason to think that the restrictions which stem from theoretical identification procedures have a strong impact on the results, we avoid imposing such restrictions. We identify the shocks statistically and then try to interpret and label the shocks according to their impact on our SVAR. The advantage is that we are sure to find the most important shocks on the real exchange rate. The disadvantage of this approach is that labeling the shocks may be more difficult.

## 2.1 Standard VAR Theory

As stated above, SVARs have proven useful in the context of analyzing exogenous shocks within a system of simultaneously determined variables. In comparison to macroeconometric micro-founded models, SVARs make few assumptions about the underlying structure of the economy and focus on deriving a good statistical representation of the interactions between the variables. The assumption they make though is that macroeconomic dynamics in reality are well represented by a VAR; moreover by definition, the shocks are uncorrelated. They are particularly useful for two objectives: to forecast values of variables and to examine the different responses of variables to common economic shocks.

Technically, SVARs are dynamic systems of equations that describe the relations between interrelated variables and structural uncorrelated exogenous shocks. They have the following structure: the current value of each variable in the system depends on its own and on all other variables in the system; each variable is expressed by one equation which explains the endogenous variable as a linear combination of an intercept (constant), its own lagged (autoregressed) values, actual and lagged values of the other variables and an error term (innovation).

To illustrate, consider the following dynamic system of equations representing a simple bivariate SVAR with one lag:

$$x_t = c^x + \alpha_1^{xx} x_{t-1} + \alpha_0^{yx} y_t + \alpha_1^{yx} y_{t-1} + \varepsilon_t^x$$

$$y_t = c^y + \alpha_1^{yy} y_{t-1} + \alpha_0^{xy} x_t + \alpha_1^{xy} x_{t-1} + \varepsilon_t^y$$

where $x$ and $y$ are interrelated variables, the $c$'s are intercepts, the $\alpha$'s are slope coefficients and the $\varepsilon$'s are structural shocks that are supposed to bc uncorrelated with each other and over time, i.e. $E[\varepsilon_t^x \varepsilon_t^y] = 0 \ \forall$t.

The structural economic exogenous shock is the unexplained movement in the variable. The influence of a shock is expressed by the change in the forecast-error variance of the variables in the periods following the shock. Hence, the researcher determines the effect on the variance of each variable in the SVAR. In the favorable case a substantial fraction of the forecast-error variance is explained. This is the principal criterion to measure the relevance of the employed approach and the candidate variables chosen.

The problem with simultaneously determined variables –and hence with SVARs– is that the direction of causation is not clear: variable $x$ determines $y$ and in the same period $y$ determines $x$. Consequently, one cannot estimate the system without making further assumptions. To show how to proceed, consider the bivariate SVAR again, this time stated in matrix form:

$$\begin{bmatrix} 1 & -\alpha_0^{xy} \\ -\alpha_0^{yx} & 1 \end{bmatrix} \begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} c^x \\ c^y \end{bmatrix} + \begin{bmatrix} \alpha_1^{xx} & \alpha_1^{xy} \\ \alpha_1^{yx} & \alpha_1^{yy} \end{bmatrix} \begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t^x \\ \varepsilon_t^y \end{bmatrix} \tag{2.1}$$

Redefining the vector of variables $\begin{bmatrix} x_t \\ y_t \end{bmatrix}$ as $\Phi_t$ and the $\alpha$-matrices as $A_0$ and $A_1$ yields the following, compact form:

$$A_0\Phi_t = c + A_1\Phi_{t-1} + \varepsilon_t. \tag{2.2}$$

For ease of notation we drop the constants at this stage.[1]

The problem lies in the presence of the contemporary variables, captured by the $A_0$-matrix. To show how to determine the contemporary values, we further transform the equation.

$$\Phi_t = A_0^{-1}A_1\Phi_{t-1} + A_0^{-1}\varepsilon_t.$$

We redefine the product of the matrices $A_0^{-1}A_1 \equiv B_1$.

$$\Phi_t = B_1\Phi_{t-1} + A_0^{-1}\varepsilon_t.$$

The lagged values are condensed by the lag-operator: $B_1\Phi_{t-1} \equiv B_1L\Phi_t$.

$$\Phi_t = B_1L\Phi_t + A_0^{-1}\varepsilon_t.$$

$$[I - B_1L]\Phi_t = A_0^{-1}\varepsilon_t.$$

The hypothesis that the VAR is stationary allows inversion.[2]

$$\Phi_t = [I - B_1L]^{-1}A_0^{-1}\varepsilon_t.$$

[1] Our Matlab program takes them into account though.

[2] This means that its values fluctuate around a (natural) fixed value which is theoretically expressed by a long-run general equilibrium (steady state). We make this hypothesis in accordance with the common economic literature.

Redefinition of $[I - B_1 L]^{-1} \equiv C(L)$ eventually yields the (structural) vector moving average representation of a SVAR:

$$\begin{aligned} \Phi_t &= C(L)A_0^{-1}\varepsilon_t && (2.3) \\ &= R(L)\varepsilon_t. && (2.4) \end{aligned}$$

Written in matrix form:

$$\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} C(L)_{11} & C(L)_{12} \\ C(L)_{21} & C(L)_{22} \end{bmatrix} \begin{bmatrix} A_{0;11} & A_{0;12} \\ A_{0;21} & A_{0;22} \end{bmatrix}^{-1} \begin{bmatrix} \varepsilon_t^{shock1} \\ \varepsilon_t^{shock2} \end{bmatrix} \quad (2.5)$$

$$= \begin{bmatrix} R(L)_{11} & R(L)_{12} \\ R(L)_{21} & R(L)_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{shock1} \\ \varepsilon_t^{shock2} \end{bmatrix}. \quad (2.6)$$

At this stage, one can obtain the residuals $u_t$ and thus the variance-covariance matrix of the residuals $V$ by estimating the reduced-form VAR with the ordinary-least-squares (OLS) method. The $R$-matrix is to be determined but as it is the result of the product containing $A_0^{-1}$ it still depends on contemporary (unknown) values and the calculus of $A_0$ is not evident. Consider the relation between the residuals $u_t$ and $A_0$ which is a linear combination of unknown structural shocks $\varepsilon_t$:

$$u_t \equiv A_0^{-1}\varepsilon_t. \quad (2.7)$$

Multiplying each side with $u_t'$ yields

$$E[u_t u_t'] = E[A_0^{-1}\varepsilon_t\varepsilon_t' A_0^{-1\prime}]$$

or equivalently

$$V = A_0^{-1}\Sigma A_0^{-1\prime} \quad (2.8)$$

where $V$ is the variance-covariance matrix of the residuals $u_t$ and $\Sigma$ is the variance-covariance matrix of the structural shocks $\varepsilon_t$. Assuming that the variance-covariance matrix of the structural shocks is normalized to one ($\Sigma = I$) yields

$$V = A_0^{-1}A_0^{-1\prime}.$$

The $A_0$-matrix contains $n^2$ unknown, non-identical elements. Due to symmetry, the $V$-matrix has $\frac{n(n+1)}{2}$ known, non-identical elements. That means we have to impose $\frac{n(n-1)}{2}$ restrictions on $A_0$ to solve equation 2.8.

## 2.2 Theoretical Identification Procedures

The specific sets of restrictions to identify the link between the shock and the residual are called identification procedures. There are two classes of identification procedures which distinguish themselves by the time horizon on which they are imposed.

### 2.2.1 Short-Run-Restrictions

Identification procedures involving short-run restrictions capture the idea that a shock $j$ may not have an effect on a specific variable $x$ at the time the shock occurs. The variable $x$ is not directly affected by the shock $j$ but it might be affected with a lag. To see how short-run restrictions are imposed consider equation 2.5 again. As short-run restrictions influence contemporary values, we impose them on the $A_0$-matrix. As shown above, with $E[\varepsilon_t \varepsilon_t'] = \Sigma = I$ we get $V = A_0^{-1} A_0^{-1\prime}$ which provides $\frac{n(n+1)}{2}$ known elements of the $A_0$-matrix.[3] To completely identify $A_0$, we have to impose $\frac{n(n-1)}{2}$ more restrictions on the elements of the $A_0$-matrix.[4] These (imposed) restrictions are motivated by conventional wisdom which states a relation between a shock and a variable. For example, if the variable $x$ is not affected by shock 2 in the short-run the researcher imposes $A_{0;12} = 0$.

Example: Eichenbaum and Evans (1995) use the Christiano and Eichenbaum (1992) identification procedure to impose short-run restrictions. As presented in the literature review, their SVAR contains seven variables, only one labeled shock and can be written in the following form:

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[3] For this bivariate case, this formula yields three known elements of $A_0$.

[4] For the SVAR exposed, the formula indicates that only one more restriction is needed.

$$\begin{bmatrix} US-Y_t \\ US-P_t \\ foreign-Y_t \\ foreign-R_t \\ US-MPI_t \\ US-R_t \\ rExR_t \end{bmatrix} = \begin{bmatrix} C(L)_{11} & \ldots & C(L)_{17} \\ C(L)_{21} & \ldots & C(L)_{27} \\ C(L)_{31} & \ldots & C(L)_{37} \\ C(L)_{41} & \ldots & C(L)_{47} \\ C(L)_{51} & \ldots & C(L)_{57} \\ C(L)_{61} & \ldots & C(L)_{67} \\ C(L)_{71} & \ldots & C(L)_{77} \end{bmatrix}_{7\times 7} \begin{bmatrix} A_{0;11} & \ldots & A_{0;17} \\ A_{0;21} & \ldots & A_{0;27} \\ A_{0;31} & \ldots & A_{0;37} \\ A_{0;41} & \ldots & A_{0;47} \\ A_{0;51} & \ldots & A_{0;57} \\ A_{0;61} & \ldots & A_{0;67} \\ A_{0;71} & \ldots & A_{0;77} \end{bmatrix}_{7\times 7} \begin{bmatrix} \varepsilon_t^{Shock1} \\ \varepsilon_t^{Shock2} \\ \varepsilon_t^{Shock3} \\ \varepsilon_t^{Shock4} \\ \varepsilon_t^{MonetaryShock} \\ \varepsilon_t^{Shock6} \\ \varepsilon_t^{Shock7} \end{bmatrix}$$

They impose 20 restrictions which depend heavily on the ordering of variables, particularly on the position of the U.S. monetary-policy instrument and the monetary shock. Specifically:

(1) Shock 2 has no short-run effect on U.S. output ($A_{0;12} = 0$).

(2-3) Shock 3 has no short-run effect on U.S. output ($A_{0;13} = 0$) and the U.S. price level ($A_{0;23} = 0$).

(4-6) Shock 4 has no short-run effect on U.S. output ($A_{0;14} = 0$), the U.S. price level ($A_{0;24} = 0$) and foreign output ($A_{0;34} = 0$).

(7-10) The monetary shock has no short-run effect on U.S. output ($A_{0;15} = 0$), the U.S. price level ($A_{0;25} = 0$), foreign output ($A_{0;35} = 0$) and the U.S. interest rate ($A_{0;45} = 0$).

(11-15) Shock 6 has no short-run effect on U.S. output ($A_{0;16} = 0$), the U.S. price level ($A_{0;26} = 0$), foreign output ($A_{0;36} = 0$), the U.S. interest rate ($A_{0;46} = 0$) and the U.S. monetary-policy instrument ($A_{0;56} = 0$).

(16-20) Shock 7 has no short-run effect on U.S. output ($A_{0;17} = 0$), the U.S. price level ($A_{0;27} = 0$), foreign output ($A_{0;37} = 0$), the U.S. interest rate ($A_{0;47} = 0$) and the U.S. monetary-policy instrument ($A_{0;57} = 0$).

For a graphical display see the right part of figure 4.6 showing the impulse-response functions.

### 2.2.2 Long-Run Restrictions

An identification procedure imposing long-run restriction is based on the idea that a shock $j$ may have an effect on variable $x$ at the time of the shock and thereafter, but does not have a permanent impact. Otherwise said: a variable $x$ is directly affected by the shock $j$ and immediately changes its value but returns to its initial (natural) value in the long-run. An example is the case that a monetary shock has no effect on output growth in the long-run ("money is neutral"). This means that the researcher does not restrict the $A_0$-matrix –as $A_0$ captures the contemporary values– but the $R$-matrix. The lag polynomial $R(L)$ can be written as $R(L) = \sum_{h=0}^{\infty} R_h L^h$. Long-run restrictions are imposed on sum of the elements of the $R$-matrix which is $R(1) = \sum_{h=0}^{\infty} R_h$.

Example: Clarida and Galí (1994) use the Blanchard and Quah (1989) identification procedure involving long-run restrictions. As presented in the literature review, their SVAR contains three variables and can be written in the following form:

$$\begin{bmatrix} Y-diff_t \\ rExR_t \\ P-diff_t \end{bmatrix} = \begin{bmatrix} R(L)_{11} & R(L)_{12} & R(L)_{13} \\ R(L)_{21} & R(L)_{22} & R(L)_{23} \\ R(L)_{31} & R(L)_{32} & R(L)_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{SupplyShock} \\ \varepsilon_t^{DemandShock} \\ \varepsilon_t^{MonetaryShock} \end{bmatrix}$$

The three restrictions they impose are:

(1) Demand shocks have no long-run effect on the output differential: $R(1)_{12} = 0$

(2) Monetary shocks have no long-run effect on the output differential: $R(1)_{13} = 0$

(3) Monetary shocks have no long-run effect on the rExR: $R(1)_{23} = 0$

Consequently, the upper triangle of the $R$-matrix is zero and as a result, the effects of shocks on the concerned variables will fade out. For a graphical display see figure 4.4 showing the impulse-response functions.

We resume that many theoretical identification procedures –employing short and long-run restrictions– have been developed to determine the remaining elements.[5] Un-

[5]Cf.: Sims (1980), Blanchard and Quah (1989), King, Plosser, Stock and Watson (1991), Chris-

fortunately, restrictions are often based on economically implausible assumptions as Cooley and LeRoy (1985) point out or depend on some (abitrary) ordering of the variables (Uhlig, 2005). As a result, researchers strive to impose widely accepted restrictions. Nevertheless, as stated in the literature review, the results seem to depend heavily on the restrictions imposed.

## 2.3 A Statistical Identification Procedure

In this thesis, we employ a statistical identification procedure which is developed by Uhlig (2003), who calls it an agnostic approach. We will refer to it as the Uhlig method. The main idea is to seek shocks that maximize the forecast-error variance of the real exchange rate; we therefore decompose the variance. Once the shocks are determined, we analyze their impact on our SVAR in order to gain information about the origin of the shocks. This step is based on impulse-response functions. Here an outline how it works mathematically. We present the two main steps of this approach.

### Disaggregate the Shocks to the System

Our objective is to dismantle the shocks captured by the variance-covariance matrix. To establish a link between the source of the shock and the forecast-error variance, we have to determine the structural shocks $\varepsilon_t$ behind the residuals $u_t$. As mentioned before by equation 2.7, the residuals $u_t$ can be built by the $A_0$-matrix and the structural shocks $\varepsilon_t$ as

$$u_t = A_0^{-1}\varepsilon_t$$

where the $A_0$-matrix has the property $A_0^{-1}A_0^{-1\prime} = V$ with $V$ representing the variance-covariance matrix of the residuals $u_t$. The relation between the residual and the shock is established by the $A_0$-matrix which transmits the shocks.

Given that we are only interested in the shocks that lead to the greatest fluc-

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tiano and Eichenbaum (1992), Galí (1992), Bernanke and Mihov (1995), Sims and Zha (1996), Christiano, Eichenbaum and Evans (1998) tuations of the forecast-error variance, we can limit our search to a submatrix of $A_0 = [A_j \mid A_h]$. We concentrate on the submatrix $A_j$ which is called the impulse matrix. With this specification, our problem consists of solving

$$u_{jt} = A_j^{-1}\varepsilon_{jt}.$$

Before moving on, we facilitate the calculus by the Cholesky decomposition (factorization).[6] We decompose the $A_0$-matrix so that $A_0 = \tilde{A}_0 Q$ where $Q$ is the orthogonal matrix to $\tilde{A}$ with the property $QQ' = I$. $\tilde{A}_0$ is a matrix of $A_0$ with the property $\tilde{A}_0^{-1}\tilde{A}_0^{-1\prime} = V$. Relating this to the previous paragraph yields $A_j^{-1} = \tilde{A}_j^{-1}Q_j$. Accordingly, we get

$$u_{jt} = \tilde{A}_j^{-1}Q_j\varepsilon_{jt}.$$

The SVAR representation given by equation 2.3

$$\Phi_t = C(L)A_0^{-1}\varepsilon_t$$

in combination with equation 2.7 can be written as

$$\Phi_t = C(L)u_t.$$

With $u_t = \tilde{A}_0^{-1}\widetilde{\varepsilon}_t$ we receive

$$\Phi_t = C(L)\tilde{A}_0^{-1}\widetilde{\varepsilon}_t$$

and introducing the impulse-response functions[7] $\tilde{R}(L) = C(L)\tilde{A}_0^{-1}$ yields

$$\Phi_t = \tilde{R}(L)\widetilde{\varepsilon}_t.$$

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[6]The Cholesky decomposition of $V$ yields a matrix $\tilde{A}$ which has three useful properties: (i) the lower triangle of $\tilde{A}$ is zero; (ii) $\tilde{A}\tilde{A}'=V$; and (iii) $A=\tilde{A}Q$. Cf. Hamilton (1994), pages 91, 147 or Greene (2003), page 832

[7]Cf. section 2.4 in this thesis, Wickens and Motto (2001) or Hamilton (1994), page 318

With $R(L) = \tilde{R}(L)Q$, we can calculate the variance-covariance matrix of the (forecast) prediction error.[8] The k-period-ahead (forecast) prediction error $u_{t+k}$ of $\Phi_{t+k}$ is given by

$$u_{t+k} = \sum_{l=0}^{k} R_l \varepsilon_{t+k-l} = \sum_{l=0}^{k} \tilde{R}_l Q \varepsilon_{t-k-l}. \tag{2.9}$$

The variance-covariance matrix of the prediction error is

$$\Sigma(k) = u_{t+k}u'_{t+k} = \sum_{l=0}^{k} \tilde{R}_l Q \varepsilon_{t+k-l}\varepsilon'_{t+k-l} Q' \tilde{R}'_l = \sum_{l=0}^{k} \tilde{R}_l \tilde{R}'_l \tag{2.10}$$

and can be divided into $m$ pairs

$$\Sigma(k) = \sum_{j=1}^{m} \Sigma(k,j) = \sum_{j=1}^{m}\sum_{l=0}^{k} (\tilde{R}_l q_j)(\tilde{R}_l q_j)' \tag{2.11}$$

which provides us the $j^{th}$ shock corresponding to the $j^{th}$ prediction error $u_{t+j}$, giving the variance-covariance matrix of the prediction error $\Sigma(k) = u_{t+j}u'_{t+j}$.[9]

### The Most Influential Shocks

After having elaborated the link between the source of a shock $u_j$ and its impact on the variance-covariance matrix $\Sigma(k)$ of the prediction error $u_{t+k}$ we strive to find the shocks which exert the strongest influence on the VAR. This consists of finding the impulse matrix $A_j$, transmitting the shocks of the shocks $u_j$ which explain most of the variation of the variance-covariance matrix.

First of all, we limit our prediction horizon to $k = [\underline{\mathrm{k}}, \bar{\mathrm{k}}]$. These upper and lower bounds indicate the number of periods considered. The impulse matrix which explains most of the fluctuations of the variance-covariance matrix maximizes

$$\sigma^2(\underline{\mathrm{k}}, \bar{\mathrm{k}}) = \sum_{k=\underline{\mathrm{k}}}^{\bar{\mathrm{k}}} \Sigma(k)_{jj}$$

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[8] Cf. section 2.4 in this thesis or Greene (2003), page 111, 576

[9] Note that for $k = 0$: (i) the prediction error equals the residual $[u_{t+k} = u_t]$ and (ii) the variance-covariance matrix of the prediction error equals the variance-covariance matrix of the residual $[\Sigma(k) = V]$.

which can be reduced to the $j^{th}$ impulse matrix $A_j$:

$$\sigma_j^2(\underline{k}, \bar{k}; q_1) = \sum_{k=\underline{k}}^{\bar{k}} \sum_{l=0}^{k} trace[E_{jj}(\tilde{R}_l q_1)(\tilde{R}_l q_1)'] = q_1' S q_1$$

where $q_1$ is the an eigenvector of $S$ which is short for $S = \sum_{k=\underline{k}}^{\bar{k}} \sum_{l=0}^{k} \tilde{R}_l' E_{jj} \tilde{R}_l$.[10] $E$ stands for the expected value.

We solve the given optimization problem, subject to the constraint $q_1' q_1 = 1$, to maximize the variance of the $j^{th}$ impulse matrix executing the Lagrangian technique on the objective function:

$$Z(q_1, \theta) = q_1' S q_1 + \lambda(1 - q_1' q_1).$$

The first order condition we are interested in is $\frac{\partial Z}{\partial q_1} = 0$ and is given by

$$S q_1 = \lambda q_1.$$

This relation reveals that the eigenvector $q_1$ has the eigenvalue $\lambda$.[11] Hence, the maximal variance is given by the eigenvector with the maximal eigenvalue. This means finding the first principal component

$$a = \tilde{A}_0 q_1$$

or –if expressed for several shocks– in more general writing[12]:

$$A_i = \tilde{A}_0 Q_1.$$

The first and second principal components provide the two most influencing, exogenous shocks on the VAR. Identifying these shocks will amount to finding the shocks corresponding to the largest eigenvalues. As each shock cannot be connected to a single

[10] Cf. Hamilton (1994), page 729 or Johnston and DiNardo (1997), page 476-478

[11] Cf. Greene (2003), page 827

[12] Cf. Greene (2003), page 58

eigenvalue, we have to find the combination of eigenvalues which generates the maximal total variance. As there may be several such combinations of shocks, we have to consider several variance decompositions. Let the vector $a_1$ represent the shock corresponding to the largest eigenvalue $\lambda_1$ and $a_2$ represent the orthogonal shock corresponding to the second largest eigenvalue $\lambda_2$. We may then find pairs of shocks $[a(\Theta); a(\Theta + \frac{\Pi}{2})]$, where $a(\Theta) = \cos(\Theta * \frac{2\Pi}{360})a_1 + \sin(\Theta * \frac{2\Pi}{360})a_2$, which represent orthogonal decompositions. $\Theta$ takes the values {0;30;60;90;120;150} yielding three[13] orthogonal pairings, which we call rotations henceforth:

(i) $a_1(\Theta = 0)$ and $a_2(\Theta = 90)$
(ii) $a_1(\Theta = 30)$ and $a_2(\Theta = 120)$
(iii) $a_1(\Theta = 60)$ and $a_2(\Theta = 150)$.

## 2.4 Analytical Tools

For the interpretation of the results obtained with VARs, two instruments are very useful: the calculus of impulse-response functions and the variance decomposition. Both show the relation between a variable and a shock as stated in the equations 2.5 and 2.6. For a concrete example see chapter 4. Here, we provide a short introduction on how to use and understand these tools.

Impulse-response functions trace out how a single, exogenous shock affects a variable under the assumption that no other shock occurs at that time and thereafter. Initially, one supposes that the model –i.e. all variables– is in its (natural) equilibrium. The values of the variables are fixed and consequently there is no fluctuation. This changes at the occurrence of the shock at time $t_0$: the variable directly affected by the shock shows an immediate response by changing its value. This change is usually measured by the percentage fluctuation of the variable. Most commonly, response func-

[13]To be exact, there are six orthogonal pairings. We abstract from the latter three {180;210;240;270;300;330} as they do not contain any new information and are only different in sign.

tions are portrayed in graphical form. The axis of abscissae contains the k-step-ahead prediction (time) horizon which starts in $t_0$ and depicts how the variable evaluates in the k-periods following the shock. A shock can have a positive or a negative effect and a temporary or a permanent effect on a variable.

The second tool is the variance decomposition which states how much of the forecast-error variance of a variable can be explained by a specific shock. The researcher generally supposes that a variable is stationary meaning that it has a fixed (natural) value in equilibrium. The variance of such a variable gives the deviation of that (natural) value if the variable is exogenously influenced by a non-systematic shock. Often, there is reason to think that several (unknown) shocks influence the variables. In that case the impacts of different shocks sum up to compose the total variance.

A variance decomposition offers the possibility to decompose the (total) variance to see how many shocks influence the variable and to what extent (explanatory power in percent). Therefore, the variance decomposition can also be seen as a $R^2$ measurement. Commonly it is shown as a graph. The axis of abscissae contains the k-step-ahead prediction (time) horizon. The prediction horizon shows how the impact of a shock evolves over time as shocks may gain importance after a number of lags.

# CHAPTER III

# EMPIRICAL SPECIFICATIONS

This chapter outlines the buildup of our SVAR. We define the countries analyzed (section 1) and provide motivation for the variables we choose (section 2). Furthermore, we explain the data set (section 3) and finally assemble our SVAR in explicit matrix form.

## 3.1 Country Panel

As the researchers cited in the literature review, we strive to obtain robustness by generating results for several countries. The vast majority of researchers chose among Japan, Western European and North American countries. In this thesis we also propose an analysis of three emerging countries: the United Mexican States (MEX), the Republic of South Africa (RSA) and the Kingdom of Thailand (THL).
As a benchmark, we first analyze Canada (CAN), an industrialized country. This has three reasons and advantages: (i) we are able to hark back on more extensive and reliable data; (ii) we can compare our results –obtained with a statistical identification procedure– to results achieved with methods implying theoretical identification procedures which used Canadian data as well; and (iii) we are able to compare our results for emerging countries to those for an industrialized country. Following the pertinent literature we choose the United States of America (USA) as the reference country.

## 3.2 Variable Choice

The target variable is the real exchange rate for which we maximize the forecast-error variance.[1] The other variables of the VAR are chosen according to their appearance in the pertinent literature as most common relations with exchange rates. We include output, the price level, the interest-rate spread, the monetary-policy instrument and the stock-market index. The selection of variables is motivated by the following theoretical considerations:

The definition of the real exchange rate suggests a relation between the exchange rates and the price levels (P).[2] Written in logarithmic form it is stated as:

$$q = e + p^* - p \tag{3.1}$$

where $q$ denotes the real exchange rate, $e$ the nominal exchange rate, $p^*$ the foreign price level and $p$ the domestic price level. Purchasing-power parity implies a constant real exchange rate (equal to one) as all fluctuations in the price levels are neutralized by the nominal exchange rate.

The second relation we want to include is stated by the uncovered-interest-rate parity (UIP):[3] $1 + i_{t+1} = (1 + i^*_{t+1})E_t[\frac{\exp(e_{t+1})}{\exp(e_t)}]$ or written in approximated, logarithmic form:

$$i_{t+1} = i^*_{t+1} + E_t[e_{t+1}] - e_t \tag{3.2}$$

where $i_{t+1}$ denotes the domestic nominal interest rate on bonds, $i^*_{t+1}$ the foreign nominal interest rate on bonds, $E_t[e_{t+1}]$ the anticipated (future) nominal exchange rate and $e_t$ the current nominal exchange rate. Under the hypothesis that domestic and foreign bonds are perfect substitutes and given full international capital mobility, the UIP states

[1] We define the real exchange rate as the ratio of domestic over foreign goods. Henceforth and in all graphs we abbreviate it by rExR.

[2] Cf. Rogoff (1996), Froot and Rogoff (1994) or Obstfeld and Rogoff (1996), page 200-202

[3] Cf. Baxter (1994), Cumby (1988) or Obstfeld and Rogoff (1996), page 527-528

that the two bonds can only pay different interest rate if agents expect there will be compensating movement in the exchange rate. We use the monetary-policy instrument (MPI), which is a very short-term (prime) interest rate of the central bank (Bernanke and Blinder, 1992), as the relevant interest rate.

The third relation we take in consideration is the goods market equilibrium of the Mundell-Flemming-Dornbusch model which elaborates a relation between the real domestic (national) output (Y) and the real exchange rate.[4] It can be written as $y_t^d = \overline{y} + \delta(e_t - p_t^* + p_t - \overline{q})$ or simplified:

$$y_t^d - \overline{y} = \delta(q_t - \overline{q}) \tag{3.3}$$

where $y_t^d$ denotes the demand for domestic output, $\overline{y}$ the natural (full employment) rate of output, $q_t$ the real exchange rate and $\delta$ a weighting parameter which we assume to take strictly positive values.

The fifth and sixth variable we want to add to our SVAR concern the presumption that news and anticipation about the future of the economy might cause real exchange rate fluctuations (Bachetta and Wincoop, 2003). Such information is reflected in (i) the stock market (Crise, 2000); and (ii) the interest-rate spread (Kwark, 2002). We therefore add the stock-market index (SMI) as the fifth variable. It represents the performance of a whole stock market and thereby reflects investors' perceptions of the current and the future state of the economy. The sixth variable is the real interest-rate spread (R-sp) which is the differential of the long-term interest rate and the short-term interest rate and indicates the anticipated progression of the economy. We use the spread instead of the simple long-term interest rate to have comparable rates between countries where different market risks apply.

In an earlier version of this thesis, we also considered an eight-variable SVAR containing (world) commodity prices and the trade balance to account for the Harrod-

[4] Cf. Obstfeld and Rogoff (1996), page 610

Balassa-Samulson effect.[5] As both variables are statistically non-significant as sources of rExR movements we abstract from them.

## 3.3 Data Set

### Data Sources

Our data collection starts after the Bretton Woods era (post March 1973). Thereby, we try to draw conclusions with respect to the widely noted fact that real exchange rates have been substantially more volatile after the collapse of this agreement.

The Canadian dataset is at monthly frequencies for the sample 1973:5 until 2006:2. With one observation lost to differentiating the interest-rate spread (cf. Data construction) and three more to lagging, the sample size for Canada is T=390.

The dataset for the emerging countries is different in three aspects: (i) we constructed our SVAR for emerging countries only with the price-level differential, the interest-rate-spread differential and the output differential as the additional candidate variables were not collected for a sufficiently long horizon; (ii) we use quarterly data for all emerging countries as monthly data is not available for some variables; and (iii) we reduce the sample range to 1980:1 until 2005:4 as, after Bretton Woods, many developing and emerging countries did first shift from fixed exchange-rate regimes to international reserve assets and only in the late 1970s to floating exchange-rate regimes.[6] Consequently, data is available for a shorter period. With one observation lost to differentiating the interest rate and two more to lagging, the sample size for emerging

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[5] According to this effect, countries with higher productivity in tradable goods –compared to non-tradable goods– tend to have higher price levels. Cf. Harrod (1933), Balassa (1964) and Samuelson (1964) or Obstfeld and Rogoff (1996), page 210-216

[6] The Special Drawing Right (SDF) of the International Monetary Fund is such an international reserve asset. The SDF is a basket of major currencies against which countries can peg their domestic currencies. The idea is to diversify the dependence of the trading partners' currency fluctuations which exist in regimes where the domestic currency is pegged to a single foreign currency.

countries is T=97.

We received most of the envisaged time series data form the International Financial Statistics (IFS)[7] database of the International Monetary Fund (IMF) and from the Main Economic Indicators (MEI)[8] database of the Organization for Economic Co-operation and Development (OECD). Additional data was obtained by national sources: Canadian data was provided by the Canadian Socio-Economic Information Management System (CANSIM II)[9]. Mexican data was provided by the Mexican National Institute for Statistics, Geography and Informatics (INEGI)[10]. South African and Thai data came respectively from Statistics South Africa (Stats SA)[11] and the National Statistical Office (NSO)[12] of Thailand. U.S. data was received from the Federal Reserve Economic Databank (FRED)[13] of the Federal Reserve Bank in St. Louis.

### Data Construction

Three variables of our model were not directly available and had to be constructed. First, monthly data for the Canadian/U.S. real exchange rate had to be calculated based on equation 3.1. Second, monthly data of Canadian output was not available in one single series for our sample horizon; we had to construct it by combining two series that

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[7] http://imfstatistics.org

[8] http://www.oecd.org

[9] http://dc1.chass.utoronto.ca

[10] http://www.inegi.gob.mx

[11] http://www.statssa.gov.za

[12] http://www.nso.go.th

[13] http://research.stlouisfed.org/fred2

appear to be highly correlated.[14] Third, as the adequate measure of the real interest rate is the ex ante interest rate, we would have to account for expected inflation which in turn is difficult to determine. Therefore, we simply use the realized rate of the previous period: the ex post real interest rate.

### Data Transformation

We undertook the following data transformation. The domestic variables have been divided by the U.S. variables.[15] In addition, we took the logarithm of these ratios and multiplied them by 100, except of those already expressed in percent. For variables given in percent, we calculated the differences. Specifically:

1. Real Exchange Rate: rExR $\equiv ln(\frac{\text{DomesticGoods}}{\text{U.S.Goods}}) * 100$
2. Price-Level Differential: P-diff $\equiv ln(\frac{\text{Domestic\_PriceLevel}}{\text{U.S.\_PriceLevel}}) * 100$
3. Interest-Rate-Spread Differential: R-sp-diff $\equiv$ $(\text{Domestic\_LongTermInterestRate} - \text{Domestic\_ShortTermInterestRate}) -$ $(\text{U.S.\_LongTermInterestRate} - \text{U.S.\_ShortTermInterestRate})$
4. Output Differential: Y-diff $\equiv ln(\frac{\text{Domestic\_Output}}{\text{U.S.\_Output}}) * 100$
5. Monetary-Policy-Instrument Differential: MPI-diff $\equiv \text{Domestic\_PrimeRate} - \text{U.S.\_PrimeRate}$
6. Stock-Market-Index Differential: SMI-diff $\equiv ln(\frac{\text{Domestic\_StockMarketIndex}}{\text{U.S.\_StockMarketIndex}}) * 100$

Price levels are based on the national consumer-price indexes (CPI). The short-term interest rate is the three-month treasury bill. The long-term interest rate is the

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[14] The series are GDP in 1992 constant prices and GDP in 1997 constant dollars. The correlation coefficient of the two series is 0,999264. Cf. figure A.1.

[15] This is motivated by the fact that the rExR in this thesis is defined as domestic goods over US-American goods.

three-year government bond. Canadian, Mexican, South African and Thai output is the real gross domestic product (GDP). U.S. output is industrial production. The Canadian monetary-policy instrument is the Overnight Rate (ONR). The U.S. monetary-policy instrument is the Federal Funds Rate (FFR). The Canadian stock-market index is the Toronto Stock Exchange Composite Index (TSXCI). The U.S. stock-market index is the Standard and Poor's 500 (S&P 500).

### SVAR Specification

These six variables constitute our model. Based on equation 2.6 of the methodology chapter and the variable choice, we construct the following SVAR for Canada:

$$\begin{bmatrix} rExR \\ P-diff \\ R-sp-diff \\ Y-diff \\ MPI-diff \\ SMI-diff \end{bmatrix} = \begin{bmatrix} R(L)_{11} & \dots & R(L)_{16} \\ R(L)_{21} & \dots & R(L)_{26} \\ R(L)_{31} & \dots & R(L)_{36} \\ R(L)_{41} & \dots & R(L)_{46} \\ R(L)_{51} & \dots & R(L)_{56} \\ R(L)_{61} & \dots & R(L)_{66} \end{bmatrix}_{6\times 6} \begin{bmatrix} \varepsilon^{shock1} \\ \varepsilon^{shock2} \\ \varepsilon^{shock3} \\ \varepsilon^{shock4} \\ \varepsilon^{shock5} \\ \varepsilon^{shock6} \end{bmatrix}$$

According to the Akaike (information) criterion, the dynamics of these variables for Canadian data are best described by a SVAR with three lags.

Our SVAR for Mexico, South Africa and Thailand is represented by:

$$\begin{bmatrix} rExR \\ P-diff \\ R-sp-diff \\ Y-diff \end{bmatrix} = \begin{bmatrix} R(L)_{11} & \dots & R(L)_{14} \\ R(L)_{21} & \dots & R(L)_{24} \\ R(L)_{31} & \dots & R(L)_{34} \\ R(L)_{41} & \dots & R(L)_{44} \end{bmatrix}_{4\times 4} \begin{bmatrix} \varepsilon^{shock1} \\ \varepsilon^{shock2} \\ \varepsilon^{shock3} \\ \varepsilon^{shock4} \end{bmatrix}$$

This four-variable version is most precise with two lags.

# CHAPTER IV

# RESULTS

This chapter analyzes our results. We draw conclusions about what moves the real exchange rate (section 1) applying Canadian data. A comparison between our econometric method with those employing theoretical identification procedures (section 2) and a series of robustness checks on our model (section 3) complements this chapter.

## 4.1 Sources of Exchange Rate Volatility in Canada

### 4.1.1 Extracting the Most Important Shocks

Figure 4.1 shows the historical variance decompositions for the three possible rotations of the two shocks explaining most of the forecast-error variance of the rExR. The prediction horizon is 20 periods (months) as we focus on short-run volatility. The horizontal axis depicts 60 periods to expose the medium and long-run effects as well. On the vertical axis we show the explanatory power of each shock in percent; 1 represents 100%. The solid line is the median of the resulting posterior distribution and the dotted lines are the confidence intervals which are calculated with the (Litterman) Minnesota prior for the 10%-90% bounds.[1]

Both shocks together explain a remarkable 96% of the forecast-error variance of

[1] The Minnesota Prior assumes that the variables follow a random walk. Cf. Litterman (1986) or Hamilton (1994), page 360-362

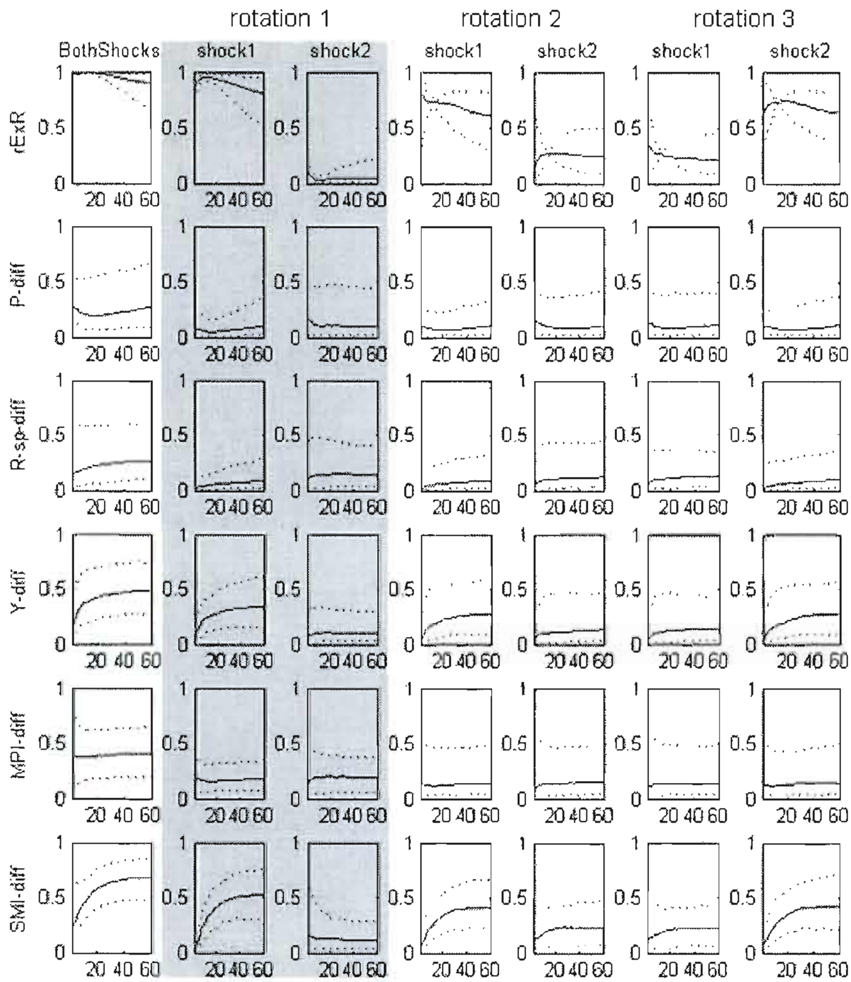


Figure 4.1 Variance Decomposition; Canada/USA

the rExR at the time they occur ($t_0$) and even 98% two periods later. A closer look reveals that their influence decreases only slightly over the prediction horizon and still explain 93% in $t_{60}$. We can say with a high level of confidence that two shocks drive the real exchange rate. The two shocks together have the following explanatory power of the forecast-error variance of: the price-level differential (26% in $t_0$), the interest-rate-spread differential (9% in $t_0$) and the output differential (13% in $t_0$). This fact points rather towards an approval of the disconnect effect, as the two most important shocks for the rExR do not explain a substantial amount of the volatility in the fundamentals.

In comparison, our additional candidate variables seem more likely to share these two shocks: monetary-policy-instrument differential (41% in $t_0$) and the stock-market-index differential (17% in $t_0$). Nevertheless, these variables do not share the shocks to a substantial part either.

Among the three rotations (columns two to six), the first one is the most interesting as its shock 1 has the most explanatory power of all six shocks provided. Thus, we concentrate only on this shock 1 which alone always explains far more than the majority of the rExR fluctuations. It causes approximately 80% of its volatility in $t_0$ and increases to reach its height of 95% in $t_{12}$ from where it decreases to about 82% in $t_{60}$. Shock 2 has 16% explanatory power of the forecast-error variance of the rExR in $t_0$ and even less over the horizon (3% in $t_{10}$ and 5% in $t_{60}$). In comparison to shock 1, we have to conclude that this shock is not a major driving force of rExR fluctuations. Consequently, the following analysis is done for shock 1 (of rotation 1) only.

Shock 1 explains little of the macro fundamentals in $t_0$: price-level differential (6%), interest-rate-spread differential (1%) and output differential (3%) and only little more of the additional candidate variables: monetary-policy-instrument differential (25%) and the stock-market-index differential (2%). Over the medium-run ($t_{20}$) and long-run ($t_{60}$) two variables stand out: the output differential (36% in $t_{20}$; 30% in $t_{60}$) and of stock-market-index differential (42% in $t_{20}$; 53% in $t_{60}$).

Summary

Our results reveal that there are two shocks causing virtually all of the forecast-error variance of the rExR. This is particularly true during the first twelve periods after the impulse of the shock (>95%) but even thereafter, the two shocks drive the rExR to a substantial amount (>90%). We find that one of these shocks appears to be the major source of the forecast-error variance of the rExR as its explanatory power ranges between 75% and 92%. The interpretation of this single shock (shock 1) is our focus.

We corroborate the exchange-rate disconnect with our model and data; at least in the short-run. The main variables output, the price level and the interest-rate spread (all as differentials) do not seem to substantially share (9%-26%) the two most important shocks which drive the rExR. An alternative reading of the fact is that the propagation of the shock on the fundamentals is largely damped by monetary policy which would as well explain the response function of the differential of the monetary-policy instruments.

### 4.1.2 Evaluating the Impact of the Shocks on Macro Aggregates

We analyze the (dynamic) impulse-response functions as they are shown below in figure 4.2. As stated earlier, they present the amplitude and propagation of shock 1 (rotation 1) on each variable of our SVAR. The vertical axis is the percentage change representing the volatility of a variable; 1 represents a 1% change. The horizontal axis is the (60 periods) prediction horizon. As for the variance decomposition, the solid line represents the median of the resulting posterior distribution and the dotted lines the confidence intervals which were calculated with the Minnesota Prior for a 10%-90% lower bound. The interpretation is done from the Canadian perspective as we hold the U.S. variables fixed.[2]

Shock 1 does not seem to have a permanent effect on any variable.

[2] As we define the ratios as CAN/USA, an increase in the ratio consequently implies an increase in the value of the Canadian variable.

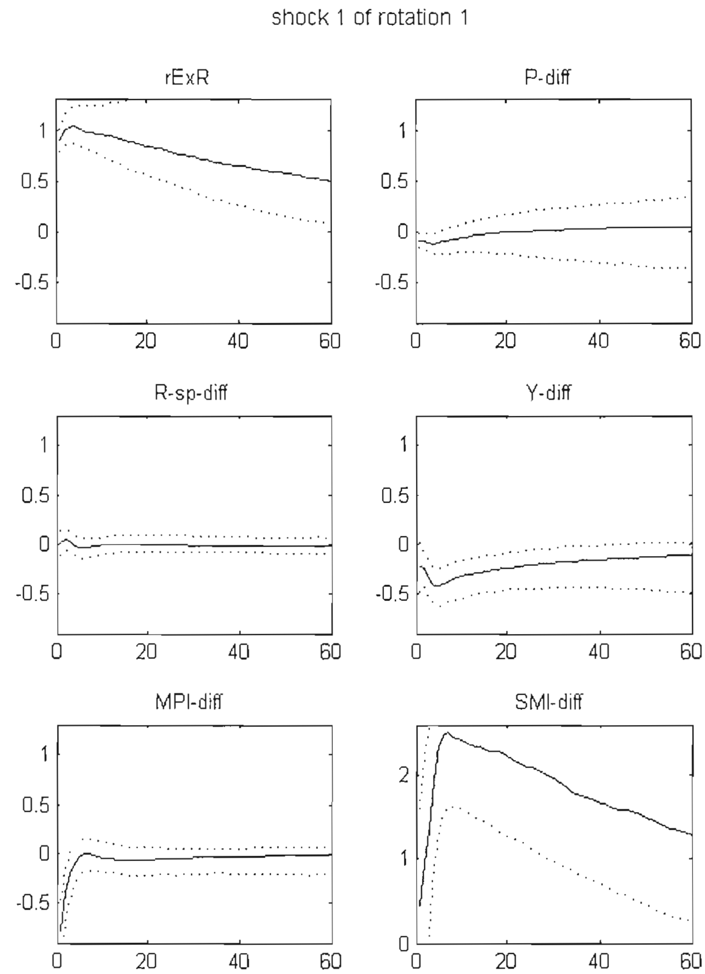


**Figure 4.2** Impulse Response Functions; Canada/USA

*rExR:* The real exchange rate depreciates about 0,9% at the time of the occurrence ($t_0$) of the shock. Interestingly its response is hump-shaped with a peak (1%) in $t_3$ and a declining but long-lasting impact over the horizon. The response is statistically significant.

*P-diff:* From the price-level differential we deduce a deflationary impact of the shock, although it is rather modest: -0,1% in $t_0$ from where it slowly returns back to zero. The response is statistically non-significant.

*R-sp-diff:* No significant impact is exerted on the differential of the interest-rate spread which is affected to always less than 0,01%. The response is statistically non-significant.

*Y-diff:* The effect on the output differential implies a negative growth effect of the shock. The response has a similar hump shape to the rExR. In $t_0$, it is -0,2% which doubles until $t_4$ to reach the minimum of -0,4% before it slowly fades out. This response is statistically significant for $t_1$ and the following periods.

*MPI-diff:* The shock has a negative impact on the differential of monetary-policy instrument which indicates a decrease in the Canadian prime rate. In $t_0$, the MPI-diff jumps down about -0,7% before it sharply increases towards zero. The response is statistically significant until $t_3$.

*SMI-diff:* The differential of the stock-market index shows another very strong and extended hump-shaped response. In $t_0$, the effect of the shock is 0,3%. The main impact occurs in $t_{17}$ (2,4%) from where the response slowly returns back to zero. This response is statistically significant from $t_3$ onwards.

### Summary

The marked and significant reaction of the rExR indicates that (relative) purchasing-power parity (PPP) does not to hold. The findings support the view often stated in the literature that large and persistent deviations from PPP occur (Adler and Lehmann, 1983; Aizenman, 1984). We find evidence in the propagation of both shocks. The reason is the stickiness of prices which prevents immediate neutralization by the nominal ExR.

We further conclude that uncovered-interest-rate parity (UIP) does not hold. Equation 3.2 rewritten says that the cross-country difference $[i_t - i_t^*]$ is the same as the temporal difference of the ExR $[e_{t+1} - e_t]$. This is not the case. The amplitude of the responses of the rExR and the MPI-diff are not equivalent. This effect is even stronger after a few periods, as the rExR returns back to zero slowly and the MPI-diff virtually jumps back to zero. There needs to be a risk premium to balance the movements of the rExR and the interest rates.

### 4.1.3 Interpretation

*Demand Shock:* We suspect a demand shock –in real terms– to account for the propagation shown by shock 1. A negative demand shock means a fall of government spending, or of consumption, or of investment and thus a decrease of output below potential.[3] As a result, producers decrease the price level to incite consumption. The central bank decreases its prime rate to stimulate growth. The stock market, in turn, evaluates the loosening of monetary policy as a sound reaction and foresees positive perspectives. As these perspectives become concrete in the subsequent months, the stock-market-index differential gradually enhances. The real exchange rate depreciates as the decrease price-level differential is not fully absorbed neither by the nominal exchange rate nor the effect of the monetary policy.

*Monetary Shock:* Our results do not support the idea of a monetary shock. A classic monetary shock is induced by an exogenous shock to the monetary-policy instrument. If the shock is expansionary, the central bank is decreasing its prime rate. The propagation effects on our variables would be: an increase in the price level and an

[3] We describe the shock as a negative demand shock in order to establish a coherent interpretation of the propagation of the variables. But as all shocks a mean-zero shocks the signs cannot be interpreted with certitude.

increase of output. On the one hand, we observe an immediate decrease in the monetary-policy-instrument differential, but on the other hand, the price-level differential and the output differential behave exactly the opposite as predicted. This is implausible. We hence exclude the possibility that shock 1 is a monetary shock.

*Supply Shock:* We do not read the results as a supply shock either. Generally, a negative supply shock results in a decrease in output (productivity). The impact on other variables is the following: an increase of the price level given that supply falls. The stock-market index reacts with a slump to such a negative productivity shock. Monetary policy is likely to decrease the prime rate to lower the price level; thus the monetary-policy-instrument differential increases. Our results provide a decrease of the output differential, but as well a decrease in the price-level differential, an increase in the stock-market-index differential and a decrease in the monetary-policy-instrument differential. The behavior of all these variables is contradictory. Consequently, we may exclude the alternative of a supply shock as well.

*Information Shock:* We can rule out an information shock as well. Departing with the increase of the stock-market-index differential, positive information about the Canadian economy could be the source of the shock. Such good news could be a fall in production costs and a subsequent decrease of the price level. Falling prices incite consumption and thus output rises. The reaction of the monetary authority depends on the objective of the bank. Supposing that deflationary effects induce costs would make a decrease of the prime rate adequate. A comparison with our graphs shows that output falls, which is not coherent, particularly as a decrease of output is not considered as good news. We hence rule out the possibility of information shocks.

*Exogenous Exchange Rate Shock:* An exogenous shock on the exchange rate is another potential option even though it is hard to see why such a shock should be truly exogenous. But leaving aside this reservation, suppose that a shock on financial markets causes a sudden depreciation of the Canadian dollar. A plausible propagation on other variables would be an increase of Canadian output as Canadian exports become relatively cheaper abroad. The effect on the price level is ambiguous as the relative increase of imported goods might have a less strong effect. In our data, we observe a decrease of the rExR but output decreases by remarkable 0,5%. This is implausible in the light of the definition given.

## 4.2 Robustness Tests

### 4.2.1 Comparison to Different Identification Procedures

As a robustness check of our results, we put the Uhlig approach in competition with traditional identification procedures. We want to find out if the Uhlig method provides different results for the same dataset and therefore test it against the two most important papers in this line of literature: Clarida and Galí's (1994) application of long-run restrictions and Eichenbaum and Evans's (1995) application of short-run restrictions.

#### Long-Run Restrictions versus Uhlig

We begin with a reproduction of the Clarida and Galí (1994) results by imposing long-run restrictions. In a second step we generate results with the Uhlig method. The Clarida-Galí SVAR contains three variables: the output differential (Y-diff), the real exchange rate (rExR) and the price-level differential (P-diff). The three restrictions they impose are: a monetary shock neither has a long-run effect on output nor on the rExR and a demand shock has no long-run effect on output. We use Canadian and U.S. data for the sample horizon 1973m5 until 2006m2.

The variance decomposition (cf. figure 4.3) shows that demand shocks are the main driving force of the rExR but explain literally nothing of the Y-diff and the P-diff. In $t_0$, the rExR is driven to 5% by supply shocks, to 90% by demand shocks and to 5% by monetary shocks. Over the prediction horizon, the explanatory power of the supply shock rises to 30%, the impact of the demand shock falls to 70%. The output

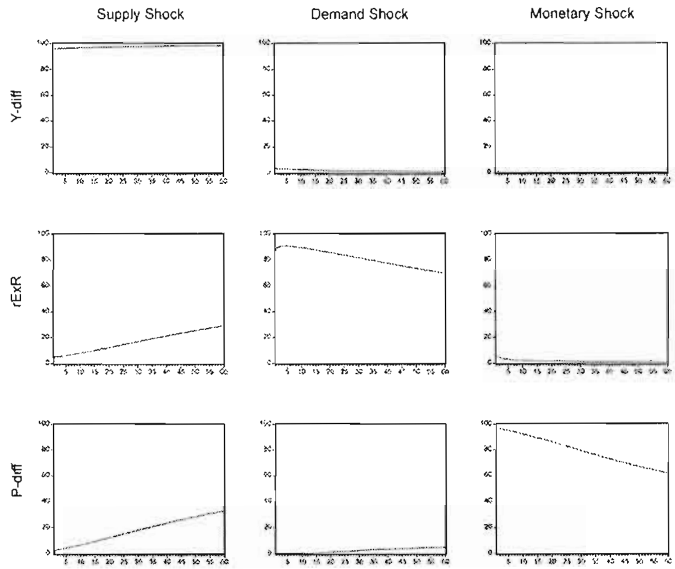


**Figure 4.3** Variance Decomposition; Clarida and Galí with long-run restrictions

differential is affected in $t_0$ to 96% by the supply shock and to 3% by the demand shock while monetary shocks have virtually no explanatory power. The price-level differential on the contrary is only very little explained by supply and demand shocks in $t_0$ (4%; 1%) but monetary shocks drive it to a large extend (95% in $t_0$). Our reproduction of Clarida and Galí (1994) yields very similar results even though we extended the horizon for about 14 years and changed from quarterly to monthly data.

We analyze the impulse-response functions (cf. figure 4.4) only for the demand shock as it has the most explanatory power of the forecast-error variance of the rExR. In $t_0$, the rExR depreciates about 1,1% and increases in a hump shape to reach a maximum of 1,4% in $t_3$. The output differential increases about 0,2% in $t_0$ and fades out afterwards. The price-level differential is particularly affected in the medium and long-run. In $t_0$, it jumps to approximately 0,05% but it increases to 1% over the prediction horizon.

The Uhlig method yields the following results: the variance decomposition (cf.

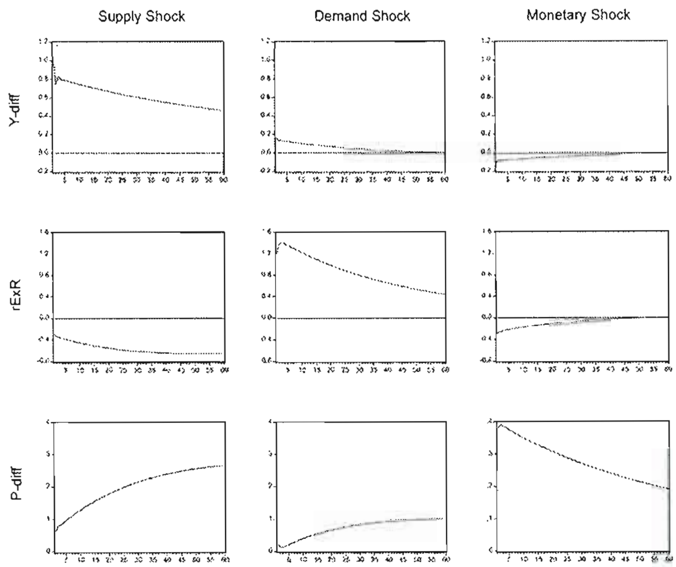


**Figure 4.4** Impulse Response Functions; Clarida and Galí with long-run restrictions

left part of figure 4.5) reveals that the first shock alone (shock 1) explains 100% of rExR fluctuations in $t_0$ and over 90% over the five-year prediction horizon. This was found by Clarida and Galí as well. They attributed 93% to demand shocks. That means that there is only one major driving force behind the rExR. We analyze this shock 1 only.

To label shock 1, we first have to look if it is shared by the two other variables. The second column of the variance decomposition reveals that in $t_0$, shock 1 does not seem to affect neither the price variance nor the output variance significantly which further supports the exchange-rate disconnect. We turn towards the response functions to see how shock 1 affects the variables.

Our impulse-response functions (cf. right part of figure 4.5) to the two shocks show that shock 1 causes a 1% depreciation of the rExR in $t_0$, which is followed by a little hump (1,2% after three periods) and a slow decline. In comparison to the method imposing long-run restrictions, we find different reactions of the two candidate variables: the output differential and the price-level differential are negatively impacted

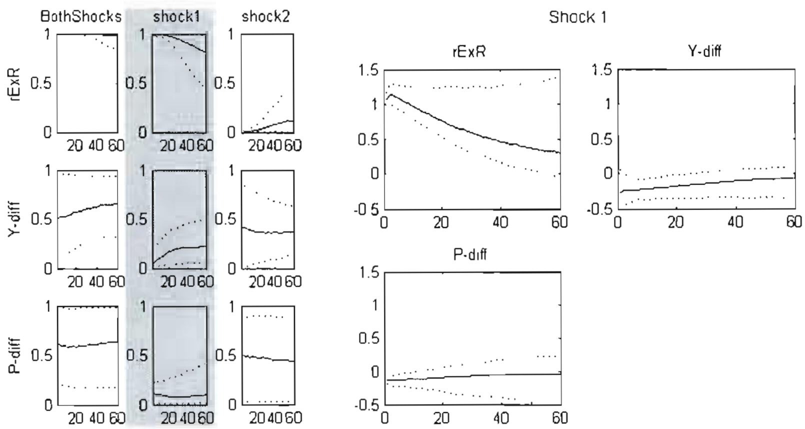


**Figure 4.5** Variance Decomposition and Impulse Response Functions: Clarida and Galí's vs. Uhlig method

(both about -0,2% in $t_0$).

We resume that imposing long-run restrictions –as Clarida and Galí do– and not imposing them –as the Uhlig method suggests– does not lead to strikingly different results. The Uhlig method has the disadvantage that labeling shock 1 has to be done with a more complex SVAR as three variables are not enough to establish a coherent interpretation. But our six-variable SVAR with monthly data proposes the same (demand) shock as Clarida and Galí do.

Another interpretation of the finding is that there is only one major shock stems from the econometrics of the Uhlig method. As the SVAR explains the forecast-error variance of the rExR with the error terms, we seem to attribute all the explanatory power to the error term of the rExR. The other two error terms –of the output differential and price-level differential– do simply not affect the rExR. That is further support of the disconnect.

### Short-Run Restrictions versus Uhlig

Next, we verify if imposing monetary policy short-run restrictions –the way Eichenbaum and Evans (1995) imposed– can be squared with results from the Uhlig method. As before, we first reproduce their results for the Canadian case.[4] In a second step we generate results with the Uhlig method. A particularity of the Eichenbaum-Evans SVAR is their choice of variables. Rather than using differentials, they simply utilize log-values. Seven variables are included: the real exchange rate (rExR), the U.S. output (US-Y), U.S. price level (US-P), Canadian output (CAN-Y), the U.S. short-term interest rate (US-R), the Canadian short-term interest rate (CAN-R) and the U.S. monetary-policy instrument (US-MPI). Only an U.S. monetary shock is analyzed. We use Canadian and U.S. data for the sample horizon 1973m5 until 2006m2.

Our reproduction of the Eichenbaum and Evans's variance decomposition (cf. left part of figure 4.6) shows that a monetary shock has virtually no explanatory power of the rExR in $t_0$ and only very little over the prediction horizon. The monetary shock has –as the literature predicts– much explanatory power of the U.S. interest rate and evidently on the U.S. monetary-policy instrument (prime rate). We have to conclude that monetary shocks have only very little influence on the rExR volatility.[5] In contrast, Eichenbaum and Evans found in their paper a contribution between 10% and 40% according to the country considered. Faust and Rogers (1999) found –in their reproduction of Eichenbaum and Evans– a more diffuse impact (2%-56%) of monetary shocks on the rExR. Our findings for Canada seem to lie at the lower end of these two studies.

The corresponding impulse-response functions (cf. right part of figure 4.7) display

[4] As Eichenbaum and Evans did not analyze Canada in their paper. As a check, we first reproduced the results for the United Kingdom. As our results matched with theirs', we introduced Canadian data.

[5] At least according to our data set for U.S. and Canadian data. If this conclusion holds with generality has still to be examined.

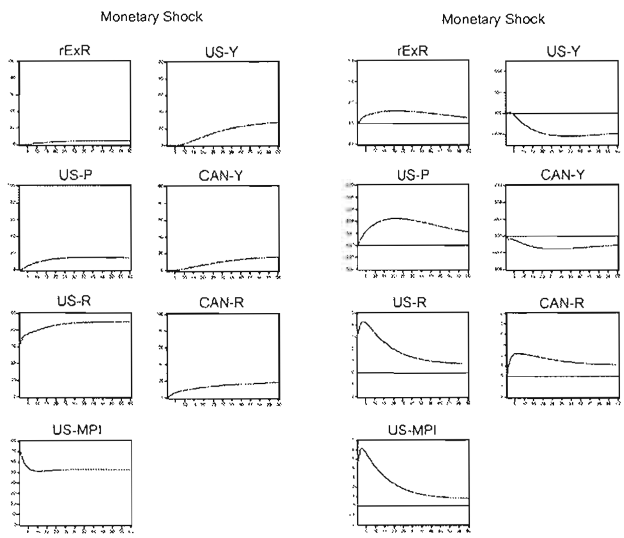


**Figure 4.6** Variance Decomposition and Impulse Response Functions; Eichenbaum and Evans with short-run restrictions

that monetary shocks lead to virtually no response of the rExR in $t_0$. The effects on the candidate variables are the following: the U.S. output, U.S. prices and Canadian output are affected by less than 1%. The U.S. interest rate increases by 30% in $t_0$ and until 43% in $t_5$ before decreasing back to zero. The Canadian interest rate is not affected in $t_0$ but increases sharply during the following periods to reach 20% in $t_5$. The U.S. monetary-policy instrument increases by 50% ($t_0$) and even 60% in $t_3$ before it returns back to zero.

Generating results with the Uhlig method yields very different findings. Our variance decomposition (cf. left part of figure 4.7) identifies again two shocks which explain 96% of the forecast-error variance of the rExR in $t_0$. Three variables of the Eichenbaum-Evans SVAR share these two shocks to a relatively large extend at the moment of the shock: the U.S. interest rate (35%), the Canadian interest rate (40%) and the U.S. monetary-policy instrument (25%). The other variables are as well affected but to a minor degree. This is similar to the results Eichenbaum and Evans generated, although the rise in the Canadian interest rate is enigmatic. Looking at one shock only

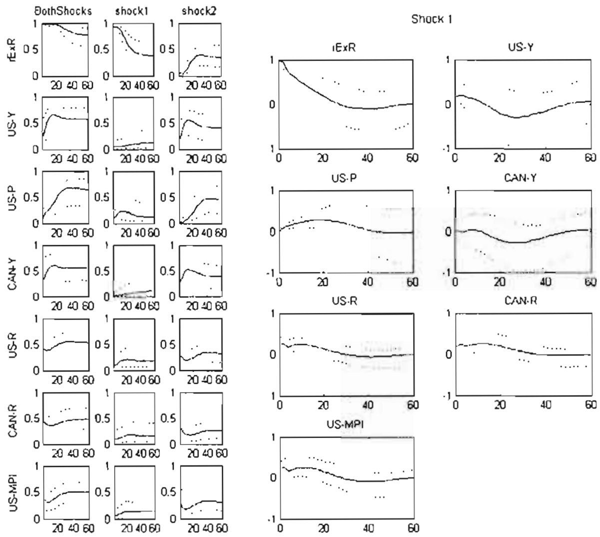


**Figure 4.7** Variance Decomposition and Impulse Response Functions; Eichenbaum and Evans' vs. Uhlig method

shows that shock 1 explains 92% of the rExR volatility in $t_0$. The same three variables, which were most impacted by the two shocks together, seem to share this shock: the U.S. and the Canadian interest rates are explained to 10% in $t_0$. The U.S. monetary-policy instrument is driven to about 7% in $t_0$. In addition, the U.S. price level is affected to 7% in $t_0$.

Impulse-response functions from the Uhlig method (right part of figure 4.10) for shock 1 provide the following results: the impact on the rExR of shock 1 causes a depreciation of 1% in $t_0$, which is in contrast to the results of Eichenbaum and Evans. We further observe an increase in U.S. output (0,1% in $t_0$). There is an inflationary effect on U.S. price level (0,1% in $t_0$) and a fall in Canadian output (0,05% in $t_0$). The greatest responses are observed for the U.S. and Canadian interest rates and the U.S. monetary-policy instrument. All increase by about 0,2% in $t_0$. These movements in the variables are quantitatively consistent with those obtained by imposing short-run restrictions.

We conclude that applying such short-run restrictions yields different results. The Uhlig method exposes a far more important shock –according to its explanatory power– than the monetary shock of Eichenbaum and Evans. Employing their short-run restrictions may obscure this most important shock.

### 4.2.2 Parameter Variations

In order to verify if our model provides reliable results, we modify some of its most important specification parameters. We check robustness along three dimensions:

(i) The prediction horizon: Throughout this thesis, the prediction horizon $k = [\underline{k},\bar{k}]$ is fixed at $k$=[0,20]. Here we enlarge it to $\bar{k}$=60 and $\bar{k}$=100; $\underline{k}$ is always zero. In a second test we change the position of the prediction horizon: it is being lagged away from the moment of the shock. Otherwise said, we manipulate $[\underline{k},\bar{k}]$ to take the values [40,60] and [80,100]; $k$ continues to be fixed at 20.

(ii) The number of variables: The number of variables included in our SVAR is changed. We reduce the model to five and three variables. The choice of variables which we keep in the SVAR is based on their responses in the benchmark case.

(iii) The time horizon: Clarida and Galí (1994) found that shocks affect the rExR to a varying extend over time. We therefore divide our total sample horizon (1973m5-1990m2) in two: 1973m5-1990m2 and 1990m3-2006m2.

All results are provided in figures in the appendix. The visible horizon is enlarged from 60 to 100 periods throughout all tests for better comparison.

Analysis of the tests under (i), based on figures A.2, A.3 and A.4: The prediction horizon does not have a significant impact on the results as the impulse-response functions and the variance decomposition do not seem to be significantly altered. This modification has no effect on the shape, nor on the amplitude of the response functions, nor on the explanatory power of the shocks. The only exception is the price-level differential which tends to be slightly more driven by the shock if the prediction horizons

becomes larger.
Figures A.2, A.5 and A.6 show the results if the position of the prediction horizon changes: neither the response functions, nor the variance decomposition are changed significantly.

Analysis of the tests under (ii), based on figures A.2, A.7 and A.8: Our SVAR depends lightly on the number of variables involved as the variance decompositions reveal evidence that the explanatory power of shocks increases as the number of variables is reduced. This is not surprising due to the underpinnings of a SVAR: the SVAR explains the volatility of each variable with error terms in the system. Evidently, the less variables we keep in the SVAR, the more we explain the forecast-error variance of each variable. In the extreme case of just one variable, we would always find 100% explanatory power in the variable's own error term.

Analysis of the tests under (iii), based on figures A.2, A.9 and A.10: The time horizon is highly influential for the results. We are thus able to support another finding of Clarida and Galí (1994). The left part of figure A.9 reveals that all variables share the shocks on the rExR to a larger extend for the period 1973m5-1990m2; particularly after some lags. The impulse-response functions (right part of figure A.9) differ substantially to those of figure A.2; except the R-sp-diff. In contrast, figure A.10 looks relatively similar to figure A.2. Only the P-diff shares the shocks to a greater extend. The impulse-response functions (right part of figure A.10) are changed in the following: the rExR returns faster to zero, the output differential increases in $t_0$ and differential of monetary-policy instruments decreases less in $t_0$ and the stock-market-index differential is affected negatively in $t_0$.

# CHAPTER V

# COMPARISON TO EMERGING COUNTRIES

As above, we use variance decompositions to separate the different shocks driving the real exchange rate. Figures 5.1, 5.2 and 5.3 show these variance decompositions for three emerging countries: Mexico, South Africa and Thailand. We chose these three countries as they are undoubtedly emerging and due to their regional importance. The reference country is the USA. We only present the first out of three rotations as it is the most interesting for all three countries. The horizontal axis depicts the forecast horizon in quarters and the vertical axis the explanatory power of each shock in percent. The confidence intervals are calculated with the Minnesota Prior for a 10%-90% lower bound.

## 5.1 Mexico

The variance decomposition depicts two shocks which explain together 100% of the forecast-error variance of the rExR in $t_0$ and over the prediction horizon. One of these shocks (shock 1) causes virtually all of (>97%) the fluctuations while the second shock (shock 2) has very little (1%-3%) explanatory power. We therefore analyze only shock 1. The three main macroeconomic variables are affected (on average) to a modest extend in $t_0$ by shock 1: the price-level differential shares the shock to 25%, the interest-rate-spread differential to 10% and the output differential only to 2%.

The impulse-response functions show a remarkable 9,3% depreciation of the Mex-

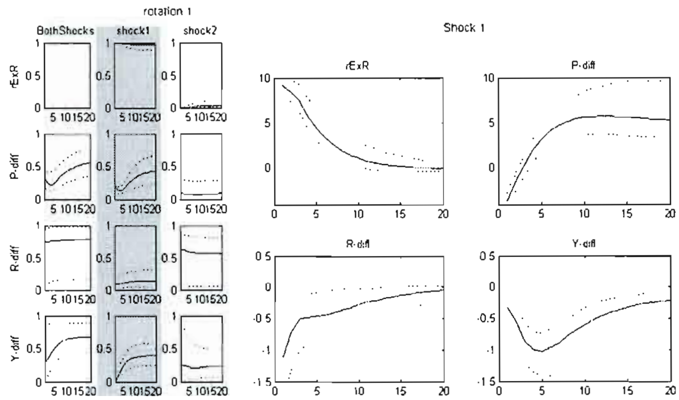


**Figure 5.1** Variance Decomposition and Impulse Response Functions; Mexico/USA

ican Peso in $t_0$, which gradually returns back to zero. Our three main variables are all affected negatively: the price-level differential jumps down -3,7% ($t_0$) and strongly increases until $t_{13}$ to attain a maximum of 6%. The interest-rate-spread differential decreases in $t_0$ by -1,1% before it returns to zero and the output differential first falls about -0,34% ($t_0$) and decreases further until -1,1% ($t_5$) to return to zero afterwards. Particularly, the responses of the rExR and the differential of price levels are remarkable. They indicate high volatility, maybe induced by the financial (Tequila) crisis in 1994 (cf. Lederman, Menéndez, Perry and Stiglitz, 2001).

## 5.2 South Africa

We determine –by variance decomposition– again two shocks which induce virtually 100% of the rExR variance in $t_0$. Their explanatory power falls about 2% at the end of the horizon. The second column presents the impact of shock 1 and we see that this shock drives the rExR to 93% in $t_0$. The second shock contributes only 7% and will therefore not be considered further. The core macroeconomic variables do not share shock 1 at the time it occurs. The price-level differential is driven to 3% by this shock, the interest-rate-spread differential to 2% and the output differential to less than 1%.

The impulse-response functions show a depreciation of the rExR of about 6,2%

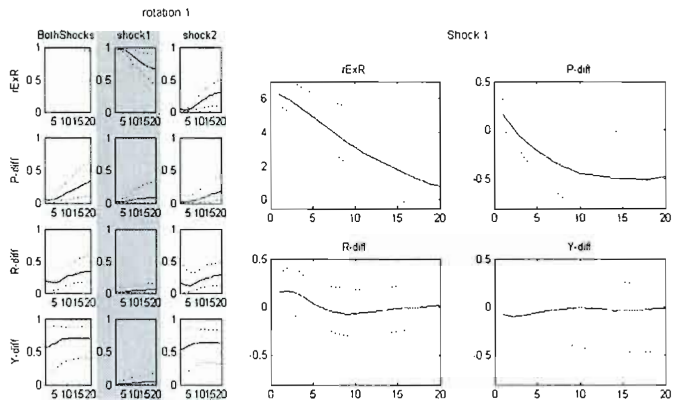


**Figure 5.2** Variance Decomposition and Impulse Response Functions; South Africa/USA

and a gradual decline thereafter. The two additional variables increase as well in $t_0$ due to shock 1. The price-level differential goes up about 0,16%, then falls to -0,6% ($t_{15}$) and finally returns back to zero. Interest-rate-spread differential and output differential increase rather modestly (0,05% and 0,1%, respectively) and return to zero after a few periods. These responses do not resemble to those due to a demand shock. Except for the rExR, the three variables are statistically non-significant.

## 5.3 Thailand

As in the cases before, both shocks together account for the total of the forecast-error variance of the rExR in $t_0$. Their explanatory power falls about 9% at the end of the horizon. Shock 1 is again of particular interest as it causes 95% of the rExR volatility in $t_0$ whereas the second shock contributes only 5%. The most important shock for rExR movements does not seem to be shared by the main variables. Shock 1 has 3% explanatory power on the price-level differential and only 1% on the interest-rate-spread differential and the output differential, respectively.

For Thailand, all four variables show a positive response to the shock at $t_0$. The rExR increases by 6,2%, the price-level differential by about 0,12% (hump in $t_3$:

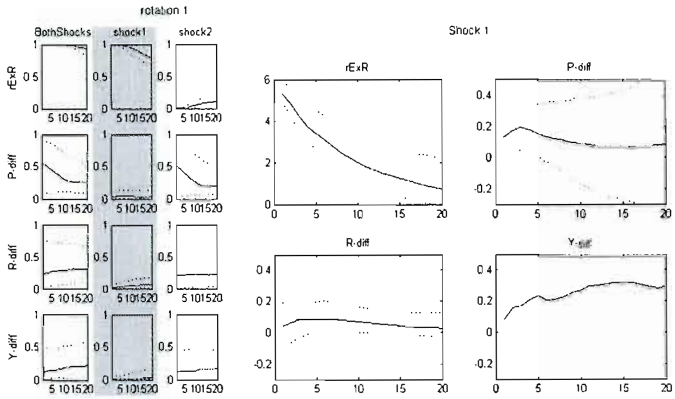


**Figure 5.3** Variance Decomposition and Impulse Response Functions; Thailand/USA

0,18%), the interest-rate-spread differential by 0,05% and the output differential by approximately 0,1%. They all return back to zero quickly.

## 5.4 Summary

For all three countries, we find two shocks which contribute (almost) 100% to the forecast-error variance of the rExR in $t_0$. One of these shocks appears to be the sole driving force (95%-99%). Labeling the shocks is difficult due to the fact that we have only three variables to draw conclusions from. Moreover, the responses due to the shocks vary across countries. We do not think that the exchange rates in all four countries are driven by demand shocks. The impact of country-specific shocks might have more weight in emerging countries.

For two countries (South Africa and Thailand), the main macroeconomic variables as price level, interest-rate spread and output (all as differentials) do not share the most important shock (1%-3%). Mexican data provokes suspicion as the variables are affected by much more (2%-25%), but do neither represent a substantial amount.

The effect of the shock on the rExR is between five to nine times greater in the three emerging countries than in Canada, but it vanishes faster, too.

## 5.5 Interpretation

We conclude that the exchange-rate disconnect is found in data from emerging countries as well. Our impression of this country panel is that the disconnect is even more extreme for emerging countries.

The link between the shock and the rExR is much stronger for emerging countries as the induced responses are of much greater amplitude. Supposing the shock is the same in industrialized and emerging countries, means that the rExR is more volatile in the latter. This fact is consistent with empirical observations (Gray and Irwin, 2003).

# CONCLUSION

This thesis outlined an application of the Uhlig method to determine the sources of real exchange rate fluctuations. We have shown its characteristics and advantages and tested its robustness in comparison to traditional methods. Our panel of Canada, Mexico, South Africa, Thailand and the United States has determined one principal shock which causes a vast amount of the fluctuations of the real exchange rate. We read this shock –at least for the case of Canada– as a demand shock. Furthermore, we find evidence that purchasing-power parity and uncovered-interest-rate parity are violated. The exchange-rate disconnect is undoubtedly present in our results. Great disparities in the extend of the disconnect seem to exist though. They appear to be greater in emerging economies than in industrialized countries. This finding confirms earlier work (Kandil, 2004).

This line of research (including this thesis) has to be read with caution as there are many caveats about econometric modeling and choice parameters (Rudebusch, 1998; Uhlig, 2005). We have outlined the differences in the results due to the application of a theoretical identification procedure. Particular restrictions, the choice of candidate variables, specific countries and sample horizons seem to influence the output of SVARs. We avoided theoretical identification procedures but the method we used instead is new and needs to be tested further to assure its robustness. The countries we chose is new material as well, but we hope to stimulate the use of emerging and developing countries in empirical research.

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# APPENDIX A

## FIGURES

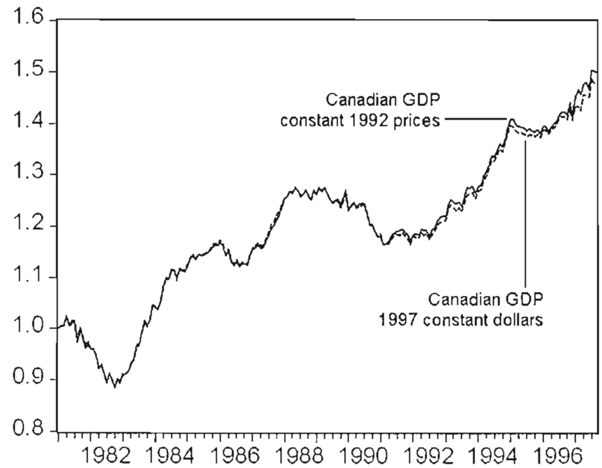


**Figure A.1** Construction of monthly Canadian output

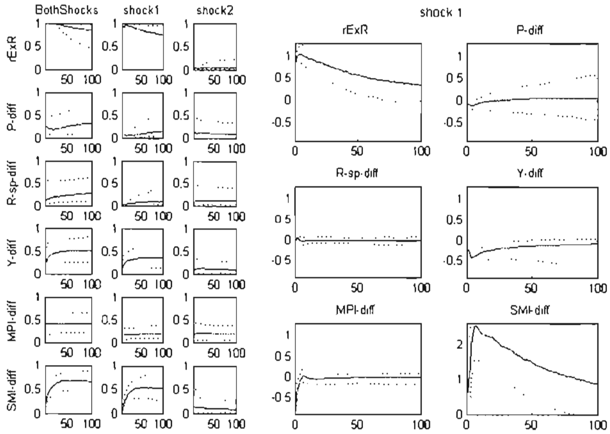


**Figure A.2** Robustness Test; Prediction horizon: k=[0;20] / 6-variable SVAR / Time horizon 1973m5-2006m2: Variance Decompositition and Impulse Response Functions

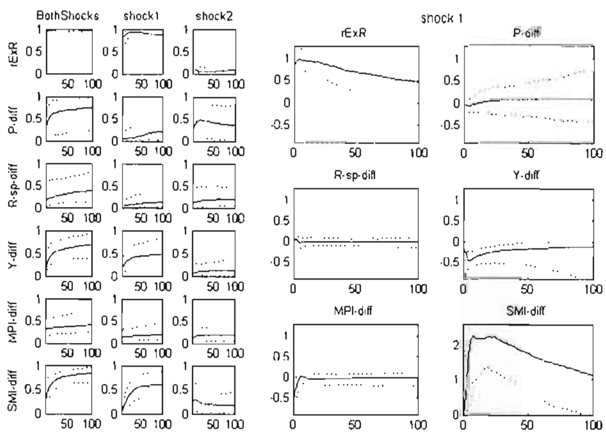


**Figure A.3** Robustness Test; Prediction horizon k=[0;60]: Variance Decompositition and Impulse Response Functions

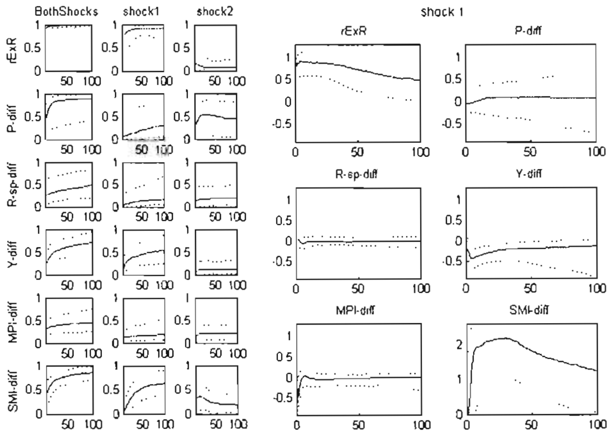


**Figure A.4** Robustness Test; Prediction horizon k=[0;100]: Variance Decompositition and Impulse Response Functions

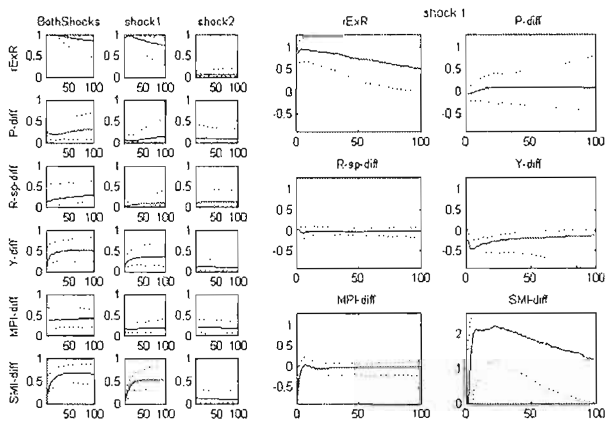


**Figure A.5** Robustness Test; Prediction horizon k=[40;60]: Variance Decompositition and Impulse Response Functions

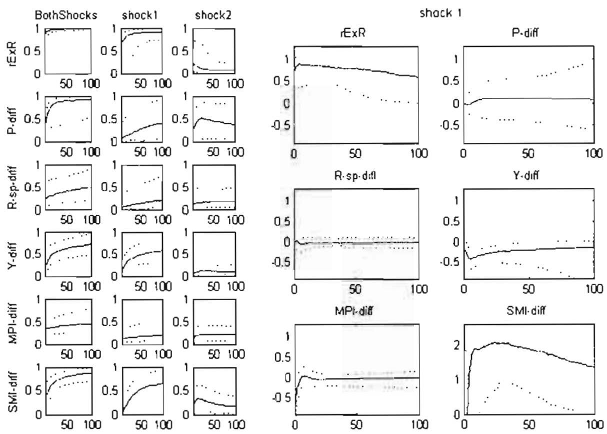


**Figure A.6** Robustness Test; Prediction horizon k=[80;100]: Variance Decompositition and Impulse Response Functions

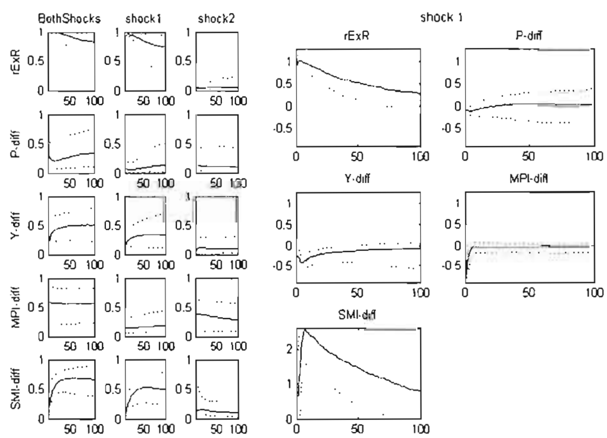


**Figure A.7** Robustness Test; 5-variable SVAR: Variance Decompositition and Impulse Response Functions

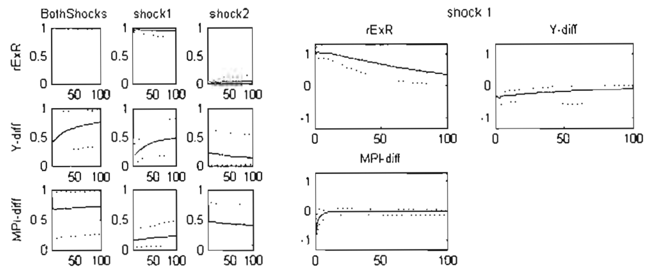


**Figure A.8** Robustness Test; 3-variable SVAR: Variance Decompositition and Impulse Response Functions

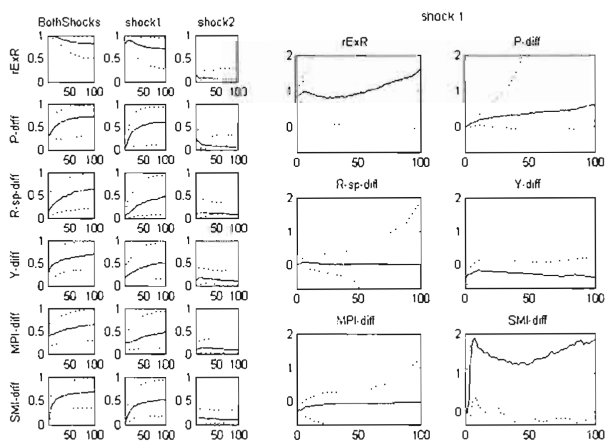


**Figure A.9** Robustness Test; Time horizon 1973m5-1990m2: Variance Decompositition and Impulse Response Functions

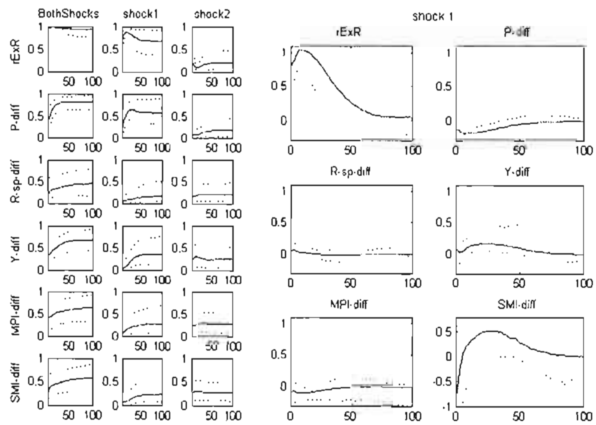


**Figure A.10** Robustness Test; Time horizon 1990m3-2006m2: Variance Decomposition and Impulse Response Functions