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THE CHANGING NATURE OF REAL EXCHANGE RATE FLUCTUATIONS. NEW EVIDENCE FOR INFLATION-TARGETING COUNTRIES[*]

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Abstract

We assess the role of real and nominal shocks on the real exchange rate (RER) dynamics for a set of small open economies. In doing so, we estimate a SVAR model for five inflation targeting countries: Australia, Canada, Chile, Israel and Norway. In sharp contrast with the existing empirical evidence, we find that in most countries demand shocks tend to explain a small proportion of RER volatility for the period 1986-2011. In that period nominal shocks are relatively more important in explaining RER fluctuations. When we perform a subsample analysis, however, we can reconcile the empirical findings in the literature with our results. In particular, we conclude that the relative importance of demand shocks has been declining substantially over time. In contrast, the relative importance of nominal shocks, and in particular exchange rate shocks, increased importantly in the last decade.

Resumen

En este documento analizamos los roles de los shocks reales y nominales en la dinámica del tipo de cambio real para un conjunto de economías pequeñas y abiertas. Con este propósito estimamos un modelo de vectores autorregresivos estructurales para cinco países cuya política monetaria se rige por el esquema de metas de inflación: Australia, Canada, Chile, Israel y Noruega. A diferencia de la literatura empírica existente, encontramos que en la mayoría de estos países los shocks de demanda tienden a explicar un pequeño porcentaje de la volatilidad del tipo de cambio real en el periodo 1986-2011. En este periodo, los shocks nominales son la fuente relativamente más importante detrás de las fluctuaciones del tipo de cambio real. Cuando realizamos un estudio por submuestras podemos reconciliar los hallazgos de la literatura con nuestros resultados. Concluimos que la importancia relativa de los shocks de demanda ha declinado sustancialmente en el tiempo. En cambio, la importancia relativa de los shocks nominales, en particular de los shocks de tipo de cambio, ha aumentado significativamente en la última década.

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1 Introduction

In open economies the real exchange rate (RER) is a key relative price, hence understanding the sources of its variability is one of the challenging issues in international economics. As noted by Juvenal (2011) the literature has focused on the leading role of monetary policy shocks in accounting for RER movements. The empirical evidence, however, has not provided much support in this respect. Farrant and Peersman (2006) estimate structural vector autoregressions (SVARs) for a set of four economies (UK, Canada, Japan and the Eurozone). They find that demand shocks explain the greatest proportion of RER fluctuations, whereas supply shocks tend to explain a small fraction of the overall RER volatility. Nominal shocks (either monetary policy shocks or exchange rate shocks) play, in general, a secondary role in determining RER dynamics. In a paper for the U.S., Juvenal (2011) find that monetary shocks are unimportant in explaining exchange rate fluctuations. By contrast, demand shocks explain between 21% and 37% of exchange rate variance at 4-quarter and 20-quarter horizons, respectively. Steinsson (2008), on the other hand, concludes that in response to different types of real shocks a micro-founded model is able to replicate the hump-shaped dynamics empirically found in the RER. In the face of nominal shocks, however, the model is unable to replicate the empirical persistence of the RER.

Despite the previous findings, there are still some unsettled issues regarding the behavior of the RER in small open economies. On the one hand, there is no evidence of the relative importance of real and nominal shocks on RER variability in many inflation-targeting (IT) countries. On the other hand, it is not clear to which extent the relative contribution of those shocks has changed over time. For instance, the volatility of the RER has increased steadily in Australia, Canada and Chile since 1996 (Figure 1) whereas in Israel and Norway it has remained stable in the same period (Figure 2). What are the reasons for the behavior of the RER in these countries? Has the adoption of a full-fledged IT regime changed the way in which shocks are transmitted to the RER, or is it the size of the shocks that has changed over time? In this context, the objetive of this paper is twofold. First, we quantify the relative importance of real and nominal shocks in shaping the RER dynamics in five IT countries: Australia, Canada, Chile, Israel and Norway. Second, we determine the extent to which the contribution of those shocks has changed over time.

We estimate a SVAR model for the five IT economies for the period 1986-2011. In order to identify the impact of structural shocks on the RER in particular, and in the rest of the macro variables in general, we follow Uhlig (2005), Canova and Nicolo (2002), Farrant and Peersman (2006) and Juvenal (2011) by imposing sign restrictions on the responses of the variables to orthogonal disturbances. These restrictions are derived from the predictions of a simple open economy monetary model, with sticky prices and an inflation targeting central bank. Our model is an extension of Clarida and Gali (1994) and Farrant and Peersman (2006) setup.

In general, most empirical studies that try to distinguish between the real and nominal sources of exchange rate movements have used SVARs to identify structural disturbances. However, they disagree in their results. As noted by Farrant and Peersman (2006), the source of the disagreement seems to be the identification strategy that is used. In a seminal paper, Clarida and Gali (1994) examine the importance of nominal shocks in explaining real exchange rate fluctuations. They use a long-run triangular identification scheme proposed by Blanchard and Quah (1989) and King et al. (1991). The nominal shocks are identified by assuming that such shocks do not affect real variables (the real exchange rate and output) in the long-run. They find that demand shocks explain most of the variance in the real exchange rate and that the exchange rate acts as a shock absorber. These results are confirmed by Funke (2000) for the UK versus the Eurozone. Using an alternative identification strategy, based on sign restrictions, Farrant and Peersman (2006) find evidence that fluctuations in the RER are, in general, determined by demand shocks. Nominal shocks (either monetary policy or exchange rate shocks) play a secondary role. They also conclude that the results depend on the identification strategy used: if the long-run approach of Blanchard and Quah (1989) is used, demand shocks tend to explain an even greater proportion of RER fluctuations.

Using the restrictions from our theoretical model, we assess the role of real and monetary shocks on the exchange rate's behavior using a SVAR model for five small open economies. Our main findings are as follows. In sharp contrast with the empirical evidence, we find that for the period 1986-2011 demand shocks tended to explain a small proportion of RER volatility in most countries. In that period nominal shocks were relatively more important in explaining RER fluctuations. When we perform a subsample analysis, however, we can reconcile the empirical findings in the literature with our results. In particular, we conclude that the relative importance of demand shocks declined importantly over time. In contrast, the relative importance of nominal shocks and, in particular, exchange rate shocks, have increased in recent years. Those results are based on 15-year rolling window estimations in the spirit of Wong (2000). Overall, our results suggest that the adoption of a full-fledged IT regime, along with a floating exchange rate regime, may have contributed to the shift in the relative importance of demand and exchange rate shocks in determining the RER. This, in a context in which international financial markets were subject to important disruptions in the aftermath of the 2008 crisis.

The rest of the paper is organized as follows. The second section reviews the main structure of the theoretical model and discusses the sign restrictions that can be derived from it. In section three, we describe the methodological approach to estimate a SVAR. In particular, we discuss the way the model is estimated using the sign restriction methodology. In the fourth section we present the main results. Finally, section five concludes.

2 An Open Economy Model and Sign Restrictions

We develop a sticky-price open economy model that extends the Clarida and Gali (1994) and Farrant and Peersman (2006) model in three dimensions. First, we allow for structural disturbances to follow AR(1) processes. This will imply that the relative price level, the relative output level and the RER will be stationary variables. Clarida and Gali (1994) and Farrant and Peersman (2006), on the contrary, assume that stochastic shocks are simple random walks and, as a consequence, there is a non stationary behavior in the relevant variables. We are able to obtain an explicit solution to the model in which the random walk shock is a particular case. Second, we explicitly derive the impact that RER shocks (or country risk premium shocks) have on the main macro variables. Farrant and Peersman (2006) mention the impact that this innovation has, but there is no explicit derivation of the transmission mechanism of this shock nor of its magnitud. Finally, we explicitly consider a monetary policy rule that reacts systematically to the price level and to output. In this way, we are able to identify, independently, monetary and exchange rate shocks.

The model is composed by the following equations:

$$y_t^d = d_t + \eta q_t - \sigma \left(i_t - E_t(p_{t+1} - p_t)\right) \tag{2.1}$$

$$p_t = (1-\theta)E_{t-1}(p_t^e) + \theta p_t^e \tag{2.2}$$

$$m_t^s - p_t = y_t - \lambda i_t \tag{2.3}$$

$$i_t = E_t(s_{t+1} - s_t) + \varphi_t \tag{2.4}$$

All variables represent domestic versus foreign variables and are expressed in logs, except for the inters rate, i_t. Equation (2.1) is an open economy IS equation where the relative demand for output, y^d, is an increasing function of the real exchange rate, $q_t = s_t - p_t$, and a decreasing function of the ex-ante real interest rate. The variable d_t represents a relative demand shock, whereas s_t is the nominal exchange rate and p_t is the relative price level.

Equation (2.2) is a price-setting equation in which p_t is a weighted average of the expected market clearing price, $E_{t-1}(p_t^e)$, and the price that would actually clear the output market in period t, p_t^e. When θ=1, prices are fully flexible and output is supply-determined. When θ=0, prices are fixed and predetermined one period in advance.

Equation (2.3), on the other hand, is a standard LM equation where relative real money balances, $m_t^s - p_t$, are positively related to relative output and negatively related to the interest rate.

The behavior of the nominal exchange rate is determined according to the interest parity condition, equation (2.4), and it depends on the interest rate and a stochastic disturbance, φ_t. In the Clarida and Gali (1994) and Farrant and Peersman (2006) specifications this latter shock is not explicitly introduced.

Before solving the model, we need to specify the stochastic processes that govern the supply of output, y^s, the demand shock, d_t, the money supply, m_t, and the RER shock, φ_t. Unlike previous studies, we assume that those processes have a stationary AR(1) representation. This will make the solution of the model more difficult, but will induce stationarity in the variables. Furthermore, in our general setup the random walk representation of shocks can be considered a particular case. The stochastic shocks are:

$$y_t^s = \rho_s y_{t-1}^s + \varepsilon_t^s \tag{2.5}$$

$$d_t = \rho_d d_{t-1} + \varepsilon_t^d \tag{2.6}$$

$$m_t = \rho_m m_{t-1} + \varepsilon_t^m \tag{2.7}$$

$$\varphi_t = \rho_q \varphi_{t-1} + \varepsilon_t^q \tag{2.8}$$

where ε_t^s, ε_t^d, ε_t^m and ε_t^q are structural i.i.d disturbances, and $0 < \rho_j < 1$, for $j = s, d, m, q$. In Clarida and Gali (1994) and Farrant and Peersman (2006) it is assumed that $\rho_j = 1$ for all j. In order to obtain uncluttered solutions we assume that $\rho_s = \rho_d = \rho_m = \rho$ [1]. The flexible price equilibrium, when $\theta = 1$, is characterized by the following equations:

$$y_t^e = y_t^s \tag{2.9}$$

$$q_t^e = \frac{y_t^s - d_t}{\phi} + \frac{\sigma}{\phi_q}\varphi_t \tag{2.10}$$

$$p_t^e = \frac{m_t - y_t^s}{1 + \lambda(1-\rho)} + \frac{\lambda(1-\rho)}{(1+\lambda(1-\rho))\phi}(d_t - y_t^s) + \frac{\lambda\eta}{(1+\lambda(1-\rho_q))\phi_q}\varphi_t \tag{2.11}$$

where $\phi = \eta + \sigma(1-\rho)$ and $\phi_q = \eta + \sigma(1-\rho_q)$. Now, the short-run dynamics of this system, when prices are sticky can be obtained by combining equations (2.1)-(2.4) and equations (2.5)-(2.11). The system is:

$$y_t = y_t^e + \phi_0(1-\theta)\left(\frac{\varepsilon_t^m - \varepsilon_t^s}{1+\lambda(1-\rho)} + \frac{\lambda(1-\rho)}{(1+\lambda(1-\rho))\phi}(\varepsilon_t^d - \varepsilon_t^s) + \frac{\lambda\eta}{(1+\lambda(1-\rho_q))\phi_q}\varepsilon_t^q\right) \tag{2.12}$$

$$q_t = q_t^e + \phi_1(1-\theta)\left(\frac{\varepsilon_t^m - \varepsilon_t^s}{1+\lambda(1-\rho)} + \frac{\lambda(1-\rho)}{(1+\lambda(1-\rho))\phi}(\varepsilon_t^d - \varepsilon_t^s) + \frac{\lambda\eta}{(1+\lambda(1-\rho_q))\phi_q}\varepsilon_t^q\right) \tag{2.13}$$

$$p_t = p_t^e - (1-\theta)\left(\frac{\varepsilon_t^m - \varepsilon_t^s}{1+\lambda(1-\rho)} + \frac{\lambda(1-\rho)}{(1+\lambda(1-\rho))\phi}(\varepsilon_t^d - \varepsilon_t^s) + \frac{\lambda\eta}{(1+\lambda(1-\rho_q))\phi_q}\varepsilon_t^q\right) \tag{2.14}$$

where $\phi_0 = \frac{(\eta+\sigma)(1+\lambda)}{\eta+\sigma+\lambda}$ and $\phi_1 = \frac{1+\lambda}{\eta+\sigma+\lambda}$. Now, from the short-run dynamic system, represented by equations (2.12)-(2.14), it is possible to use sign restrictions for identification purposes.

[1] Our results hold even in the case in which different AR(1) coefficients are assumed for each shock.

In particular, different shocks are identified according to the direction of their impact on the variables in the system. Sign restrictions are used by Faust and Leeper (1997), Uhlig (2005), and Canova and Nicolo (2002) to identify monetary policy shocks and are generalized by Peersman (2005) to a full set of shocks. In the case of the exchange rate, this methodology is used by Farrant and Peersman (2006), Artis and Ehrmann (2006) and more recently by Juvenal (2011).

The sign restriction approach has several advantages over alternative methods. First, it avoids distortions related to small sample biases and measurement errors that are present in methods based on zero long-run restrictions. Second, the zero short-run restrictions used in alternative methods, typically in the Choleski decomposition, are sometimes difficult to reconcile with theoretical models and may yield counterintuitive impulse response functions. The sign restriction approach overcomes this latter problem because short-run restrictions are explicitly derived from a microfunded model.

2.1 Sign Restrictions

In the long-run, output reacts only to a supply shock, equation (2.5). In the short-run, however, output is positively related to supply, demand, exchange rate and monetary policy shocks, equation (2.12) [2]. In the case of the RER, equation (2.13), there is a depreciation in the face of money supply and a country risk premium shocks. A demand shock, on the other hand, generates a RER appreciation. In the case of supply shocks, the effect over the RER, in the short-run, is ambiguous and will depend on the specific calibration of the model. Finally, there is a positive relationship between the relative price level, equation (2.14), and monetary, demand and country risk premium shocks. A positive supply shock, on the other hand, generates a decline in relative prices. Table 1 shows a summary of the sign restrictions derived from the short-run dynamic model.

[2] As in Clarida and Gali (1994) we assume that $\eta + \sigma < 1$. This ensures, on the one hand, that there is a nominal exchange rate overshooting as a response to a monetary shock and, on the other, that the short-run impact of a supply shock on output is positive.

Table 1: **Sign restrictions (3 variables)**

Supply shock	$\frac{\partial(y/y^*)}{\partial\varepsilon^s} \geq 0$	$\frac{\partial(p/p^*)}{\partial\varepsilon^s} \leq 0$	$\frac{\partial q}{\partial\varepsilon^s} \gtrless 0$
Demand shock	$\frac{\partial(y/y^*)}{\partial\varepsilon^d} \geq 0$	$\frac{\partial(p/p^*)}{\partial\varepsilon^d} \geq 0$	$\frac{\partial q}{\partial\varepsilon^d} \leq 0$
Monetary shock	$\frac{\partial(y/y^*)}{\partial\varepsilon^m} \geq 0$	$\frac{\partial(p/p^*)}{\partial\varepsilon^m} \geq 0$	$\frac{\partial q}{\partial\varepsilon^m} \geq 0$
Exchange rate shock	$\frac{\partial(y/y^*)}{\partial\varepsilon^q} \geq 0$	$\frac{\partial(p/p^*)}{\partial\varepsilon^q} \geq 0$	$\frac{\partial q}{\partial\varepsilon^q} \geq 0$

Clearly, only three shocks can be identified in this system: supply (ε_t^s), demand (ε_t^d) and nominal (which is composed by ε_t^m and ε_t^q). In this setup, more structure is needed to disentangle nominal shocks.

In order to identify monetary policy shocks, independently of country risk premium shocks, we explicitly introduce a monetary policy reaction function. In particular, we consider a Wicksellian rule in which the nominal rate reacts to the price level and to output:

$$i_t = \psi_p p_t + \psi_y y_t - \tau\varepsilon_t^m \tag{2.15}$$

It has been shown that, in simple sticky-price models, this rule is able to induce determinacy as long as ψ_p and ψ_y are positive (see Giannoni (2010)). In this case, a monetary policy shock (ε_t^m) reduces the interest rate and, as a consequence, increases output and prices. A supply shock increases prices and reduces output. As a result, the impact of this shock on the policy rate is ambiguous and will depend on the relative importance that the monetary authority gives to prices and output volatility. An exchange rate shock, on the other hand, increases prices and output and, given the positive policy coefficients, it also increases the nominal interest rate. Hence, identification is possible given an additional variable (interest rate) and the opposite effects that a monetary and exchange rate shock have on the nominal policy rate. The sign restrictions under the model that incorporates the Wicksellian rule are summarized in Table 2.

Table 2: **Sign restrictions (4 variables)**

Supply shock	$\frac{\partial(y/y^*)}{\partial\varepsilon^s} \geq 0$	$\frac{\partial(p/p^*)}{\partial\varepsilon^s} \leq 0$	$\frac{\partial(i-i^*)}{\partial\varepsilon^s} \gtrless 0$	$\frac{\partial q}{\partial\varepsilon^s} \gtrless 0$
Demand shock	$\frac{\partial(y/y^*)}{\partial\varepsilon^d} \geq 0$	$\frac{\partial(p/p^*)}{\partial\varepsilon^d} \geq 0$	$\frac{\partial(i-i^*)}{\partial\varepsilon^s} \geq 0$	$\frac{\partial q}{\partial\varepsilon^d} \leq 0$
Monetary shock	$\frac{\partial(y/y^*)}{\partial\varepsilon^m} \geq 0$	$\frac{\partial(p/p^*)}{\partial\varepsilon^m} \geq 0$	$\frac{\partial(i-i^*)}{\partial\varepsilon^m} \leq 0$	$\frac{\partial q}{\partial\varepsilon^m} \geq 0$
Exchange rate shock	$\frac{\partial(y/y^*)}{\partial\varepsilon^q} \geq 0$	$\frac{\partial(p/p^*)}{\partial\varepsilon^q} \geq 0$	$\frac{\partial(i-i^*)}{\partial\varepsilon^q} \geq 0$	$\frac{\partial q}{\partial\varepsilon^q} \geq 0$

Once the policy interest rate is included as a endogenous variable, it is possible to identify all structural shocks. In this way we can assess the relative importance of monetary and country risk premium shocks in determining the behavior of the RER. In the next section we present the method we use to estimate a structural VAR using the approach just described, and the sign restrictions presented in Table 2.

3 Methodology

In this section we describe the econometric method and the data. We follow the approach used in Peersman (2005) and Farrant and Peersman (2006).

3.1 Model and estimation

Our model consists of four endogenous variables. These are contained in the vector Y_t, where $Y_t = [\Delta(y/y^*), \Delta q, \Delta(p/p^*), i - i^*]_t$. The variable y/y^* is the logarithm of the ratio between real GDP in the domestic country (Australia, Canada, Chile, Israel, and Norway) and the real GDP in the foreign (*) country (U.S.), q is the logarithm of the real exchange rate, p/p^* is the logarithm of the price ratio and $i - i^*$ is difference between the real interest rates. We asume the dynamics of these variables are well represented by the following VAR system:

$$Y_t = \sum_{j=1}^{p} A_j Y_{t-j} + B\varepsilon_t,$$

where ε_t is a vector of structural disturbances such that $B\varepsilon_t$ are the residuals of the VAR. The covariance matrix is denoted by Ω_u. We identify four types of underlying shocks in this framework: $\varepsilon_t' = [\varepsilon^d, \varepsilon^x, \varepsilon^s, \varepsilon^m]_t$, referring to an aggregate demand shock, an exchange rate shock, an aggregate supply shock, and a monetary shock, respectively. We use sign restrictions to identify these structural shocks, following Faust (1998), Uhlig (2005), Canova and Nicolo (2002), and Peersman (2005). As in Uhlig (2005), estimation and inference are based on a Bayesian approach, where the prior and the posterior for $\{A_j\}_{j=1,\ldots,p}$ and Ω_u belong to the Normal-Wishart family. The impulse vector is given by

$$a = \tilde{A}\alpha$$

where $\tilde{A}$ is the Cholesky decomposition matrix of Ω_u and the unit length vector α is normally distributed. The posterior distribution is obtained by the product of the prior on A, Ω and α, and an indicator variable. This indicator variable is activated when the responses contained in a satisfy the sign restrictions. The impulse-response functions are then calculated and only those that satisfy the sign restrictions, at horizons that will be defined later, are saved. The procedure stops when, say, 1000 successful draws are obtained. The length of the horizon depends on the variable. For output and prices the horizon is set at four quarters. To reflect the fact that variables like the interest rate and the exchange rate are more volatile and responsive to shocks we set the horizon for these variables at one quarter.

Compared to other identification strategies, one advantage of the sign restriction approach is that it is not necessary to impose zero-restrictions neither on the contemporaneous impact matrix nor on the long-term effects. Some disadvantages are that the estimation may be computationally costly and that the percentiles, which are shown in our results, do not necessarily correspond to the responses of a single model such that the residuals are not necessarily orthogonal.[3]

3.2 Data and preliminary tests

The primary source of the data is the IMF's International Financial Statistics (IFS)[4], all series start in 1986 and end in 2011. The codes in IFS are as follows: Exchange rate: ..RF.ZF..., GDP: 99BVRZF... for Australia and Canada and 99BVPZF... for the rest of the countries, CPI: 64A..ZF... for Chile and 64...ZF... for the rest of the countries, and interest rates: OPA..ZF... for the U.S. and OP...ZF... for the rest of the countries with the exception of Norway, where the

[3]See Fry and Pagan (2011) for a critical review of the sign restriction approach.

[4]Data were extracted from the July 2012 version. The Norwegian lending rate observations are extracted from the Norges Bank's webpage

data are extracted from the webpage of Norges Bank (_1UKE_1WEEK). The analysis is made with quarterly observations. Real GDP data and price indices are seasonally adjusted. The real exchange rate is calculated with the nominal rate and the price indices, while the real interest rate is calculated ex-post, i.e. assuming that the expected annual inflation is simply the current rate. Univariate tests suggest that all variables are stationary[5] and lag-length criterions suggest one lag: for all countries the Schwarz and Hannah-Quinn (HQ) criteria suggest one lag, except in the case of Canada, where HQ suggests four lags in the model. One lag was considered in all estimations.

4 Results

We estimate the extended model, in which a Wicksellian rule is introduced, from 1986:Q1 to 2011:Q4. This model considers the four variables contained in the Y_t vector and the four structural shocks in ε_t. The sign restrictions we use to identify each of the structural shocks are displayed in Table 2.

4.1 Impulse Response and Variance Decomposition

The impulse-response functions are displayed in Figures (3) to (7) [6]. The response of the RER to a supply shock is positive in the cases of Australia and Canada, although it is statistically significant only in Canada. The RER appreciates in the case of Chile, Israel and Norway. This appreciation is transitory and the RER goes back to its initial level after few quarters. A demand shock, on the other hand, induces a RER appreciation in all five countries. In Australia and Norway this effect is transitory, whereas for Canada, Chile and Israel the appreciation is permanent. A monetary policy shock generates a RER depreciation on impact. This effect is statistically different from zero in all five countries and lasts for few quarters. The RER goes back to its initial level (in Chile and Norway), whereas in Australia, Canada and Israel the RER

[5] Three tests were applied: Augmented Dickey-Fuller, Dickey Fuller GLS for non-stationarity and the Kwiatkowski et al. (1992) test for stationarity (the three tests are described in, e.g., Hamilton (1994)). In the majority of the cases, all three tests suggested stationarity and in the remaining at least two of the tests indicated stationarity when considering a 5% significance level.

[6] Figures show the accumulated responses, except for the interest rate. This variable is also the only one that is not differenced in the VAR model.

returns to a lower level. Finally, in the face of an exchange rate shock, the RER depreciates permanently in all five countries.

The effect of supply shocks over output and relative prices is unambiguous: output increases and relative prices decline. These two effects are permanent in all five countries, though not statistically significant in a couple of cases. Demand shocks, on the other hand, increase output and prices permanently in all the countries.

In the case of demand and exchange rate shocks, the real interest rate increases, as implied by the sign restrictions, in a transitory fashion, in all five countries. These responses are in line with the behavior of inflation targeting central banks that react to increases in demand and/or the exchange rate, by raising the policy rate in order to attenuate the inflationary effects of those shocks. In the case of supply shocks, the real interest rate increases in Canada and Norway. It also increases in Australia and Israel, although this response is not statistically different from zero. In Chile, a supply shock generates an initial decline in the real interest rate. Finally, a monetary policy shock reduces the interest rate in all five countries.

In terms of the variance decomposition our results suggest that demand shocks explain, in general, a small proportion of RER volatility in the period 1986-2011 (see Table 3). Nominal shocks, in contrast, tend to have an important impact on the variance of the RER. Our results are in sharp contrast with previous evidence that concluded that demand shocks are one of the main drivers of the RER dynamics. In particular, for Canada we find that demand shocks explain between 14% and 6% of RER volatility at horizons of one quarter to four years. In contrast, Farrant and Peersman (2006) find that for Canada, between 1974 and 2002, demand shocks contribute 70% to 80% of the RER volatility in similar horizons. In the same vein, Clarida and Gali (1994), find for Canada that demand shocks account for 97% to 94% of the RER volatility between 1974 and 1994. In the case of monetary policy shocks, our results for Canada indicate that they account for 18% to 25% of the RER volatility at horizons of one quarter to four years. Previous studies, Farrant and Peersman (2006) and Clarida and Gali (1994), find a much smaller contribution: less than 4% of the RER volatility is explained by monetary shocks at any horizon.

In the case of Chile, our results are also in sharp contrast with previous evidence in Soto (2003). On the one hand, we find that real shocks (supply and demand) contribute 20% to

70% of RER volatility at horizons of one quarter to four years, whereas at similar horizons Soto (2003) finds that real shocks account for 70% and 90% of RER variance. On the other hand, we find that the contribution of nominal shocks to RER variance is between 55% and 20%, whereas Soto (2003) finds, at similar horizons, that nominal shocks contribute between 30% and 10% of RER volatility.

Overall, our results suggest that, in general, demand shocks account for a small proportion of the RER volatility, whereas nominal shocks play a much more important role in determining the RER dynamics. This is true for four of the countries, the exception being Israel. Our findings that real shocks play a less important role than nominal shocks differ from the previous literature. To understand the reason behind this discrepancy, we perform a subsample analysis. The idea is to test whether the relative importance of shocks has been changing over time. This possible change may come from two sources: i) structural changes that modify the transmission mechanisms of any *given* shock and/or ii) a change in the size of structural shocks.

In the next subsection we use Chile as a study case and test the extent to which the structure of the economy has changed over time. Then, we perform a rolling SVAR estimation for each country and compute the variance decomposition for different rolling windows. Thus we can test whether the relative contribution of real and nominal shocks has changed over time.

4.2 Have the transmission mechanisms changed? A study case for Chile

The period analyzed so far includes data from 1986 to 2011, a period in which different structural changes may have taken place in the countries under study. For instance, in this period Chile experienced several economic policy changes. As noted by Valdés (2007), in the second half of 1999, the authorities began to implement a number of changes in the macroeconomic policy framework, including the adoption of a full-fledged IT regime in September 1999, setting an explicit target of 3% for the CPI that replaced the crawling band target used in the previous decade. Other key changes included: (i) adoption of a free-floating exchange rate regime, (ii) deepening of the foreign exchange derivatives (forward) market, (iii) total opening of the capital account, and (iv) the nominalization of monetary policy in 2001 [7]. At the same time, the fiscal authority introduced in 2001 a new fiscal rule intended to isolate government expenditure from fluctuations in the copper price. This structural balance fiscal rule is such that a great proportion

[7] The monetary policy rate was changed from being real (inflation indexed) to being nominal.

of the fiscal revenues derived from copper exports are accumulated in a sovereign fund. In this way, fiscal expenditure is less sensitive to short-run fluctuations in the copper price.

Given the timing of economic policy changes, we estimate a SVAR for Chile in two different subperiods, 1990-1999 and 2000-2011, to test whether the transmission mechanisms have changed. The impulse-response function obtained from each estimation are presented in Figure 8. We find evidence of a declining pass-through: for a given exchange rate shock, the accumulated response of prices is smaller in the second subsample than in the first one (see fourth row and second column in Figure 8). Though the changes not statistically significant in the present application, the result is in line with previous findings for Chile in DeGregorio and Tokman (2004) and Caputo et al. (2006), among others.

We also find, that the policy rate was more sensitive to exchange rate fluctuations during the first subsample. In particular, in the face of an exchange rate shock the real rate increases by more in the first subsample. This result suggests that the Central Bank was more concerned with RER movements in the earlier period. This is broadly consistent with the findings in Caputo et al. (2006) who conclude that the monetary rule, characterizing the behavior of the Central Bank, reacted more strongly to RER fluctuations in the 1990s. This change in policy reaction coefficients is also found for the U.S. in Fernández-Villaverde and Rubio-Ramírez (2008). In particular, they offer compelling proof of changing parameters in the Fed's behavior. Monetary policy became appreciably more aggressive in its stand against inflation after Volcker's appointment.

In terms of the response of relative prices, we find that in the face of both supply and demand shocks, relative prices reacted more, and more persistently, in the 1990-1999 period. This evidence is suggestive of a structural change in the pricing behavior of firms. In particular, the evidence is consistent with firms setting prices more frequently when inflation is relatively high (1990-1999) than in periods of low and stable inflation (2000-2011). Our results are in line with Caputo et al. (2006) who find that prices in Chile were less sticky during the 1990-1999 period than in the 2000-2011 decade. For the U.S., Fernández-Villaverde and Rubio-Ramírez (2008) find similar results: lower rigidities correlate with higher inflation and higher rigidities with lower inflation.

Finally, we find that the RER, in the 2000-2011 period, reacted more to both interest rate and exchange rate shocks. This result is expected in a context in which a free floating exchange rate policy was adopted.

Overall, we find strong evidence of structural changes in the Chilean economy. Those changes are characterized by four elements: (i) a slightly lower degree of exchange rate pass-through to prices in the last decade, (ii) a lower degree of price flexibility in recent years, (iii) a weaker monetary policy response to RER movements, in the 2000-2011 period, and (iv) a RER that is more sensitive to interest rate and exchange rate shocks. These changes may be associated with a more credible monetary policy in a context of a free floating exchange rate regime and a countercyclical fiscal policy. To be more precise, a credible inflation targeting Central Bank can offset the impact of demand shocks on relative prices, if expectations are well anchored. In particular, the expectation channel may contribute to stabilizing prices, without the Central Bank having to move the interest rate too aggressively. This is a well know theoretical result (see Gali (2008)), which states, that the "threat" that the Central Bank will aggressively move the policy rate, in the face of demand shocks, induces price setters not to increase prices when confronted with new shocks. As a result, inflation does not increase and the central bank does not rise the interest rate: expectations are the stabilization mechanism.

4.3 The changing nature of RER fluctuations: Evidence from rolling SVARs

As discussed in the previous section, the Chilean economy experienced important structural changes that modified the transmission mechanisms. To assess the implications of these changes over the contribution of different shocks to the overall RER volatility, we perform a rolling window SVAR estimation for Chile, in the spirit of Wong (2000). We do this exercise for the full sample, 1986-2011, considering a fifteen-year estimation window. This window is shifted four quarters at a time.

In Figure 9 we present the variance decomposition derived from the rolling window estimation for Chile [8]. We find that the impact of demand shocks on the RER has declined substantially in the last decade. On the contrary, shocks to the exchange rate are transmitted much more aggressively to the RER. The relative importance of supply and monetary policy shocks remains unchanged. Overall, our results show that the relative importance of real and nominal shocks has changed dramatically since the mid 2000s. In particular, during the first 15 years of the

[8] The information is the average variance decomposition from the first to the sixteenth quarter.

sample, demand and supply shocks accounted for 70% and 20% of the RER variance, respectively, whereas monetary and exchange rate shocks accounted for the rest of the variance. As a consequence, in the first rolling window we find results similar to the ones reported in Soto (2003): real shocks are the most important source of RER variability. In the last rolling windows, however, results are reversed: demand and supply shocks account for a smaller fraction of the RER volatility, whereas nominal shocks are the main drivers of the RER dynamics. In particular, in the last estimation window demand shocks explain less that 1% of the overall RER volatility, whereas exchange rate shocks explain more than 50% of this volatility. This result is not determined only by the financial crisis of 2008, that may have contributed to give more importance to exchange rate shocks. It is a trend that began well before the crisis broke out.

The reason for the above results, for Chile, may be related to the arguments given in the previous section. In particular, a credible inflation-targeting regime implies that relative prices react less in the face of demand shocks and as a result, for a given nominal exchange rate, the RER will be more stable. Therefore, the relative impact of demand shocks on the RER is lower. At the same time, to the extent that other competing objectives (like nominal exchange rate control) are abandoned, shocks to the exchange rate itself are transmitted more strongly to the RER. In addition to the adoption of an IT regime, a fiscal rule is also able to attenuate the impact of a real shock over the RER. As shown by Medina and Soto (2007) for Chile and by Pieschacón (2012) for Mexico and Norway, the implementation of a fiscal rule, that saves a proportion of the commodity windfall, is capable of reducing the volatility of the RER in the face of a given commodity price shock. This reduction happens in all horizons. The main intuition for this result is that the fiscal rule, by saving part of the windfall, is able to smooth tradable and non tradable consumption, thus attenuating the increase in the relative price of non tradables (the inverse of the RER).

For the other countries we find similar results. For Canada (see Figure 10) the relative importance of demand shocks declined importantly in the last decade, at the same time that nominal shocks increased their relative importance. In the first rolling window, demand shocks explained nearly 50% of the RER volatility, whereas in the last estimation window (which ends in 2011), demand shocks accounted for just 3% of the RER variance. Monetary shocks increased its relative importance from 20% in the first rolling window, to 40% in the last period. In the case of exchange rate shocks, its relative importance increased from 4% to 30%, between the first and last estimation windows. As in the case of Chile, the shift in relative importance between real and nominal shocks is a process that began before the 2008 crisis hit. As a consequence, this may be related to structural changes that the Canadian economy experienced in the last decade.

Based on the rolling SVAR results for Chile and Canada it is possible to reconcile an apparent contradiction between our full sample results and the previous empirical evidence[9]. In particular, the declining relative importance of demand shocks vis-à-vis nominal shocks in both countries is a recent phenomenon[10]. Canada adopted and IT regime in 1991 and introduced a balance budget rule in 1998[11], in a context in which the nominal exchange rate has been freely floating since 1970.

For the rest of the countries we find, in general, similar results: demand shocks tend to explain less of the RER's volatility in recent periods, whereas nominal shocks increase their relative importance. In the case of Australia (Figure 11) demand shocks explained nearly 20% of the RER volatility in the first estimation window, whereas in the last estimation window those shocks explain just over 1% of the RER variance. Monetary policy shocks, on the contrary, increased its relative contribution to the overall RER variance from 10% to 60% between the first and the last estimation window. Australia adopted an IT regime in 1993 in a context in which the exchange rate was freely floating since 1983. Later on, in 1998, the fiscal policy framework, consisting of a budget balance rule (among other rules) was formalized in the Charter of Budget Honesty Act (Budina et al. (2012)).

In the case of Israel (Figure 12), the contribution of demand shocks declined from 70% to 5%, whereas exchange rate shocks increased its contribution to the overall RER volatility from 5% to 50%. As most of the countries under analysis, Israel adopted an IT in the early nineties. As in Chile, the inflation targets were changing over time: they moved from a range of 14% -15% in 1992 to 1% -3% in 2003. The exchange rate, on the other hand, has been freely floating since 1997. A budget balance rule was set in 1992, and was amended in 2004 to also include a provision for limiting real growth of the central government fiscal expenditure (Budina et al. (2012)).

[9]See Soto (2003), Farrant and Peersman (2006) and Clarida and Gali (1994).

[10]When we consider the initial periods, we obtain similar results to the ones reported in previous research: demand shocks are the main drivers of the RER dynamics in both countries.

[11]See Budina et al. (2012) for more details.

Finally, in Norway (Figure 13) the contribution of demand shocks is more stable, although it does decline over time, going from 15% to 4%. In the case of monetary shocks, the contribution increases from 11% to 20% and in the case of exchange rate shocks, the impact increases from 9% to 30%. As in the rest of the countries, in Norway the sources of RER volatility shifted from real to nominal shocks. This happened in the context of a full-fledged IT regime, adopted in 2001, and a freely floating exchange rate. Norway also adopted a fiscal balance rule in 2001. This rule established that the non-oil structural deficit of the central government should equal the long-run real return of the Government Pension Fund - Global (GPF) assumed to be 4 %. The fiscal guidelines, which also govern the GPF, allow temporary deviations from the rule over the business cycle and in the event of extraordinary changes in the value of the GPF (Budina et al. (2012)).

Overall, the sources of RER volatility in all countries shifted importantly, from real to nominal shocks. As shown, this happened in a context in which countries were moving to full-fledged IT regimes with freely floating exchange rates. It also coincided with the adoption of structural balance rules. We believe that this may explain the changing nature or RER fluctuations.

5 Conclusions

Understanding the sources of RER variability is one of the challenging issues in international economics. Based on empirical evidence[12], there is general consensus that real shocks (demand and supply shocks) play the most important role in determining the RER dynamics. On the contrary, nominal shocks (monetary policy and exchange rate shocks) contribute very little to this dynamics. In this context, the objetive of this paper is twofold. First, we quantify the relative importance of real and nominal shocks in shaping the RER dynamics in five IT countries: Australia, Canada, Chile, Israel and Norway in the period 1986-2011. Second, we determine the extent to which the contribution of those shocks, to the overall RER dynamics, has changed over time. Many of the countries under study went through several structural changes during the period analyzed. This fact is the motivation to assess the extent to which the relative importance of shocks may have changed over time.

[12]For a group of developed countries, see Farrant and Peersman (2006) and Clarida and Gali (1994). For the U.S., see Juvenal (2011) and for Chile, Soto (2003).

To address the previous issues, we estimate a SVAR model for the five IT economies for the period 1986-2011. In order to identify the impact of structural shocks on the RER in particular, and in the rest of the macro variables in general, we follow Uhlig (2005), Canova and Nicolo (2002), Farrant and Peersman (2006) and Juvenal (2011) by imposing sign restrictions on the responses of the variables to orthogonal disturbances.

Our main findings are as follows. In sharp contrast with the empirical evidence, we find that for the period 1986-2011 demand shocks tend to explain a small proportion of RER volatility in most countries. In that period nominal shocks were relatively more important in explaining RER fluctuations. When we perform a subsample analysis, however, we can reconcile the empirical findings in the literature with our results. In particular, we conclude that the relative importance of demand shocks declined importantly over time. In contrast, the relative importance of nominal shocks, and in particular, exchange rate shocks, increased in recent years. Those results are based on 15-year rolling window estimations in the spirit of Wong (2000). Overall, our results suggest that the adoption of a full-fledge inflation targeting regime, along with a floating exchange rate regime, could have contributed to the shift in the relative importance of demand and exchange rate shocks in the determination of the RER. This, in a context in which international financial markets were subject to important disruptions in the aftermath of the 2008 crisis.

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Figure 1: Nominal and Real Exchange Rate Volatility (10-year rolling window variance)

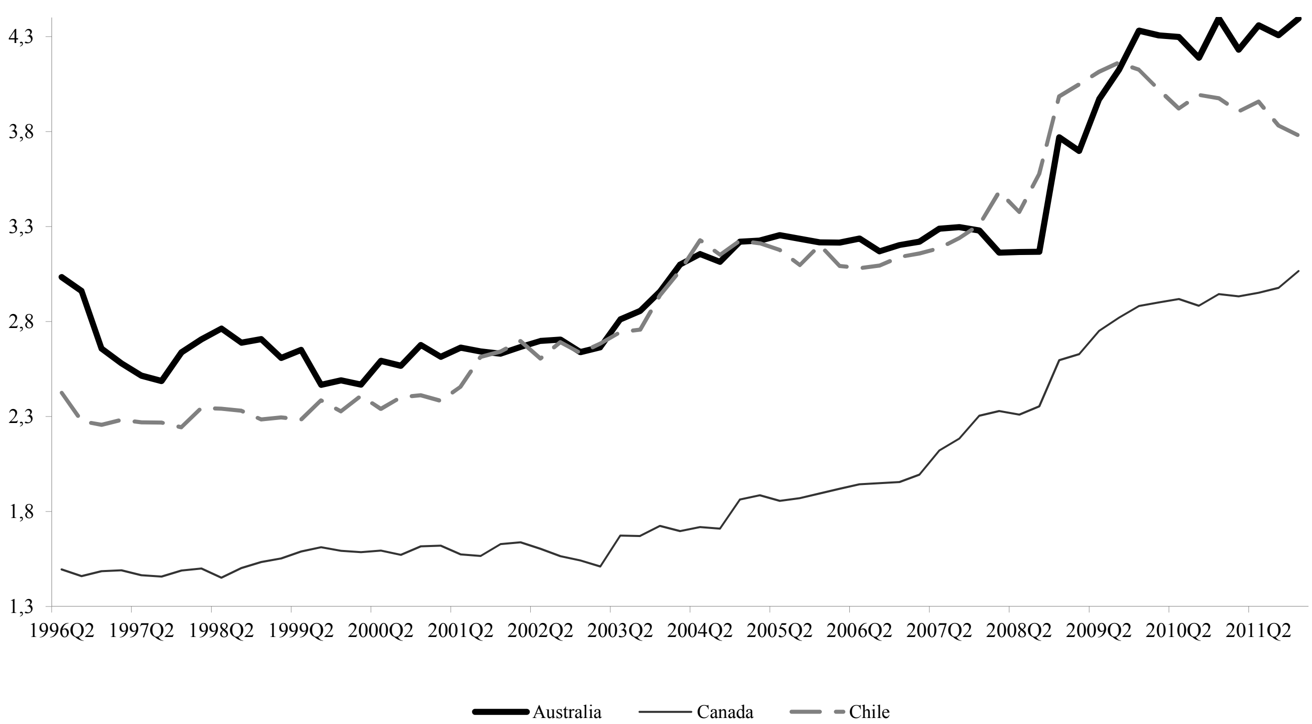


Figure 2: Nominal and Real Exchange Rate Volatility (10-year rolling window variance)

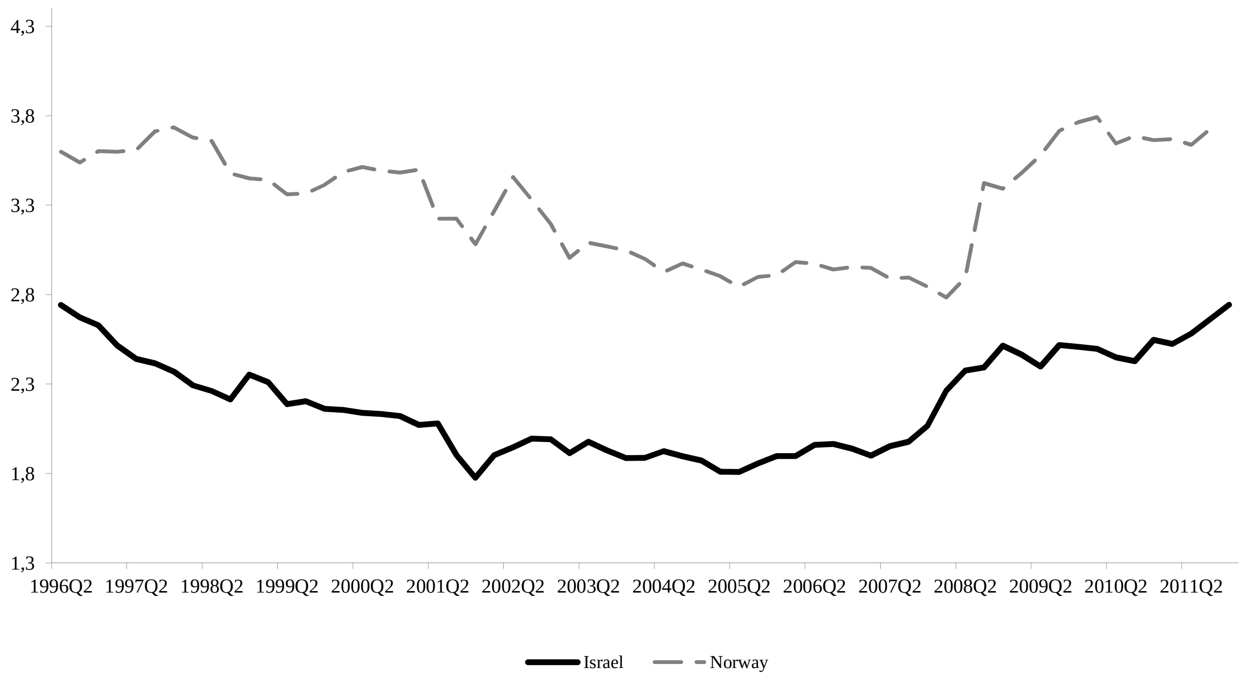


Figure 3: IRF from SVAR (solid line:median/dashed lines: 84th and 16th percentiles)

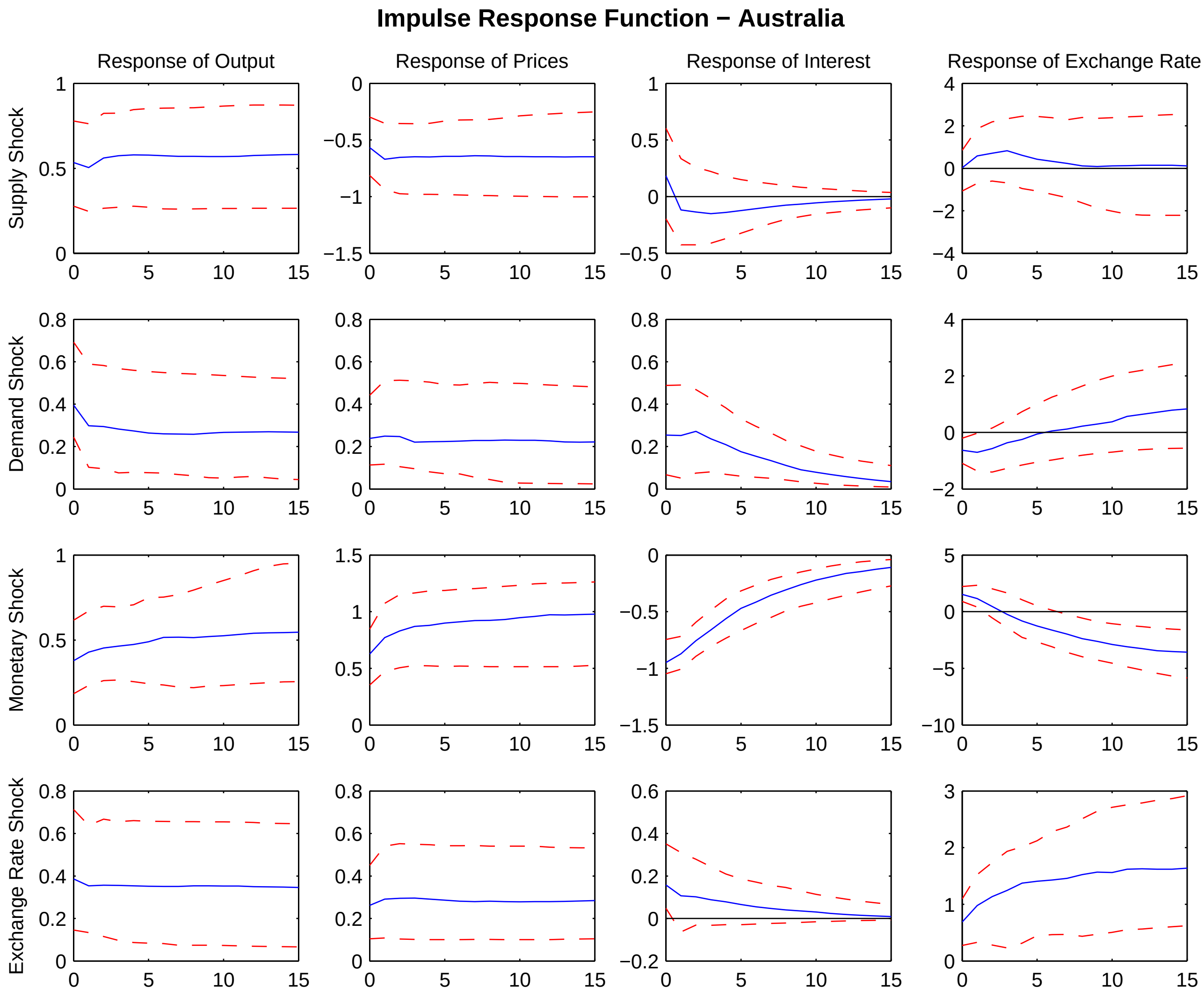


Figure 4: IRF from SVAR (solid line:median/dashed lines: 84th and 16th percentiles)

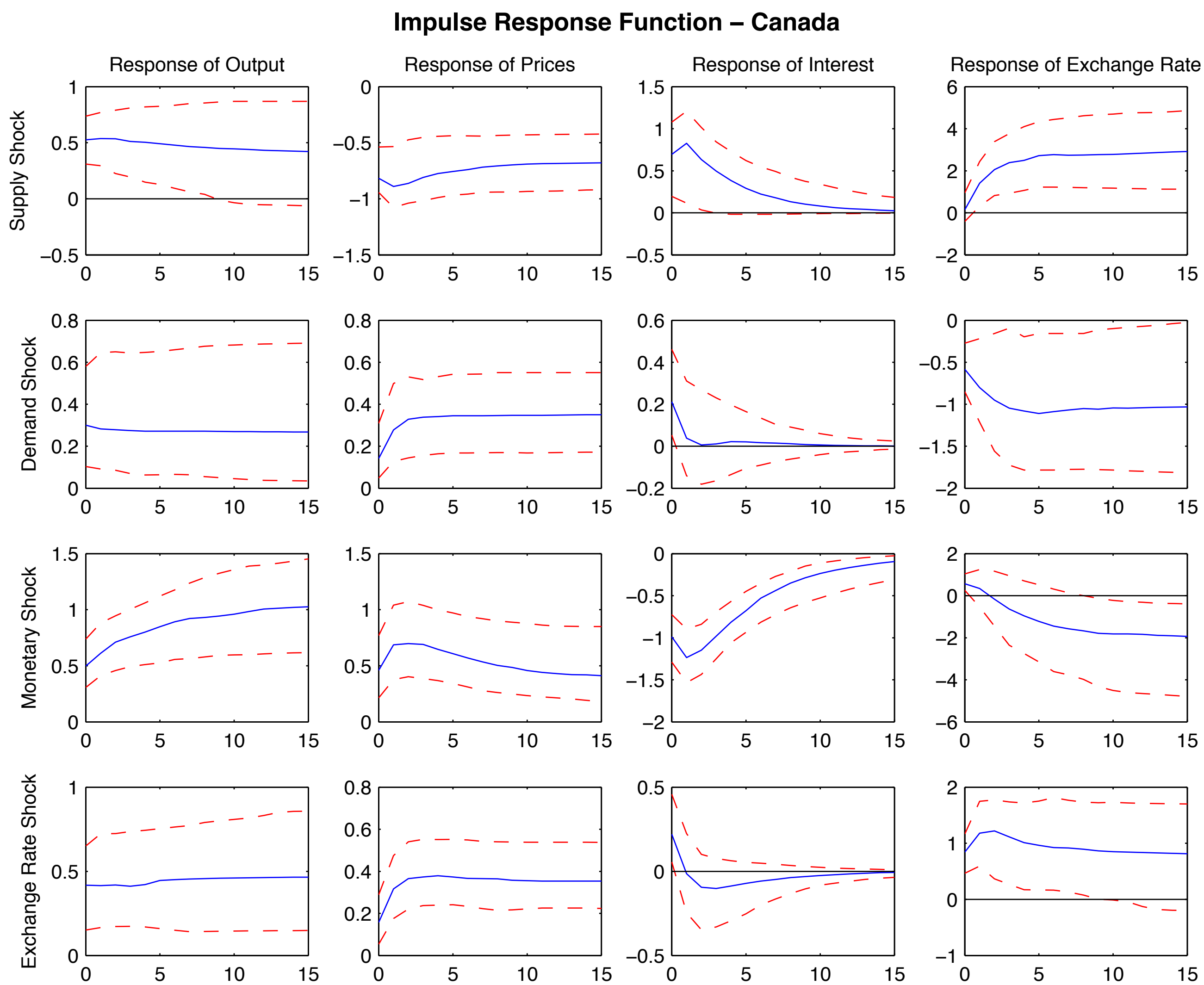


Figure 5: IRF from SVAR (solid line:median/dashed lines: 84th and 16th percentiles)

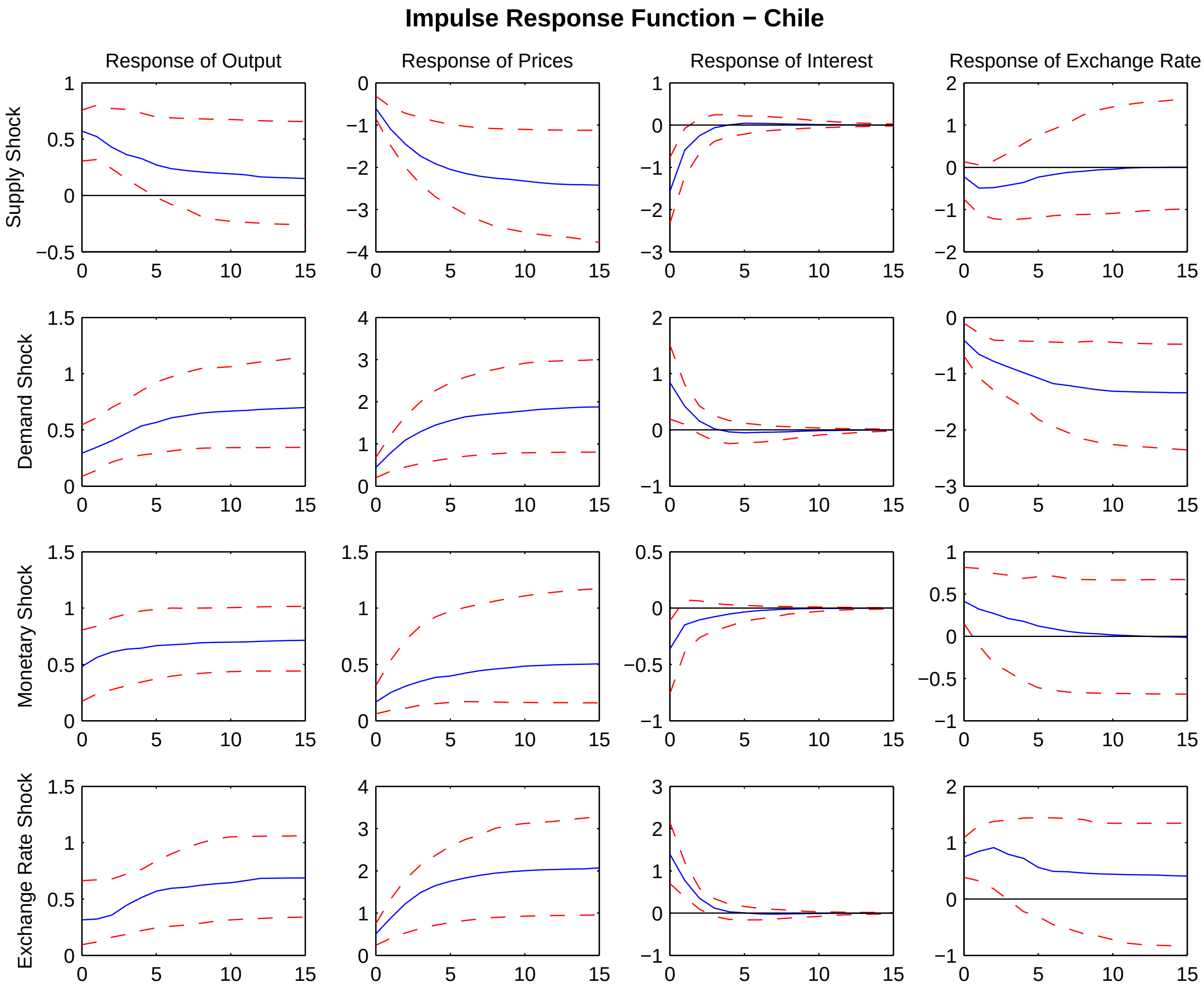


Figure 6: IRF from SVAR (solid line:median/dashed lines: 84th and 16th percentiles)

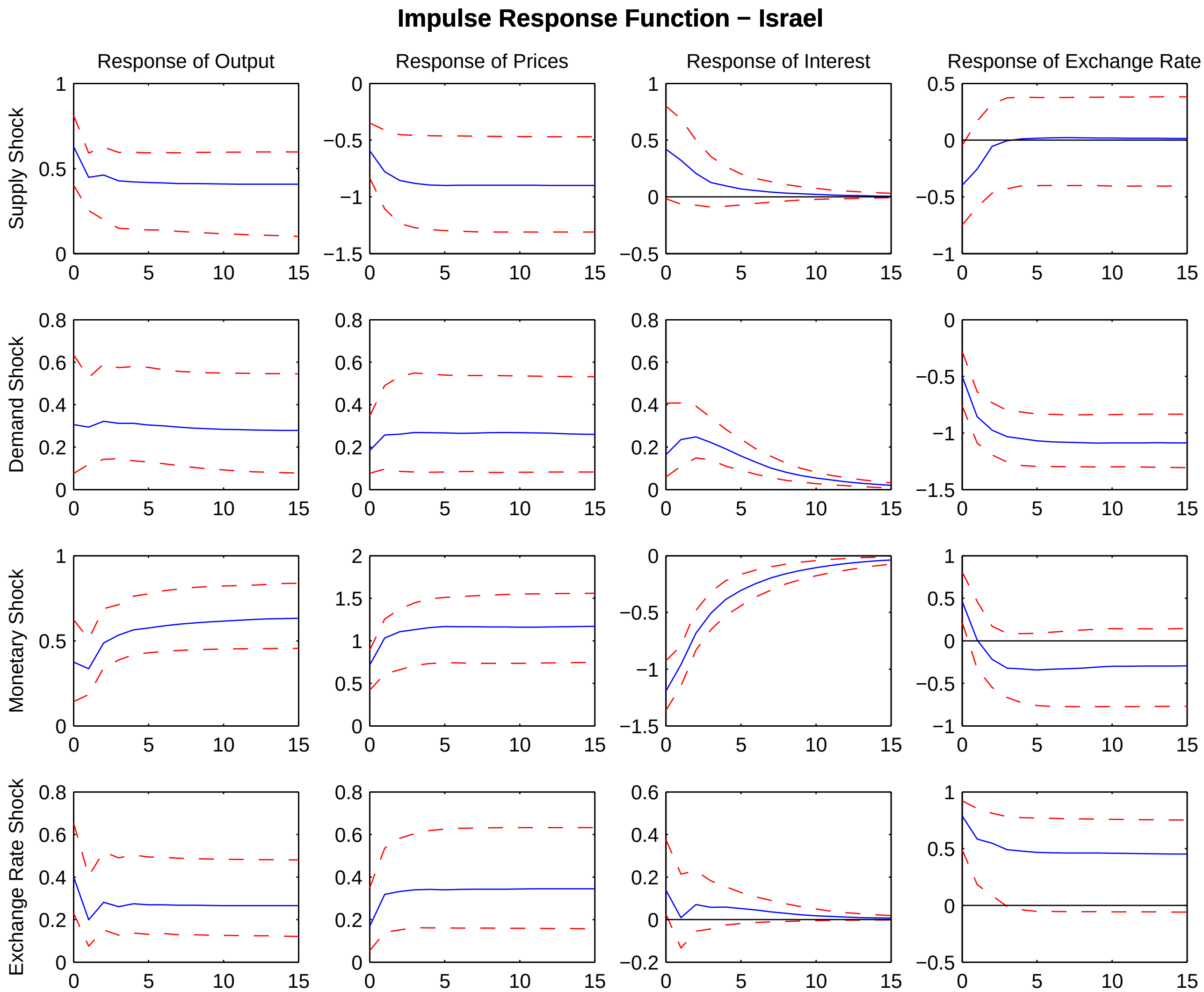


Figure 7: IRF from SVAR (solid line:median/dashed lines: 84th and 16th percentiles)

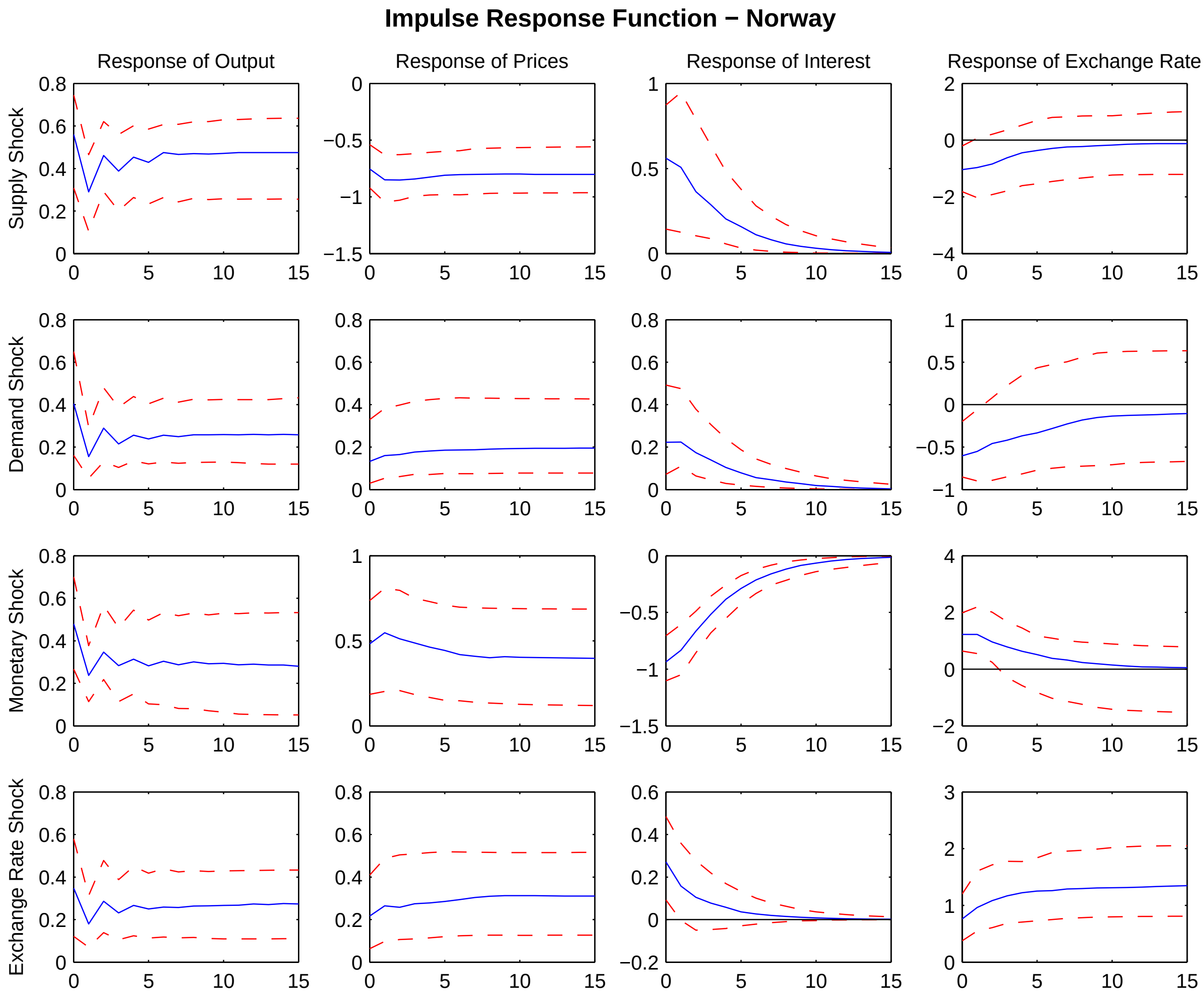


Table 3: Variance Decompositions of Real Exchange Rates

	Supply Shock			Demand Shock			Monetary Policy Shock			Exchange Rate Shock		
Horizon	Median	Upper	Lower	Median	Upper	Lower	Median	Upper	Lower	Median	Upper	Lower
Australia												
1	0.102	0.394	0.006	0.081	0.328	0.013	0.567	0.809	0.240	0.088	0.280	0.021
4	0.193	0.579	0.023	0.089	0.335	0.006	0.135	0.536	0.014	0.271	0.651	0.030
16	0.104	0.432	0.010	0.054	0.256	0.003	0.534	0.819	0.177	0.136	0.356	0.018
Canada												
1	0.122	0.387	0.009	0.143	0.459	0.031	0.175	0.408	0.028	0.374	0.590	0.096
4	0.492	0.762	0.193	0.082	0.254	0.009	0.095	0.420	0.017	0.119	0.377	0.013
16	0.472	0.763	0.136	0.062	0.176	0.005	0.256	0.712	0.045	0.043	0.215	0.004
Chile												
1	0.075	0.350	0.008	0.128	0.351	0.008	0.137	0.533	0.014	0.419	0.751	0.115
4	0.117	0.462	0.010	0.294	0.731	0.051	0.062	0.248	0.005	0.240	0.626	0.018
16	0.177	0.466	0.015	0.505	0.758	0.067	0.046	0.179	0.005	0.144	0.471	0.015
Israel												
1	0.121	0.379	0.006	0.176	0.442	0.047	0.156	0.379	0.027	0.387	0.653	0.149
4	0.038	0.172	0.004	0.629	0.802	0.390	0.092	0.287	0.007	0.140	0.379	0.010
16	0.041	0.164	0.004	0.629	0.833	0.413	0.105	0.349	0.004	0.113	0.343	0.009
Norway												
1	0.226	0.498	0.015	0.053	0.224	0.005	0.407	0.698	0.186	0.166	0.315	0.048
4	0.158	0.457	0.008	0.054	0.261	0.005	0.174	0.434	0.024	0.415	0.736	0.140
16	0.110	0.374	0.010	0.034	0.187	0.004	0.225	0.566	0.028	0.415	0.779	0.195

Upper and lower bands are,respectively, the 84th and 16th percentiles.

Figure 8: IRF Subsample Analysis (dashed-dotted lines: 84th and 16th percentiles)

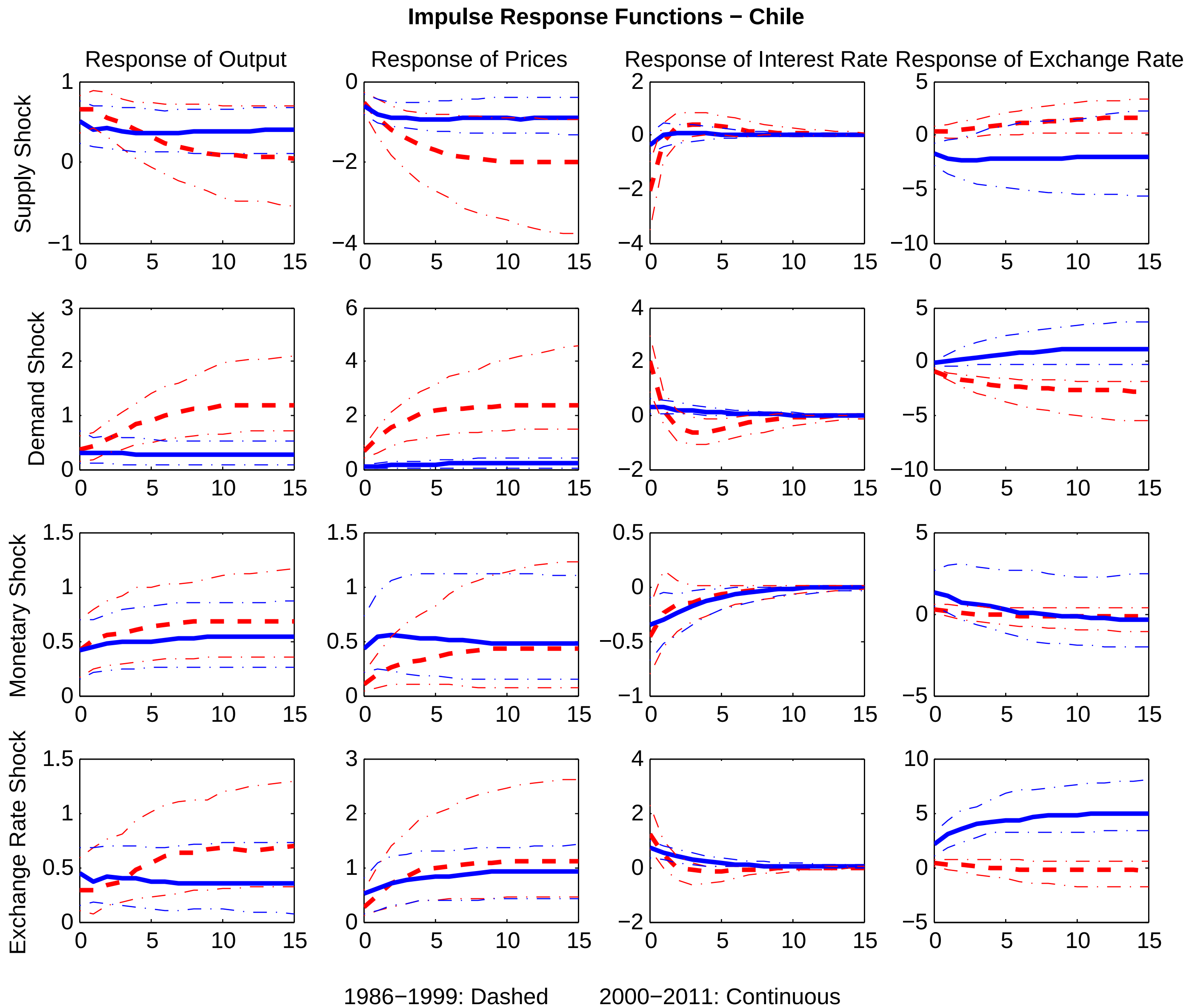


Figure 9: Variance Decomposition (solid line:median/dashed lines: 84th and 16th percentiles)

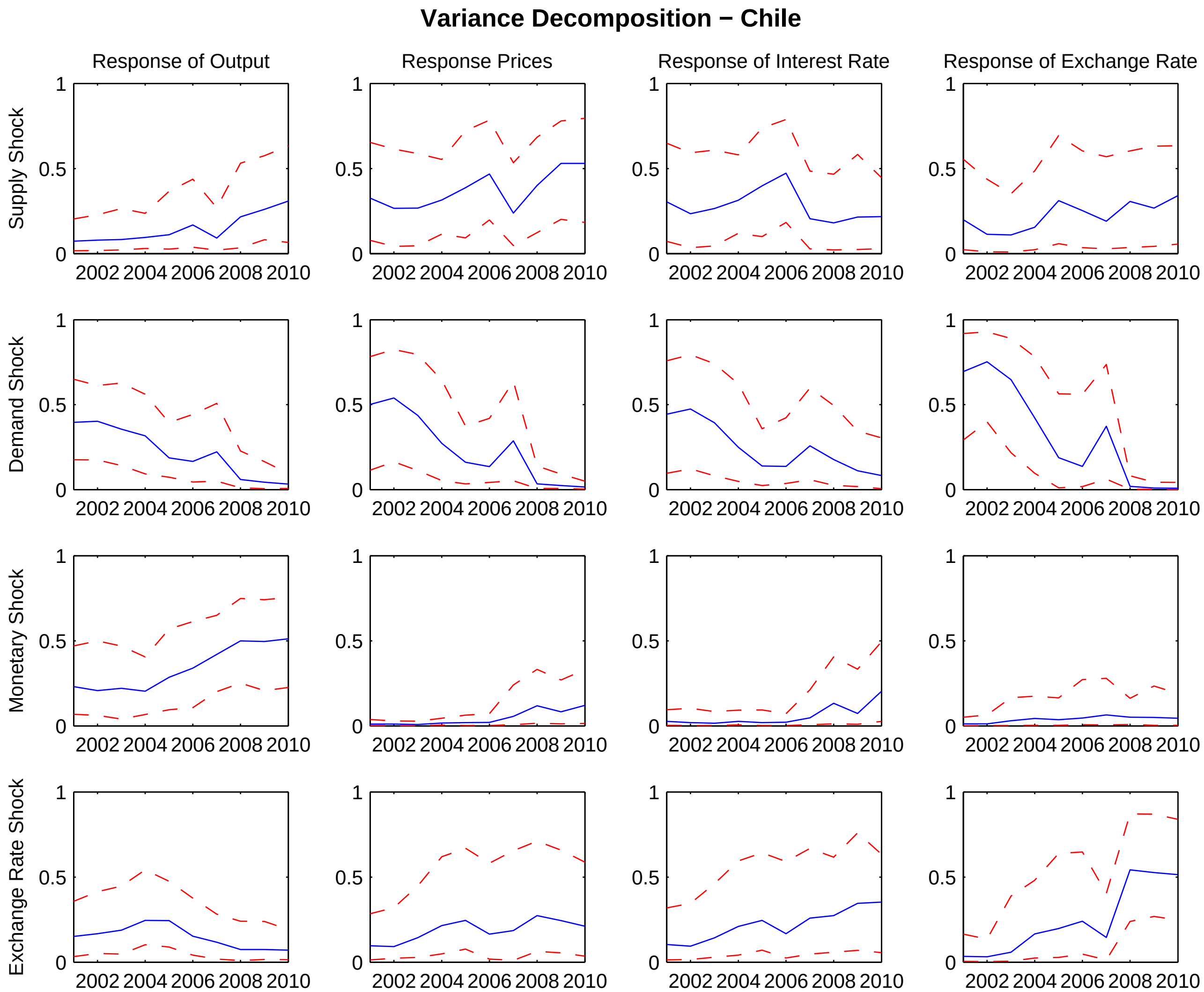


Figure 10: Variance Decomposition (solid line:median/dashed lines: 84th and 16th percentiles)

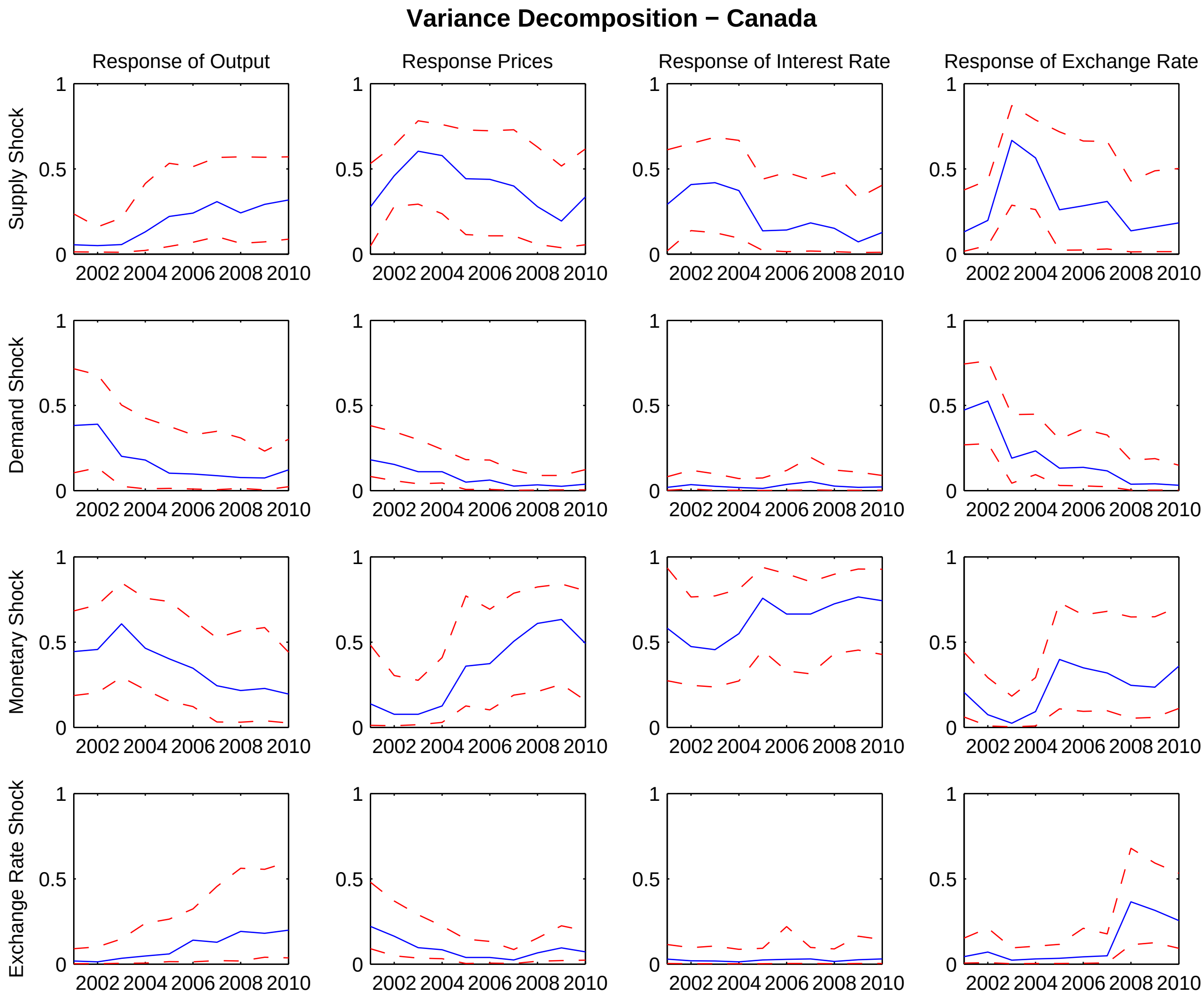


Figure 11: Variance Decomposition (solid line:median/dashed lines: 84th and 16th percentiles)

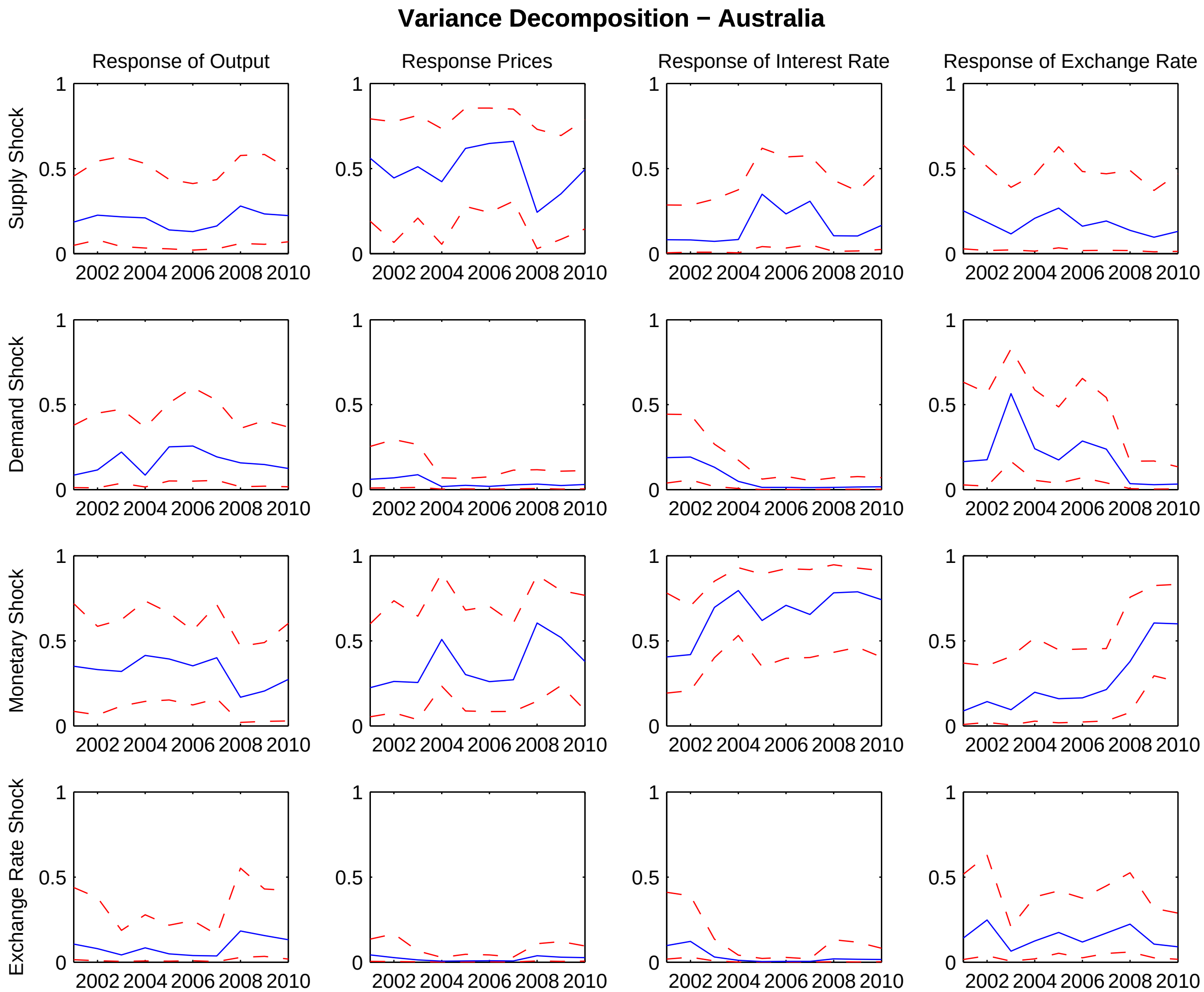


Figure 12: Variance Decomposition (solid line:median/dashed lines: 84th and 16th percentiles)

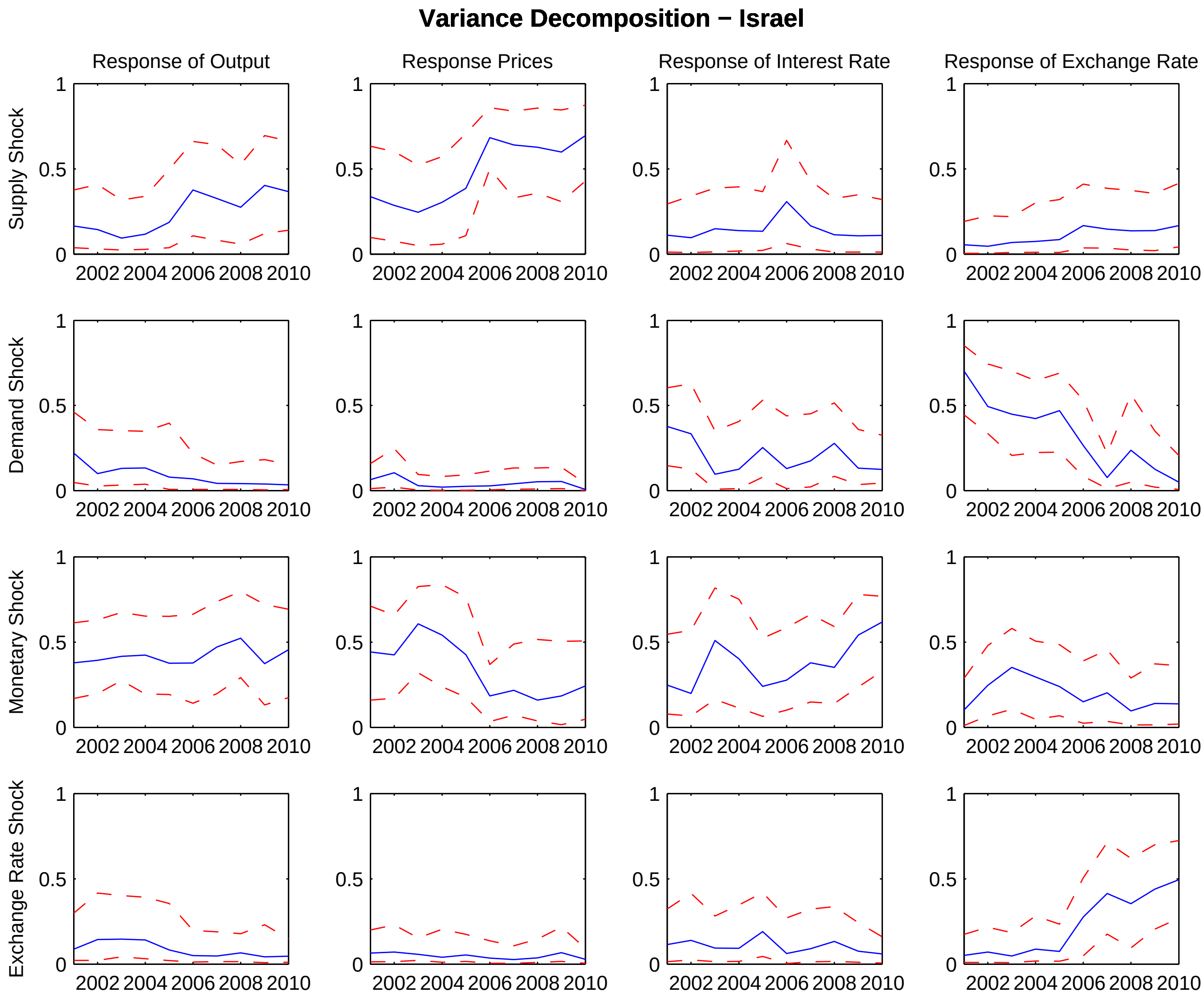
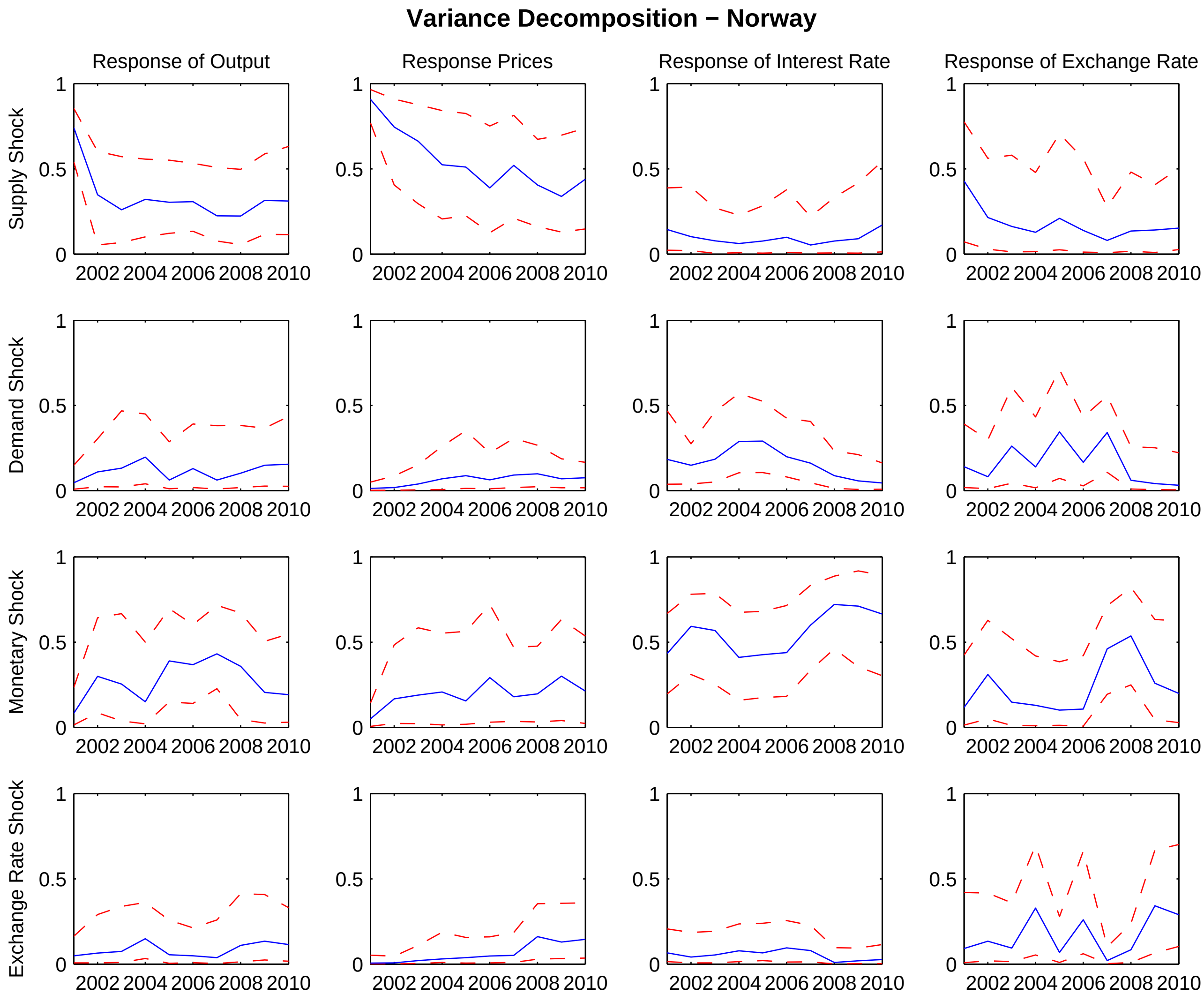


Figure 13: Variance Decomposition (solid line:median/dashed lines: 84th and 16th percentiles)



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