Reassessing the Effects of Foreign Monetary Policy on Output: New Evidence from Structural and Agnostic Identification Procedures

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Abstract

We investigate the propagation of a foreign monetary policy shock over a small open economy, in particular over the Chilean economy. Our motivation is based on the ongoing period of monetary normalization already started by the Fed. We follow Canova (2007) and compare the impulse response functions of structural VAR models and a DSGE model tailored for the Chilean economy. We use the recursive VAR model of Sims (1980) and an extension of the agnostic *VAR model of Uhlig (2005) and Arias et al. (2014) for small open economies following Koop and Korobilis (2010). The results suggest that the recursive VAR model does not properly identify the shock, and its implications are counterintuitive. On the contrary, beyond the quantitative differences, we find that the responses of the* agnostic *VAR model are qualitatively in line with those of the DSGE model except for output. However, the transmission of the shock to the local economy is limited but more persistent according to the*

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DSGE model. Finally, we spot different policy implications arising from both models. According to the agnostic *VAR model, the central bank does not need to raise its policy rate because the drop in activity offsets any jump in inflation; whereas in the DSGE model the rise in prices is partially accommodated by an increase in the policy rate. Thus, this comparison motivates an interesting discussion for the policymaker.*

Keywords: monetary policy shocks; small open economies; structural VAR; VAR identification; sign restrictions, DSGE model.

JEL classification: E32; F41.

1. INTRODUCTION

In December 2008, the federal funds rate dropped to the zero lower bound, and since then unconventional monetary policies have dominated the scene.[1] It took almost six years for the Fed to raise its policy rate and the zero lower bound was finally abandoned by the end of 2015. The ongoing period of monetary normalization combines two signals: *i)* concrete policy measures and *ii)* forward guidance. Currently, several central banks are evaluating the likely effects that US monetary normalization may have on their economies in order to inform policy decisions and assess potential risks since the propagation of that shock activates different channels (interest rate spread, exchange rate depreciation, problems of excessive debt burden if debt is denominated in dollars, etc.) that affect their economies in different dimensions. For example, private debt may have increased significantly due to lower interest rates and thus an increase in foreign rates can generate a domestic depreciation that amplifies the burden of foreign debt in domestic currency. Moreover, the current poor performance in many of these economies could further amplify the impact of the shock on debtors and the overall economy.[2]

[1] The Fed had strong reasons to intervene based on historical reasons; fears of a liquidity crisis that could lead the economy to another great depression.

[2] Consider another example to motivate the discussion further. The pass-through of exchange rate to inflation can trigger an increase in domestic interest rates to contain inflation. However, at the same time higher foreign rates can be associated with more adverse external conditions. They can have a negative impact on output, which in turn could help

Thus, this paper investigates the propagation of a foreign monetary policy shock over a small open economy, in particular over the Chilean economy. We use a comprehensive methodological framework that compares the impulse response functions (henceforth IRFs) of three models: two structural VAR models and a DSGE model tailored for the Chilean economy.[3] We follow this approach because according to Canova (2007), structural VAR models can be used to judge and validate the responses from DSGE models. Therefore, this comparison sheds new light and provides insights on the propagation of a foreign monetary policy shock over the Chilean economy, and in addition, it assesses the suitability of the micro-founded structure behind the DSGE model (i.e., the theoretical model). To this end, we use the recursive VAR model of Sims (1980) in which identification of structural shocks is based on a particular order of the variables in the system, along with an extension of the *agnostic* VAR model of Uhlig (2005) and Arias et al. (2014) for small open economies following Koop and Korobilis (2010). In this identification scheme, structural shocks are identified by imposing restrictions directly on the IRF.

Our findings can be summarized as follows. *1)* Consistent with several studies such as Bernanke et al. (2005), Mojon (2008) and Castelnuovo (2016) our analysis of IRFs lead us to conclude that identification of foreign monetary shocks is not straightforward in recursive VAR models. Therefore, the recursive VAR model fails to provide an informative benchmark to judge the plausibility of results from structural micro-founded models. *2)* On the contrary, the *agnostic* VAR model provides IRFs with dynamics that are broadly consistent with macroeconomic theory; hence, in our view results provide an informative benchmark for micro-founded models. *3)* Beyond the quantitative differences, we find that the IRFs of the *agnostic* VAR model are qualitatively in line with those of the DSGE model except for output. The DSGE model shows an initial increase in activity, which is explained by the improvement of the current account due to the real and nominal exchange rate depreciation, whereas the

to mitigate the hike in inflation and the central bank's response. Thus, we draw an interesting policy implication from this analysis.

[3] A standard dynamic stochastic general equilibrium (DSGE) model for a small open economy with nominal and real rigidities that is closely related to models developed by Christiano et al. (2005) and Smets and Wouters (2003, 2007).

agnostic VAR infers a significant drop in output. *4)* The transmission of the shock to the domestic economy in the DSGE model is limited but persistent. At least two reasons may explain this. First, by construction, there are many micro-founded restrictions in the model that increase the persistency of the shock (habit formation in consumption, quadratic adjustment cost for investment, etc.). Second, there is an excessive simplification in the definition of exogenous processes for foreign variables (e.g. foreign interest rates follow an AR(1) process). *5)* Finally, we spot different policy implications arising from both models. According to the *agnostic* VAR model, the central bank does not need to raise its policy rate because the drop in activity offsets any jump in inflation; whereas in the DSGE model the rise in prices is partially accommodated by an increase in the policy rate. Thus, this comparison enriches the discussion for the policymaker.

The results for the recursive VAR model are not new and have been documented many times before in the literature. The identification of monetary policy shocks in this setting has always been a subject of debate, and different specifications and models may lead to different responses. Bernanke et al. (2005) provided several reasons to understand this result:

1) The policy shock is not properly identified in the VAR system;

2) Variables of the VAR do not represent the real state of the economy;

3) The impulse response functions are biased because only a subset of the state variables of the economy are used to identify the shocks.

Similarly, Weber et al. (2009) argue that structural breaks may be crucial to understand the monetary transmission process. They found two structural breaks in their sample using data for the euro area. They report evidence in favor of an *atypical* interim period 1996-1999, but for the rest of the sample, the monetary transmission process remains adequate.

The *agnostic* VAR model of Uhlig (2005) imposes sign restrictions for a subset of the IRFs which in turn imply nonlinear constraints in the structural parameters of the model. In this paper, the author studies the impact of a monetary policy shock on output for the US economy by imposing a set of sign restrictions on all of the variables but leaving the response of output unrestricted. Thus, he refers to this method as an *agnostic* identification scheme.[4] Studies that follow this methodology are Canova and Nicoló (2002), Uhlig (2005), Rubio-Ramírez, Waggoner and Zha (2010) and Arias et al. (2014). These papers extended the VAR framework to also accommodate zero restrictions.

More recently, unconventional monetary policies in the US and the eurozone have encouraged the use of different frameworks to evaluate the impacts of these shocks (including SVARs, Bayesian VARs, DSGE, etc.), such as Carrera et al. (2015), Baumeister and Benati (2013), Castelnuovo (2012), Christensen and Rudebusch (2012), and Kapetanios et al. (2012), among others. Normally, the choice of restrictions is proposed by the researcher after a careful analysis based on economic theory. For example, if the interest rate differentials increase, then exchange rates are expected to rise due to adjustments one can anticipate from the uncovered power parity relation. This expected response might be questioned from several angles (e.g. UIP does hold). However, our choice is justified with sound economic theory. Other related applications are presented in Baumeister and Benati (2013), which analyzes the effects of unconventional policies with a time varying structural VAR, while Castelnuovo (2012, 2016) use a micro-founded DSGE approach to assess the macroeconomic impacts of an increase in interest rates. Finally, Carrera et al. (2015) have studied the impact of quantitative easing policies on small open economies (a subset of Latin American countries). That piece of research is a very close application to our paper because it uses similar identification methodology, but differs in the details of the posterior distribution calculation.[5]

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4 The key result from this paper is that neutrality of monetary policy is not inconsistent with the US data. More recently, Castelnuovo (2016) addresses this point for the euro area and analyzes the neutrality of monetary policy on inflation. He reports that the neutrality of VAR models may be due to a deficient identification of the policy shock, omitted variables or structural breaks.

5 The main difference of Carrera et al. (2015) and our approach is that they estimate the parameters of the blocks of the reduced-form VAR model with block exogeneity independently, whereas our approach remains closer to the original framework of Arias et al. (2014) since we estimate the parameters jointly.

The rest of the paper is organized as follows. The next section presents the VAR models. Section 3 briefly describes the structural DSGE model economy. Section 4 reports impulse response functions for each model. Finally, Section 5 concludes.

2. STRUCTURAL VAR MODELS AND IDENTIFICATION SCHEMES

Structural VAR models were introduced in the seminal paper of Sims (1980) as an alternative methodology to large-scale macroeconomic models of dynamic equations systems. A complete review of this literature is far beyond the scope of this paper, but the interested reader may refer to Kilian (2013) and Lütkepohl (2011) for a comprehensive analysis of it.

According to Canova (2007) structural VAR models can be used to judge and validate theoretical models, such as DSGE models, because VAR models are able to characterize the joint dynamics of several economic variables with only a few assumptions, whereas theoretical models rely heavily on a micro-founded structure to identify the dynamics between the variables of the system. Thus, the comparison of both methodologies enables us to assess the suitability of the micro-founded structure behind a theoretical model if and only if the structural VAR model is properly identified.

The structural VAR model for an SOE with block exogeneity (henceforth SVAR-SOE) is defined as:

1 $$\begin{bmatrix} y_t^{*\prime} & y_t^{\prime} \end{bmatrix}\begin{bmatrix} A_{01} & 0 \\ A_{03} & A_{04} \end{bmatrix} = \sum_{l=1}^{p}\begin{bmatrix} y_{t-l}^{*\prime} & y_{t-l}^{\prime} \end{bmatrix}\begin{bmatrix} A_{l1} & 0 \\ A_{l3} & A_{l4} \end{bmatrix} + c + \begin{bmatrix} \varepsilon_t^{*\prime} & \varepsilon_t^{\prime} \end{bmatrix}.$$

The zero blocks in the system reflect the block exogeneity assumption of the model in the spirit of Zha (1999). The $n \times 1$ vector y_t contains the endogenous variables for the domestic block (i.e., small open economy), whereas the $n^* \times 1$ vector y_t^* contains the endogenous variables for the foreign block. The A_i matrices and the vector of constants c are the structural parameters, whereas p denotes the lag order of the model. The inclusion of exogenous variables is straightforward, but they are excluded to simplify the notation. Finally, the vectors ε_t and ε_t^* are

Gaussian with a mean of zero and variance-covariance matrix I_{n+n^*} (the $n+n^*$ dimensional identity matrix).

The model can be compactly written as:

$$Y_t' A_0 = X_t' A_+ + \xi_t' , \tag{2}$$

where $Y_t' = \left[y_t^{*\prime} \; y_t' \right]$, $X_t' = \left[Y_{t-1}' \ldots Y_{t-p}' \; 1 \right]$, $A_t' = \left[A_1' \ldots A_p' \; c' \right]$, and the reduced-form is defined as:

$$Y_t' = X_t' B + u_t', \tag{3}$$

where $B = A_+ A_0^{-1}$, $u_t' = \varepsilon_t' A_0^{-1}$ and $E\left[u_t u_t' \right] = \Sigma = (A_0 A_0')^{-1}$. The estimation of SVAR models requires the identification of the structural shocks. Several alternative methodologies are available for the estimation and identification of these types of models. In particular, the most widely used methodologies can be grouped into three categories: recursive identification schemes, nonrecursive identification schemes and sign restriction schemes; in this paper we explore two of these identification schemes. The next two subsections explain the details of each approach.

2.1. Recursive Identification Scheme

The recursive identification scheme (henceforth recursive scheme or recursive VAR) was introduced in the seminal work of Sims (1980) and has become the conventional benchmark used in applied macroeconomics to validate responses of micro-founded structural models. The structural model is identified in four steps. First, the variables of the system are ordered in a specific way, the first variable being the most exogenous and the last one the most endogenous of the system. Second, the reduced-form model is estimated. Third, the structural innovations are recovered using a Cholesky decomposition over the variance-covariance matrix of the residuals of the reduced-form model (i.e., $\Sigma_\epsilon = PP'$). Finally, the structural parameters are estimated using the map of the reduced-form parameters to the structural parameters defined in the previous subsection:

$$B = A_+ A_0^{-1} \quad u_t' = \xi_t' A_0^{-1} \quad \Sigma_\epsilon = PP' = (A_0 A_0')^{-1}.$$

Note that the P matrix depends on the order of variables and hence is not unique, thus the econometrician needs to rely on some theoretical argument to justify his identification scheme. One of the main drawbacks of this approach is that economic theory cannot be incorporated directly into the model. Moreover, even in those cases in which the theory is able to suggest a particular order of causality among the variables of the system, the model can still generate IRFs that are counterintuitive or yield puzzling results.[6]

The block exogeneity assumption for the recursive VAR model for SOE implies that the reduced-form model cannot be estimated equation by equation using OLS. Instead, the estimation is performed by quasi-maximum likelihood; see Hamilton (1994) for a comprehensive discussion of this methodology.

2.2. Identification with Sign and Zero Restrictions

The sign restriction scheme follows a different approach to identify the structural shocks of the model. In this setting, the IRFs of the model are restricted directly according to economic theory. For instance, the contemporaneously dynamic response of inflation is set to be less than zero to a positive monetary policy shock as well as to the first periods following the shock. The methodology imposes linear and nonlinear constraints in the structural parameters of the model. In addition, the methodology does not require the complete identification of the full set of structural shocks of the model as in the recursive scheme. However, in this case the identification of the subset of structural shocks can be contaminated with other structural shocks that look alike. Thus, the full identification of the shocks should generate narrower confidence intervals for the IRFs of the system. Alternatively, the researcher can increase the number of restrictions to try to minimize the aforementioned problem.[7]

There are several ways in which sign restrictions can be introduced in VAR models. For instance, Blanchard and Quah (1989) developed an algorithm to restrict the long-run response of a set of variables

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6 Sims (1980) defines a puzzle as a situation in which the impulse response functions from an identification scheme do not match conventional wisdom from theoretical models.

7 Unfortunately, there is little guide to assess the potential gains from this approach. However, further research may help to understand the trade-off between these two approaches.

after a structural shock. Other authors have restricted the joint dynamics of the variables after a structural shock, as in Canova and De Nicoló (2002). A different approach is used in Uhlig (2005) to study the impact of a monetary policy shock on output for the US economy by imposing a set of sign restrictions in all of the variables but leaving the dynamic response of output unrestricted. The author referred to this method as an *agnostic* identification scheme since no assumptions were made with respect to the response of output. In this setting the restrictions are imposed directly over the dynamics of each variable of the system. More recently, extensions to these approaches can be found in Mountford and Uhlig (2009), Rubio-Ramírez et al. (2010) and Arias et al. (2014) (henceforth ARW). In particular, ARW expands Uhlig's methodology by incorporating zero restrictions; thus the dynamic responses of the variables after a shock can be set to zero, less than zero or greater than zero. In addition, the methodology allows the combination of these types of restrictions simultaneously in the dynamic response of the variables, which in turn should improve the identification of the structural shocks.[8]

In this paper we extend the methodology of Arias et al. (2014) for SOE; for ease of exposition we borrow Uhlig's definition and refer to this method as *agnostic* scheme or *agnostic* VAR. The block exogeneity assumption implies that the number of independent variables is not the same between the blocks of the model, and thus we follow Koop and Korobilis (2010) to use a more general framework to estimate VAR models. The implications of this identification scheme have not been explored comprehensively in the literature for SOE. This approach enables us to specify an alternative VAR model in which the identification of structural shocks is based on a set of restrictions that are driven by theory (or by stylized facts of the data) and not just by a particular order of the variables as in the recursive scheme. Thus, this method could potentially provide an interesting benchmark to evaluate and validate the responses of theoretical models.

In this setting, the identification of the structural shocks relies on Bayesian methods, and the algorithm can be summarized as follows:

8 More precisely, the inclusion of zero restrictions to Uhlig's method was developed in Mountford and Uhlig (2009) using a penalty function approach. However, according to ARW the method imposes additional sign restrictions in unrestricted variables, which generate narrower confidence intervals for the responses of the variable. Thus, ARW shows a new framework to combine the two types of restrictions.

1) Draw $(B;\Sigma)$ from the posterior of the reduced-form parameters.

2) Generate $(A_0^*;A_+^*)$ by using a mapping between the reduced-form and the structural parameters.[9]

3) Draw an orthogonal matrix Q such that $(A_0^*Q;A_+^*Q)$ satisfies the zero restrictions.[10]

4) Keep the draw if sign restrictions are satisfied.

5) Repeat 1 to 4 until the desired number of simulations is reached.

6) Compute the median and confidence bands for the full set of IRFs that satisfy the restrictions.

If no restrictions are imposed over the blocks of the SVAR-SOE, then each equation of the model has the same number of variables. In this case, the draws from the posterior of the reduced-form parameters can be obtained using the normal-Wishart prior (conjugate prior) and the posterior of the parameters are given by:[11]

$$b|\Sigma,y\sim N\left(\overline{B},\overline{\Sigma}\otimes\overline{V}\right)\text{ and }\Sigma^{-1}|y\sim W\left(\overline{S}^{-1},\overline{v}\right),$$

and:

$$\overline{S}=S+\underline{S}+\hat{B}'X'X\hat{B}+\underline{B}'\underline{V}^{-1}\underline{B}-\overline{B}'\left(\underline{V}^{-1}+X'X\right)\overline{B}.$$

The normal-Wishart prior imposes a Kronecker structure on

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9 The mapping between structural and reduced-form parameters can be implemented by using a function $h()$ such that $h(X)'h(X)=X$, i.e. Cholesky decomposition: $(A_0^*;A_+^*)=\left(h(\Sigma)^{-1};Bh(\Sigma)^{-1}\right)$.

10 Using the *QR* decomposition $(X=QR)$ which holds for any $n\times n$ random matrix in which each element is *i.i.d.* from a $N(0,1)$. In addition, ARW describes an algorithm to obtain recursively each column of Q, which improves the efficiency of the algorithm significantly when the researcher is interested in identifying more than one structural shock.

11 Where $\overline{v}=T+\underline{v}$; $b=vec(\overline{B})$ and $\hat{B}$ is the OLS estimator of B; $\overline{V}=\left[\underline{V}^{-1}+X'X\right]^{-1}$ and $\overline{B}=\overline{V}\left[\underline{V}^{-1}\underline{B}+X'X\hat{B}\right]^{-1}$; the hyperparameters $\underline{\alpha}$, $\underline{V}$, and $\underline{S}$ characterize the prior distributions of the parameters: $b|\Sigma,y\sim N\left(\underline{B},\underline{\Sigma}\otimes\underline{V}\right)$ and $\Sigma^{-1}|y\sim W\left(\underline{S}^{-1},\underline{v}\right)$.

the variance-covariance matrix of b which in turn implies that for each element of b, say b_i the $\text{cov}\left(b_i, b_j\right) \neq 0$ for all $i \neq j$. Unfortunately, the block exogeneity assumption requires a block of zeros in the reduced-form model which means that this set of parameters must be independent from the rest of the parameters. Therefore, the normal-Wishart prior is not suitable to estimate the SVAR-SOE model. Instead, we need to specify a prior that breaks the Kronecker structure in the variance-covariance matrix of b.

Following Koop and Korobilis (2010), we use the independent normal-Wishart prior that defines the posterior of the parameters as follow:[12]

$$b\left|\Sigma, y \sim N\left(\bar{B}, \bar{V}\right) \text{ and } \Sigma^{-1}\right|y, b \sim W\left(\bar{S}^{-1}, \bar{v}\right),$$

and:

$$\bar{S} = \underline{S} + \sum_{t=1}^{T}\left(y_t - Z_t b\right)\left(y_t - Z_t b\right)'.$$

Thus, the main methodological contribution of this paper is to combine the methods of Koop and Korobilis (2010) and Arias et al. (2014) to identify the SVAR-SOE model. In this setting, the model needs to be redefined in the following way. First, rewrite 3 as:

$$y_{mt} = z'_{mt} b_m + \varepsilon_{mt}.$$

Where t is the time index and m indicates the variable (i.e., equation); y_{mt} specifies the t^{th} observation of the m^{th} variable and z_{mt} is a vector that contains the explanatory variables for the m^{th} equation at time t. Second, define b_m as the vector that contains the parameters of the m^{th} equation and M as the total number of equations. Note that in this case the z_{mt} vector can vary across equations or blocks of the model. Third, stack the b_i vectors and z'_{mt} matrices as:

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12 Where: $\bar{v} = T + \underline{v}$, $\bar{B} = \bar{V}\left[\underline{V}^{-1}\underline{B} + \sum_{t=1}^{T} Z_t'\Sigma^{-1}y_t\right]$, and $\bar{V} = \left[\underline{V}^{-1} + \sum_{t=1}^{T} Z_t'\Sigma^{-1}Z_t\right]^{-1}$; the hyperparameters $\underline{\alpha}$, $\underline{V}$, and $\underline{S}$ characterize the prior distributions of the parameters: $b \sim N\left(\underline{B}, \underline{V}\right)$ and $\Sigma^{-1} \sim W\left(\underline{S}^{-1}, v\right)$ with $p\left(b, \Sigma^{-1}\right) = p(b)\,p\left(\Sigma^{-1}\right)$.

$$b = \begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ b_M \end{pmatrix} \qquad Z_t = \begin{pmatrix} z'_{1t} & 0 & \dots & 0 \\ 0 & z'_{2t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & z'_{Mt} \end{pmatrix}.$$

Next, define $y_t = \left(y_{1t}, \dots, y_{Mt}\right)'$, $\varepsilon_t = \left(\varepsilon_{1t}, \dots, \varepsilon_{Mt}\right)'$ and write the model more compactly as:

$$y_t = Z_t b + \varepsilon_t.$$

The total number of parameters is given by $k = \sum_{j=1}^{M} k_j$ and $\varepsilon_t \sim N\left(0,1\right)$. Note that b is a $k \times 1$ vector and Z_t is an $M \times k$ matrix. Finally, stack y_t, ε_t and Z_t as column vectors and define $\varepsilon \sim N\left(0, I \otimes \Sigma\right)$ to write the model as:

4 $$y = Zb + \varepsilon.$$

The notation in equation 4 is consistent with the notation of Koop and Korobilis (2010) for the independent normal-Wishart prior. Note that the posterior of Σ is not independent from the draw of b and hence direct sampling from the posterior is not feasible. Instead, a sequential algorithm can be used in which sequential draws are taken from the conditional posterior distributions of $p\left(b \middle| y, \Sigma\right)$ and $p\left(\Sigma^{-1} \middle| y, b\right)$, i.e., a Gibbs sampling algorithm.[13]

3. A DSGE MODEL FOR CHILE

In this section, we briefly describe the DSGE model for Chile. We use the model of Medina and Soto (2007a) to compute the impulse response to a 1% foreign monetary policy shock. The model is a new

[13] We use a burn-in period to achieve convergence to the posterior distribution. In particular, we made 5,500 simulations and burned the first 500 simulations. We also tried with a different number of simulations but the results did not change significantly. In addition, we discard the draws for which the eigenvalues of the companion of the VAR model were greater than one in absolute value.

Keynesian small open economy model, which is closely related to the framework of Christiano et al. (2005) and Smets and Wouters (2003, 2007). However, it has additional and specific features to describe the Chilean economy, such as a representative commodity-exporting firm, a *structural* fiscal policy rule, and a monetary policy rule that responds to changes in headline CPI inflation (we refer to Medina and Soto, 2007a, for a more detailed description of the model).

This model has been extended in several directions to address specific questions and has also been re-estimated to take advantage of recent data. Examples are the learning extension to replicate the current account dynamics of Chile as Fornero and Kirchner (2014) and Fornero et al. (2015) conduct several policy experiments simulating a copper price shock. In the current version, we abstract from these additions.[14]

A full description of the model is beyond the scope of this paper. Therefore, in the remainder of the section, we briefly describe its main features. The domestic economy is composed of a continuum of households, a fraction of which are non-Ricardian without access to the capital market. These non-Ricardian households consume their entire wage income. The remaining Ricardian households make intertemporal consumption-savings decisions in a forward-looking manner, to maximize the present value of utility.

There are three types of sectors in the domestic economy. First, there is a continuum of firms producing differentiated varieties of intermediate tradable goods, with monopoly power and sticky prices à la Calvo (1983). These firms use labor, capital and oil as inputs and sell their goods to competitive assemblers that produce final domestic goods, which are sold in the domestic and foreign market. There is a representative capital goods producer that rents capital goods to the intermediate goods producing firms. The optimal investment composition is determined through cost minimization, where we assume costs of adjusting investment, following Christiano et al. (2005). All firms are owned by Ricardian households. Second, there is an imported goods sector with a continuum of retail firms that repackage a homogenous good from abroad into differentiated

[14] Robustness exercises were done using the model of Fornero and Kirchner (2014) and Fornero et al. (2015) and we did not find any relevant advantage of adding an endogenous commodity-exporting sector in order to compute the IRFs to a foreign monetary policy shock.

imported varieties. There is a large set of firms that use a CES technology to assemble final imported goods from imported varieties. These firms also have monopoly power and set their prices infrequently. All firms are also owned by Ricardian households. Third, there is an exogenous commodity-producing sector composed of a unique representative firm. The entire production is exported abroad and the international price of the commodity is taken as given. The government owns a fraction of the assets of that firm, and foreign investors own the remaining fraction, where the revenue is shared accordingly.

The central bank conducts the monetary policy through a simple Taylor-type feedback rule for the nominal interest rate and responds to headline CPI. The fiscal policy follows a structural balance fiscal rule, where government expenditure (government consumption and transfers to households) depends on cyclical adjustments of commodity price and output gap. In addition, the model includes distortional taxes in consumption, income, and capital gains.

There is a foreign sector composed of five exogenous variables (GDP, inflation, interest rate, oil price, and commodity price). We assume that the dynamics of these foreign variables are described by independent autoregressive processes of order one, AR(1), as in Medina and Soto (2007a) and Fornero and Kirchner (2014). We choose this framework instead of a foreign SVAR block (as in Fornero et al., 2015) to avoid selecting a SVAR identification scheme in the DSGE model.[15]

Finally, the model is parameterized using estimates from Bayesian estimation techniques with quarterly data covering the period 2001Q3-2007Q4 and 2001Q3-2014Q4 to analyze the robustness of the results. We use their posterior mean to compute the impulse responses to a foreign interest rate shock.[16]

[15] In this case, the identification scheme chosen for the foreign SVAR block would influence the impulse responses computed by the DSGE.

[16] Details of the Bayesian estimation are available on request. In particular, the persistence of the shock is calibrated to 0.87 following Medina and Soto (2007a). This value arises when the AR(1) process is estimated with a sample that ends before the subprime crisis.

4. RESULTS

This section is divided into four parts for ease of exposition. The first part describes the data used to estimate the VAR models along with the set of identified assumptions behind the recursive and *agnostic* schemes. The second part shows the comparison of the IRFs for both identification schemes and highlights their similarities and differences. The third part shows the IRF from the DSGE model for the Chilean economy. Finally, the last part compares the IRFs of the VAR and DSGE models. Thus, this comparison between models sheds new light and provides insights on the propagation of a foreign monetary policy shock over the Chilean economy, while it also assesses the suitability of the DSGE model (i.e., the theoretical model).

4.1 Data and Identification Schemes for SVAR-SOE Models

The data are monthly observations covering the period from January 1996 to December 2007[17] (1996m01-2007m12). Both recursive and *agnostic* identification schemes use the same data set. Table 1 shows the variables for each block of the SVAR-SOE model.

We transform price indexes in nominal US dollar terms (original sources) to real prices by dividing (deflating) by an external price index constructed to reflect the foreign Chilean trade structure. Domestic real GDP, investment, and price indexes are seasonally adjusted using the Census X-12 procedure when they are not available in seasonally adjusted form from the original source. The interest rates are defined in levels and the rest of the variables in logs. We choose a two-month lag based on standard information criteria and also following the recommendation of Castelnuovo (2016).

[17] The data after December 2008 is excluded because we want to isolate the propagation of the shock during a *normal* monetary regime, and clearly this was not the case after December 2008 since the federal funds rate experienced a unique path compared to its historical behavior (from September 2007 to April 2008, the policy rate decreased from 5.25% to 2%). However, we also estimate the models using the implicit foreign interest rate (shadow federal funds rate) covering the period from January 1996 to December 2014 to analyze the robustness of our results since this rate is not bounded below by zero.

Table 1

SET OF VARIABLES FOR SVAR-SOE MODELS

Foreign block (US)	*Domestic block (Chile)*
Industrial production index (y*)	Index of economic activity (y)
Consumer price index (CPI*)	Real machinery and equipment investment (Ime)
US federal funds rate (r*)	Real construction investment (Ic)
(US shadow federal funds rate)	Core consumer price index (CPIx1)
(Real price of oil)	Nominal monetary policy rate (r)
	Real exchange rate (RER)

Note: We use the Chow Lin procedure to transform quarterly into monthly frequency (e.g. domestic investments). Variables in parentheses in the foreign block are considered only for robustness exercises and not for the baseline model (exercises not reported). For further details concerning variables, sources and transformations see Table 1.A in Appendix A.

We do not include cointegration relations in the SVAR-SOE because we analyze the short-term dynamics and not the long-run behavior of the model. The main drawback of this approach is that we need to rely on simulation methods to make valid inference over the IRFs of the models; see Sims et al. (1990) for a comprehensive discussion of this issue. Finally, we control for the real price of copper and linear time trends, and add a constant term to each equation of the model.

The recursive VAR model is specified as in Fornero et al. (2015); the variables for each block were ordered according to Table 1 (i.e., most exogenous variables from top to bottom). In particular, this setting assumes that the domestic policy rate reacts contemporaneously with the rest of the variables in the system except for the exchange rate. Moreover, it cannot have a contemporaneous impact on the rest of the variables of the domestic block except the exchange rate; whereas the foreign policy rate has a contemporaneous impact over the domestic block but not over the rest of the variables of the foreign block.

Table 2 shows the set of restrictions for the *agnostic* VAR model. In addition, the table also describes two alternative *agnostic* models in order to assess the robustness of the base model. The foreign monetary policy shock is assumed to be positive for at least one month. The

Table 2

SIGN AND ZERO RESTRICTIONS FOR AGNOSTIC VAR MODELS

	Base model		*Mod A*	*Mod B*
	h = 0	*h > 0*	*h > 0*	*h > 0*
Foreign block				
US federal funds rate (rus)	1	?	?	?
Industrial production index (Yus)	0	−1	−1	−1
Consumer price index (CPIus)	0	−1	−1	−1
Domestic block				
Interest rate (r)	?	?	?	?
Monthly production index (Y)	0	?	?	?
CPI core	?	?	?	?
Investment (I)	0	−2	−1	−3
Real exchange rate (RER)	1	?	?	?

Note: Restrictions are imposed over the monthly IRFs of the model after a positive foreign monetary policy shock. Positive or negative entries indicate the length of the sign restrictions, whereas zero entries indicate zero restrictions. Finally, question marks (?) indicate that no restrictions were imposed over the IRF of the variable at that horizon. We also consider two additional alternative sets of restrictions for the base model, see Table 2.A in Appendix A for more details.

shock does not have a contemporary impact on the foreign block or on domestic output and investment (both types of investment). We remain *agnostic* with respect to the contemporaneous response of the domestic policy rate and CPI, but we assume a real depreciation that lasts for at least one month. Finally, we assume that the variables of the foreign block react to the shock with a lag as well as domestic investment, but we assume a more persistent impact over the latter variable based on empirical data.[18]

[18] A different approach would be to rely on an *agnostic* VAR that heavily restricts the foreign block while minimizing the number of restrictions in the domestic block or in the extreme case leaving it completely unrestricted. However, the short sample of the data available for the Chilean economy makes this approach unsuitable since there is not enough information (data) to unveil the propagation of the shock.

The two alternative *agnostic* VAR models explore the sensitivity of the results to the restrictions imposed over domestic investment, which are perhaps the more controversial of the restrictions. In particular they consider two cases, one in which negative sign restrictions only last one period (Mod A) and a second case in which these restrictions last for at least three periods (Mod B). Thus, the base model lies between these two alternative cases. We also consider two additional alternative models in which we increase the restrictions over foreign monetary policy and the real exchange rate for the base model; see Table 2 of Appendix A for further details of these two cases.

The IFRs for the three cases are computed using monthly data, but we aggregate the monthly responses to quarterly responses in order to make the results comparable to the IRFs of the DSGE model. Alternatively, the IRFs can be estimated using quarterly data directly, but we argue that the identification of the foreign monetary policy shock is more reasonable at monthly frequency, because at quarterly frequency the restrictions constrain the contemporaneous response of the variables, which at the latter time frequency would imply stronger identifying assumptions. The same argument applies to the recursive scheme.

4.2 Results for SVAR-SOE Models

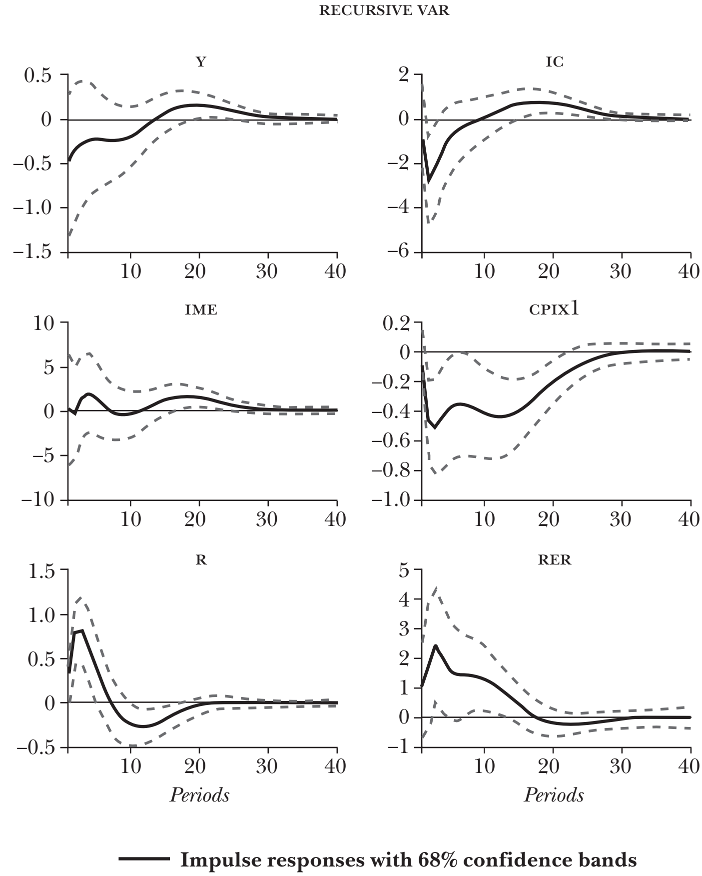
To begin with, we illustrate in Figure 1 the impulse responses of the domestic blocks to a 1% positive shock to the foreign interest rate (100 basis points) for the SVAR-SOE model according to the recursive (left panel) and *agnostic* (right panel) identification schemes.

Figure B.1 (Apenddix) shows the responses for the foreign blocks.

In general, the identification of the recursive VAR model yields puzzling responses. In particular, the monetary policy shock is associated with expansionary conditions in the world economy (a boost in trade partners' activity, increases in foreign prices, and in real commodity prices). In the domestic economy, the effect on investment is slightly positive, while at the same time the impact on local activity is not significant. The fluctuations of RER and CPIx1 turn out to behave inconsistently because the appreciation of the real exchange rate should be associated with higher inflation, but the CPI drops. The drop in inflation can be associated to the local response of the interest rate.

Figure 1

IMPULSE RESPONSES FOR THE RECURSIVE AND AGNOSTIC IDENTIFICATION SCHEMES FOR THE DOMESTIC BLOCK TO A FOREIGN MONETARY POLICY SHOCK

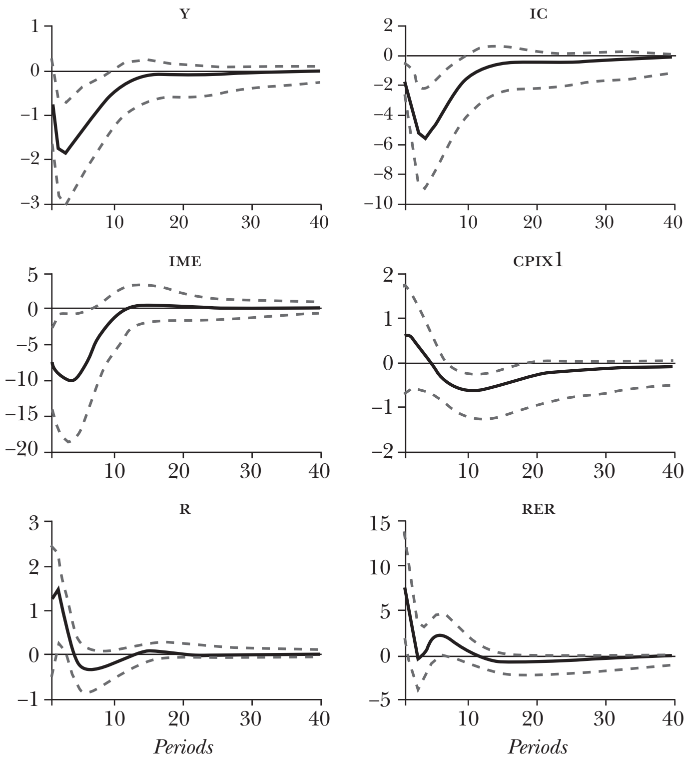


Note: The figure shows the quarterly responses to a 1% positive shock to the foreign monetary policy rate at the monthly frequency. The quarterly responses were computed by aggregating the monthly responses of the model.

Figure 1 (cont.)

IMPULSE RESPONSES FOR THE RECURSIVE AND AGNOSTIC IDENTIFICATION SCHEMES FOR THE DOMESTIC BLOCK TO A FOREIGN MONETARY POLICY SHOCK

AGNOSTIC VAR



Note: The figure shows the quarterly responses to a 1% positive shock to the foreign monetary policy rate at the monthly frequency. The quarterly responses were computed by aggregating the monthly responses of the model.

Thus, according to these results the foreign shock has a small and limited impact over the domestic economy. In addition, the identification infers that the central bank reacts aggressively to contain any jump in inflation due to the pass-through of RER to inflation. However, at the same time the recursive identification scheme infers almost no impact over the local activity and investment.[19] There are at least two problems with this interpretation. First, according to the dynamics of the foreign block, the recursive VAR model is not able to identify the shock properly, and thus the previous analysis for the domestic block is not correct. Second, even if we are willing to believe that the model was able to identify the foreign shock, the results suggest that the shock has an extremely limited impact over the domestic economy, which seems unrealistic in light of the magnitude of the shock. Thus, we conclude that in this case, the recursive VAR model fails to provide an informative benchmark to judge and validate the IRFs of our structural micro-founded model.

The results for the *agnostic* VAR model offer a completely different view of the propagation of the shock. Overall, the impulse responses show results in line with macroeconomic theory. They are also statistically significant at conventional levels (with the exception of inflation and the domestic policy rate). The responses for foreign variables show dynamics that are consistent with those expected after a negative policy shock (i.e., a contractionary effect in foreign prices and activity). It is worth noticing that the responses in the foreign block go further beyond the restrictions that were specified in this identification scheme, and thus these results suggest that the shock is properly identified. In the domestic block, the shock has a strong negative impact over output and the two types of investment in the short run (around ten quarters). Moreover, the responses are significant at conventional levels. The fall of investment is mainly due to the large real exchange rate depreciation in line with tighter monetary conditions abroad (capital outflows, etc.). Finally, results show no impact over domestic prices due to the strong drop in the domestic activity that offsets the pass-through of the exchange rate to prices in the short run, which would also explain the lack of response

[19] We explored several alternative specifications to confirm these results. The first exercise consists of changing the order of variables (we assume the interest rate to be the most exogenous variable in the foreign block) and the results are qualitatively very similar.

for the domestic rate. However, there is a small drop in prices in the median-run due to the normalization of the exchange rate and depressed domestic activity.

Therefore, we argue that the *agnostic* VAR model is able to properly identify the foreign monetary policy shock, and the responses from this identification scheme can be used to validate the responses of our DSGE model. The comparison of these two models will enable us to shed new light and provide insights on the propagation of the foreign monetary policy shock over the domestic economy. In particular, we can compare and analyze the different policy implications for the domestic central bank, as well as the short/long-run dynamics and the convergence toward the equilibrium implied by both models in order to better characterize the propagation of the shock.

We consider four alternative sets of sign restrictions to analyze the robustness of the results for this identification scheme; see Table 2 (previous section) and Table A.2 (in the Appendix) for more details. Moreover, Figures B.2 and B.3 depict the IRFs of these four alternative models. In particular, Mod A and B show that restrictions in investment have a significant impact on the real variables, but nominal variables show similar dynamics between the alternative cases and base model. Thus, our conclusions hang on the plausibility of these restrictions. Finally, additional restrictions in foreign policy rate and real exchange rate do not change the responses of the variables significantly with respect to those reported for the base model.

4.3 Results for the DSGE Model

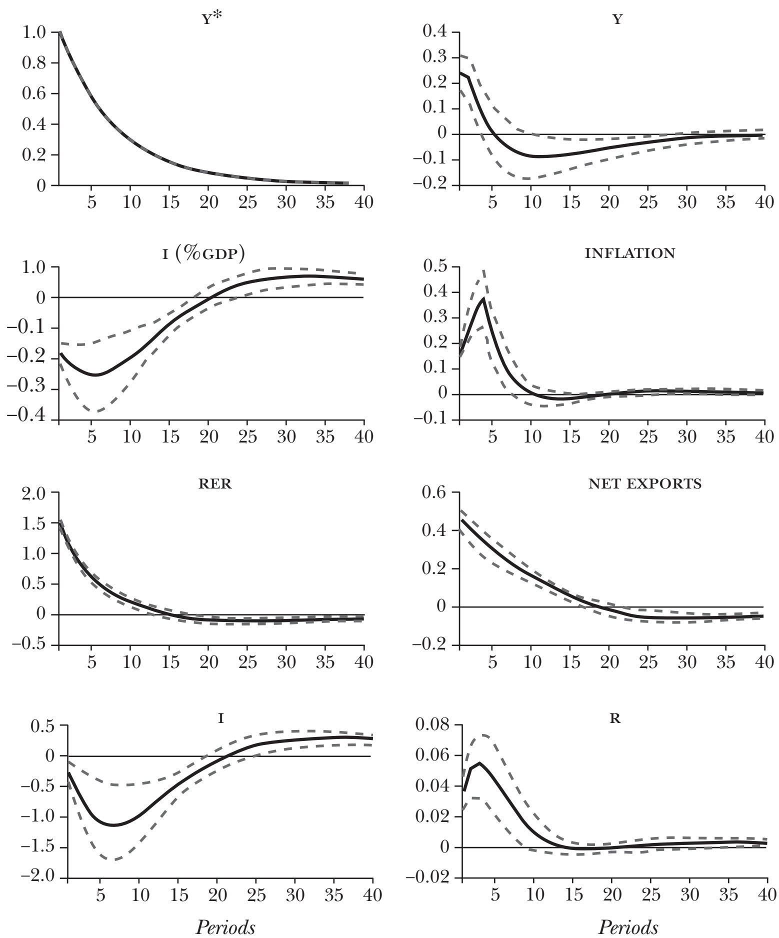
DSGE models are highly parameterized, and thus we estimate the model using data covering the period 2001Q3-2014Q4 in order to improve identification of the parameters of the models. Figure 2 illustrates the responses of the DSGE model to a 1% positive shock (100 basis points) to the foreign interest rate.

The tightening of foreign monetary conditions will lead to capital outflows away from Chile. This will endogenously influence the country risk premium (the debt burden increases if the country is a net borrower). Because of this, there will be a depreciation of the local currency in both nominal and real terms.[20] To fight against in-

[20] Notice that we take a conservative stance regarding the implications of the financial tightening in the US. We can expect additional financial

Figure 2

IMPULSE RESPONSES WITH A DSGE MODEL FOR CHILE
TO A FOREIGN MONETARY POLICY SHOCK



Impulse responses with 90% confidence bands (2001Q3-2014Q4)

Note: the model is parameterized using estimates from Bayesian estimation techniques with quarterly data covering the period 2001Q3-2014Q4. The figure shows the Bayesian impulse responses to a 1% positive shock (100 basis points) to the foreign interest rate. We assume that the dynamics of the foreign variables are described by independent autoregressive processes of order one, AR(1), as in Medina and Soto (2007a) and Fornero and Kirchner (2014).

flationary pressures, the central bank raises the policy rate. The latter causes a large fall in activity, particularly in investment, which decreases slightly more than 1% below its steady-state value

The real exchange rate rises persistently and, during the first periods, roughly depreciates by 1.5%. In consequence, marginal costs increase causing inflationary effects (around 0.2% on impact). As nominal prices are rigid, the inflation reaches its peak at the end of the first year. In addition, the results suggest that the immediate pass-through is 0.18 and increases towards the end of the first year. Moreover, consumption expenses also fall due to the increase in real interest rates (not shown in the figure). Consequently, the model predicts a modest but persistent contraction in output. Notice that the large persistence of the foreign monetary policy shock drives these important fluctuations. Finally, the persistence of the shock contributes to a large improvement of the current account, which explains the initial hike in output.

4.4 Comparing the Results of SVAR-SOE and DSGE Models

The main results from the IRFs analysis showed that the recursive VAR model was not able to identify the foreign monetary policy shock, and thus, the comparison excluded this identification scheme.

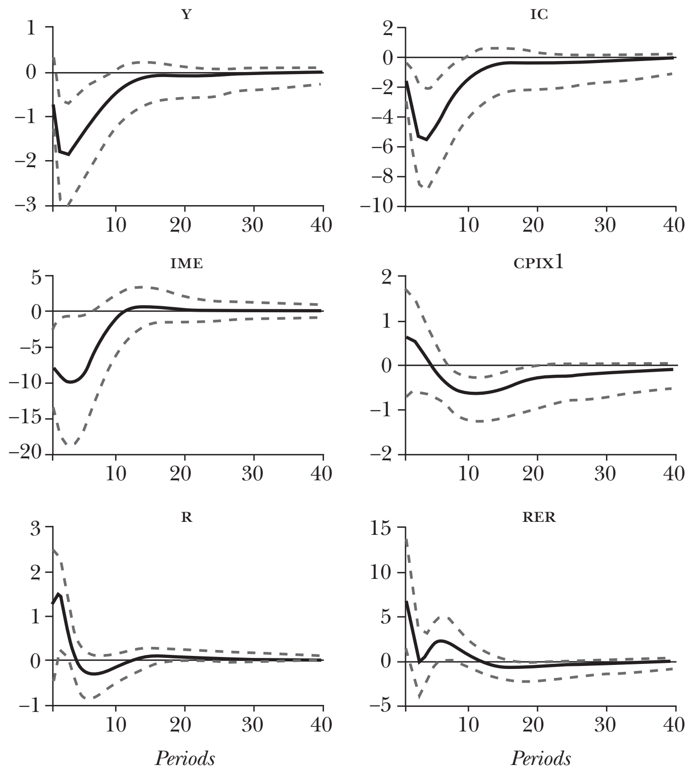
Before jumping into the comparison of the responses between the *agnostic* VAR (Figure 1) and DSGE model (Figure 2), there are two points that we need to address. First, responses for VAR models were constructed by aggregating monthly responses to quarterly frequency and hence their confidence intervals are wider than they should be because variables are smoother at higher frequencies. Thus, the sensitivity of the responses to the restrictions in investment should be reconsidered. Second, the DSGE model uses data from the period after 2008 whereas the VAR models do not, hence the comparison of

distress triggered by larger volatility in emerging economies such as: *i)* an increase of default probabilities of these countries yielding to a boost of country risk premiums; *ii*) the appreciation of the US dollar worldwide leading to unfavorable dynamics in commodity prices and in terms of trade for emerging economies. These further effects can be captured by setting a SVAR for these foreign variables instead of an AR(1) model for each variable. We avoid implementing that SVAR due to the strange implications arising from the Cholesky identification discussed above.

Figure 3

IMPULSE RESPONSES FOR THE AGNOSTIC VAR AND DSGE MODEL RESPONSES TO A 1% POSITIVE SHOCK TO THE FOREIGN INTEREST RATE

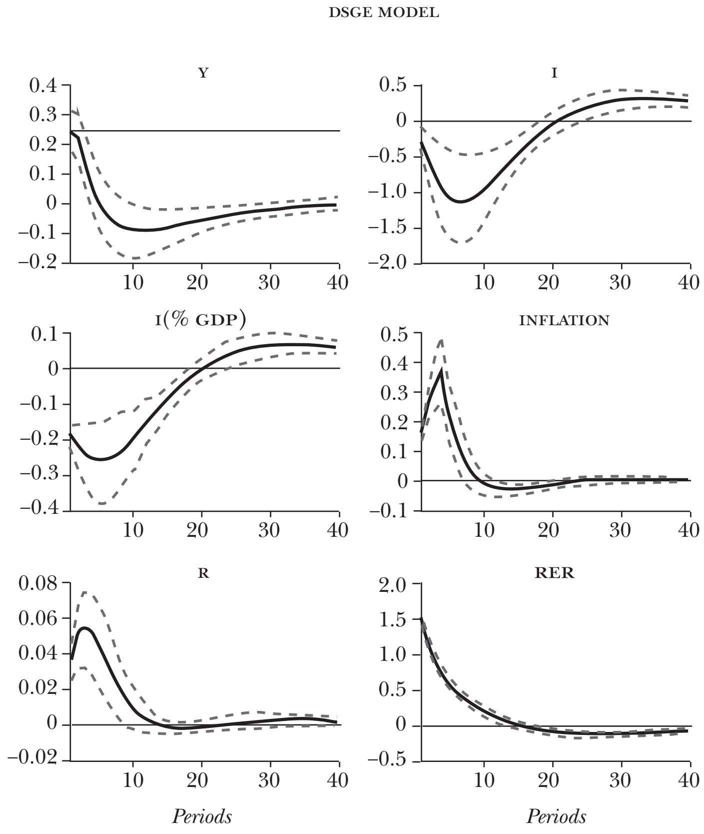
AGNOSTIC VAR



Note: Agnostic VAR, for the baseline model; quarterly responses were computed by aggregating monthly responses. DSGE model, Bayesian impulse responses. The figure shows the 68% and 90% confidence bands for the VAR and DSGE model, respectively.

Figure 3 (cont.)

IMPULSE RESPONSES FOR THE AGNOSTIC VAR AND DSGE MODEL RESPONSES TO A 1% POSITIVE SHOCK TO THE FOREIGN INTEREST RATE



Note: Agnostic VAR, for the baseline model; quarterly responses were computed by aggregating monthly responses. DSGE model, Bayesian impulse responses. The figure shows the 68% and 90% confidence bands for the VAR and DSGE model, respectively.

the results may not be straightforward. We therefore also estimated an alternative DSGE model using a more comparable data set, but the results did not change significantly.[21] Figure 3 summarizes the results for the *agnostic* VAR and DSGE model.

Beyond the quantitative differences, we find that the impulse responses of the *agnostic* VAR model are in line qualitatively with the results of the DSGE model except for output. In the DSGE model, the initial hike is explained by the improving of the current account due to the real and nominal exchange rate depreciation; whereas the *agnostic* VAR infers a drop of almost two percent in output.

There are three key issues in the dynamics of the responses inferred by the DSGE model that we want to highlight. First, the model infers a limited propagation of the shock to the domestic economy, which may seem problematic in light of the size of the shock. Second, the peak of the shock over activity occurs during the second and third year after the shock (impact of the shock accumulates slowly over time). Finally, convergence toward the steady state is reached only in the long run. The last two issues may be due to the many micro-founded restrictions that are included in the model.[22] Ironically, these mechanisms are added to better fit the persistence observed in the data. On the contrary, the *agnostic* VAR offers a slightly different view about the propagation of the shock. In particular, it clearly indicates that the shock is much less persistent, but at the same time, it has a greater impact in the short-run. Finally, policy implications from both models turned out to be different, according to the *agnostic* VAR model, the central bank do not need to rise its policy rate because the drop in activity helps to contain any jump in inflation; whereas in the DSGE model the rise in prices is partially accommodated by the increase in the policy rate.

Of course, both models are approximations and thus we favor the view that the responses will lie between the responses of both models. The main advantage of the DSGE model is that it offers a comprehensive description of the propagation of the shock that enriches policy discussions. However, this comparison enables us to:

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[21] See Figure B.4 (Appendix) for the complete set of responses for this alternative DSGE model. The main difference is that the responses are exacerbated in this case.

[22] One example of these micro-founded restrictions is the delay in domestic consumption because of the assumption of consumption habits.

1) Validate the responses of the theoretical model (i.e., DSGE model) for the Chilean economy;

2) Better understand the propagation of the shock over the domestic economy, in terms of duration, length, and depth;

3) Develop potential improvements to the structure behind the DSGE model in order to address the three key issues outlined in the previous paragraph;

4) Offer a richer policy discussion for the policymaker.

5. CONCLUSIONS AND FURTHER DISCUSSION

This paper investigates the propagation of a foreign monetary policy shock over a small open economy, in particular over the Chilean economy. Our motivation is based on the ongoing period of monetary normalization already started by the Fed. We use a comprehensive methodological framework (i.e., two structural VAR models and a DSGE model tailored for the Chilean economy) in order to shed new light and provide insights on the propagation of the shock. We use this approach because according to Canova (2007), structural VAR models can be used to judge and validate the responses from a DSGE model. This exercise is important because the main advantage of DSGE models is that they provide a comprehensive description of the economy. Our main methodological contribution is to combine the methods of Arias et al. (2014) and Koop and Korobilis (2010) to develop an *agnostic* VAR model for SOE.

The results suggest that the recursive VAR model is not able to identify the shock since some of the responses are counterintuitive (especially for the foreign block). These results are in line with Bernanke et al. (2005), Mojon (2008) and Castelnuovo (2015). Thus, this identification scheme cannot be used to judge the responses of the DSGE model. On the contrary, the *agnostic* VAR model shows results in line with macroeconomic theory. The comparison between the *agnostic* VAR and DSGE model show that both approaches infer similar responses for the economy, except for output. In addition, we identify three points that deserve further attention in the dynamics of the DSGE model: *1)* The impact of the shock; *2)* Peak of the shock;

and *3)* The convergence toward the steady state. Finally, we spot different policy implications arising from both models. According to the *agnostic* VAR model, the central bank does not need to raise its policy rate because the drop in activity offsets any jump in inflation; whereas in the DSGE model the rise in prices is partially accommodated by the increase in the policy rate. Thus, this comparison enriches the discussion for the policymaker.

Our results therefore suggest that there is a gap in the interpretation of the propagation of the foreign monetary policy shock in these models. Further research is needed to develop a better propagation mechanism in the DSGE model to solve or improve the short- and long-run propagation mechanism of the shock. We leave these issues to further work. However, we recognize and propose two potential improvements for the DSGE model. First, significant gains could be made by improving the time series properties of the foreign shocks in these types of models; the DSGE model combines an AR(1) process to describe the foreign interest rate, which is, admittedly, extremely simple. The lack of a foreign propagation mechanism can help to explain the observed responses in this model. Second, the lack of financial restrictions mitigates the propagation of the shock; the model can be improved by including a financial accelerator as in Bernanke (1999). In brief, these improvements provide an opportunity to investigate the causes of the differences between the *agnostic* VAR and DSGE model.

Finally, we recognize that our comparison does not have a real benchmark to judge each model independently. A more elegant approach to performing the comparison would be to specify a more general DSGE model and simulate data from it. We could then compute and compare the responses of each model according to a loss function. However, our approach remains valid since it fosters discussion among policy makers. In addition, the specification of a true model is always a controversial assumption and in this case it would be similar to the DSGE model, meaning the comparison could be biased toward such model.

Appendix A

Table A.1

DATA USED FOR THE ESTIMATION OF THE SVAR MODELS

Variable	*Description*
Log world real GDP	World real GDP index, US indexof industrial production (both SA)
Log foreign price index	Chilean external price index (IPE) and US consumer price index (both SA)
Foreign interest rate	Fed funds rate
Log real copper price	Real copper price
Log real oil price	Real WTI oil price
Log domestic real GDP	Monthly economic activity indicator (IMACEC) (SA)
Log domestic price index	Consumer price index (IPC, 2013=100) (SA)
Log real exchange rate	Multilateral real exchange rate
Domestic interest rate	Monetary policy rate
Log real investment in machinery and equipment	Real gross fixed capital formation in machinery and equipment (SA)
Log real investment in construction	Real gross fixed capital formation in construction (SA)

Sources: Central Bank of Chile and Federal Reserve Economic Data (FRED, Federal Reserve Bank of St. Louis). The log world real GDP was constructed using the Chow-Lin procedure with monthly world production index for the world real GDP index, the log real copper price and oil price were deflated with the international price index (IPE, 2005=100). Finally, an increase in the exchange rate denotes a depreciation.

Table A.2

ALTERNATIVE AGNOSTIC VAR MODELS SIGN AND ZERO RESTRICTIONS

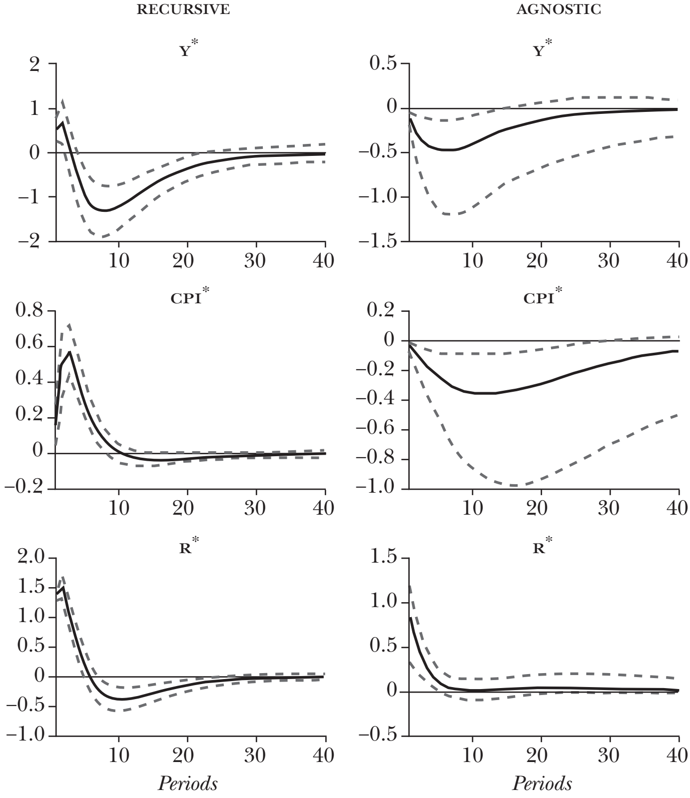
	Base model		*Mod C*	*Mod D*
	h = 0	*h > 0*	*h > 0*	*h > 0*
Foreign block				
US federal funds rate (rus)	1	?	2	2
Industrial production index (Yus)	0	−1	−1	−1
Consumer price index (CPIus)	0	−1	−1	−1
Domestic block				
Interest rate (r)	?	?	?	?
Monthly production index (Y)	0	?	?	?
CPI core	?	?	?	?
Investment (I)	0	−2	−2	−2
Real exchange rate (RER)	1	?	?	2

Restrictions are imposed over the monthly IRFs of the model after a positive foreign monetary policy shock. Positive or negative entries indicate the length of the sign restrictions, whereas zero entries indicate zero restrictions. Finally, question marks (?) indicate that no restrictions were imposed over the IRF of the variable at that horizon. We also consider two additional alternative set of restrictions for the base model; Mod C considers the foreign monetary policy to be positive for at least three months. Mod D considers the foreign monetary policy and the real exchange rate to be positive for at least three months. Thus, these two alternative *agnostic* schemes are incremental cases of the base model.

Appendix B

Figure B.1

IMPULSE RESPONSES FOR THE RECURSIVE AND AGNOSTIC IDENTIFICATION SCHEMES FOR THE FOREIGN BLOCK TO A FOREIGN MONETARY POLICY SHOCK

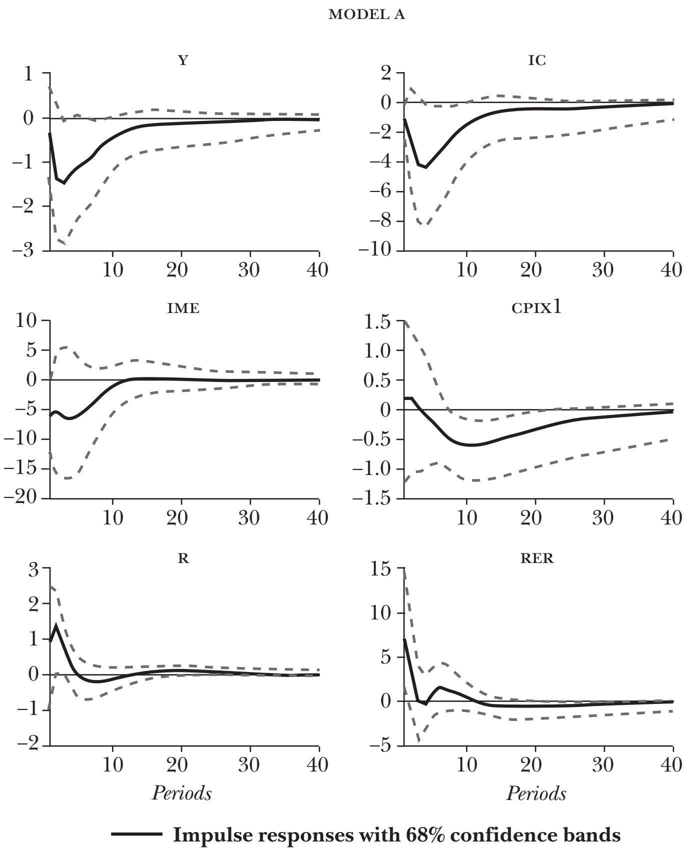


Impulse responses with 68% confidence bands

Note: Recursive VAR first column; *agnostic* VAR last column for the base line model. The figure shows the quarterly responses to a 1% positive shock to the foreign monetary policy rate at the monthly frequency. The quarterly responses were computed by aggregating the monthly responses of the model.

Figure B.2

IMPULSE RESPONSES FOR ALTERNATIVE AGNOSTIC VAR MODELS FOR THE DOMESTIC BLOCK TO A FOREIGN MONETARY POLICY SHOCK

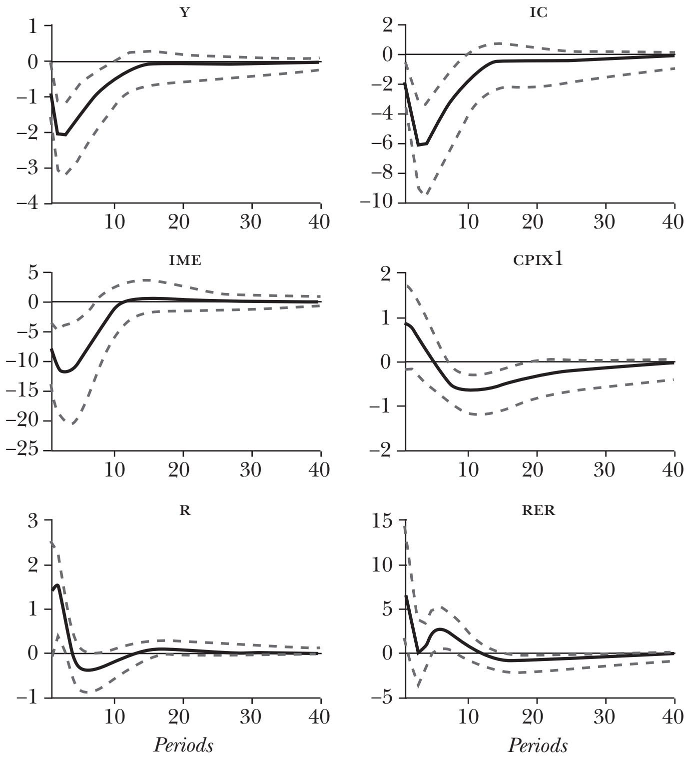


Note: Responses for the alternative restrictions over investment for *agnostic* VAR models: *1)* Mod A: negative sign restrictions only last one month; *2)* Mod B: negative sign restrictions last for three months. The figure shows the quarterly responses to a 1% positive shock to the foreign monetary policy rate at the monthly frequency. The quarterly responses were computed by aggregating the monthly responses of the model. The responses for the foreign blocks do not change in these two cases and thus they are not reported.

Figure B.2 (cont.)

IMPULSE RESPONSES FOR ALTERNATIVE AGNOSTIC VAR MODELS FOR THE DOMESTIC BLOCK TO A FOREIGN MONETARY POLICY SHOCK

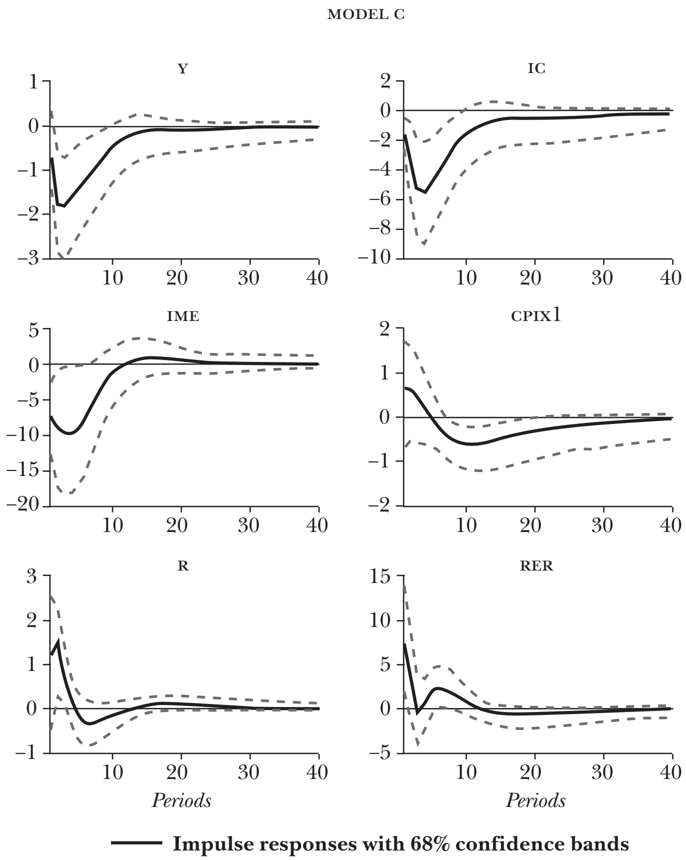
MODEL B



Note: Responses for the alternative restrictions over investment for *agnostic* VAR models: *1)* Mod A: negative sign restrictions only last one month; *2)* Mod B: negative sign restrictions last for three months. The figure shows the quarterly responses to a 1% positive shock to the foreign monetary policy rate at the monthly frequency. The quarterly responses were computed by aggregating the monthly responses of the model. The responses for the foreign blocks do not change in these two cases and thus they are not reported.

Figure B.3

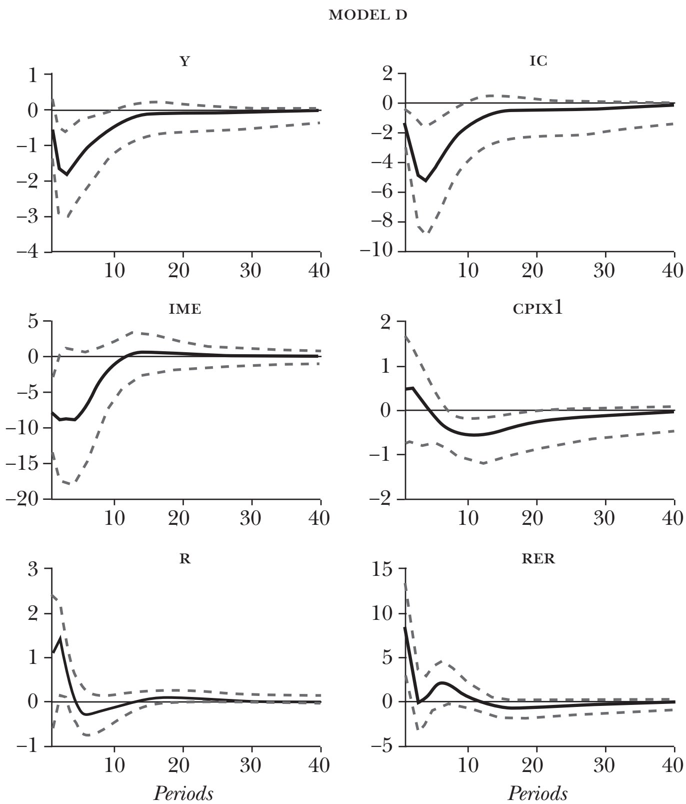
IMPULSE RESPONSES FOR ALTERNATIVE AGNOSTIC VAR MODELS FOR THE DOMESTIC BLOCK TO A FOREIGN MONETARY POLICY SHOCK



Note: Responses for the alternative agnostic VAR models: *1)* Model C: foreign monetary policy is positive for at least three months; *2)* Model D: foreign monetary policy and real exchange rate are positive for at least three months. Thus, these two alternative agnostic schemes are incremental cases of the base model. The figure shows the quarterly responses to a 1% positive shock to the foreign monetary policy rate at the monthly frequency. The quarterly responses were computed by aggregating the monthly responses of the model. The responses for the foreign blocks are the same as those in the base model and thus they are not reported.

Figure B.3 (cont.)

IMPULSE RESPONSES FOR ALTERNATIVE AGNOSTIC VAR MODELS FOR THE DOMESTIC BLOCK TO A FOREIGN MONETARY POLICY SHOCK

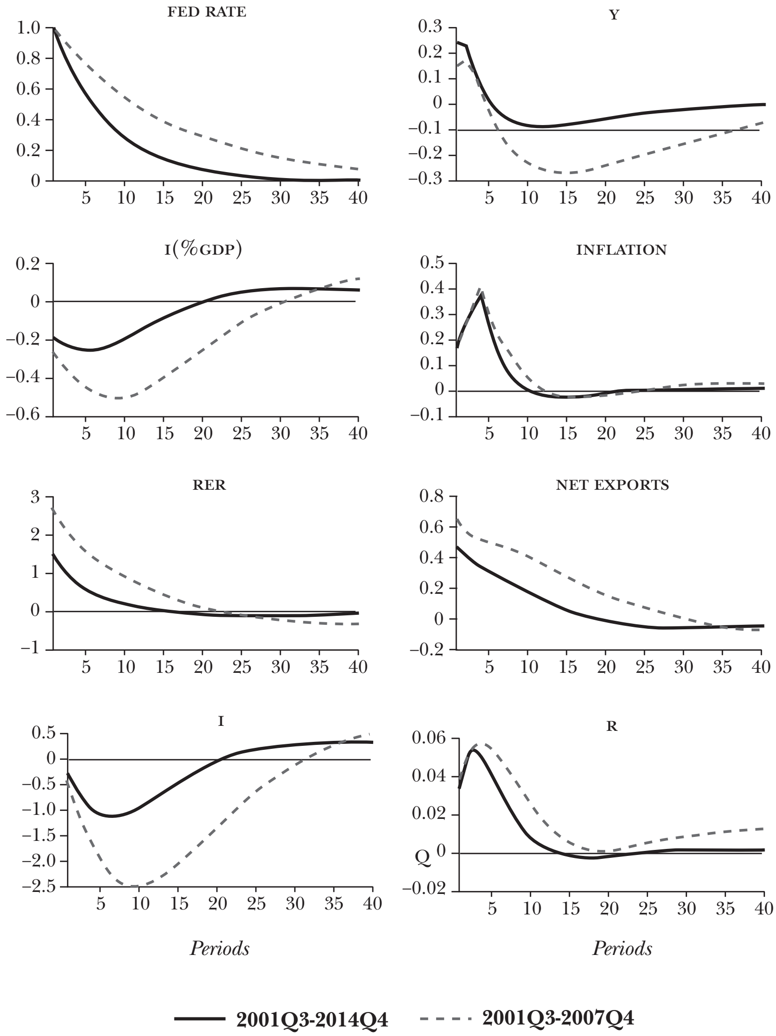


Impulse responses with 68% confidence bands

Note: Responses for the alternative agnostic VAR models: *1)* Model C: foreign monetary policy is positive for at least three months; *2)* Model D: foreign monetary policy and real exchange rate are positive for at least three months. Thus, these two alternative agnostic schemes are incremental cases of the base model. The figure shows the quarterly responses to a 1% positive shock to the foreign monetary policy rate at the monthly frequency. The quarterly responses were computed by aggregating the monthly responses of the model. The responses for the foreign blocks are the same as those in the base model and thus they are not reported.

Figure B.4

IMPULSE RESPONSES WITH A DSGE MODEL FOR CHILE TO A FOREIGN MONETARY POLICY SHOCK



Note: Model is parameterized using estimates from Bayesian estimation techniques with quarterly data covering the period 2001Q3-2014Q4 and 2001Q3-2007Q4. The figure shows the Bayesian impulse responses to a 1% positive shock (100 basis points) to the foreign interest rate. We assume that the dynamics of the foreign variables are described by independent autoregressive processes of order one, AR(1), as in Medina and Soto (2007a) and Fornero and Kirchner (2014).

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