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Abstract

The paper extends Bernanke and Mihov's [6] closed-economy strategy for identification of monetary policy shocks to open-economy settings, accounting for the simultaneity between interest-rate and exchange-rate innovations. The methodology allows a separate treatment of two distinct monetary policy shocks, one that operates through open market operations, and another one that takes place through interventions in the foreign exchange market. The results that the identification strategy yields when applied to the data of a small and open economy are free of the empirical anomalies previously found in the literature.

Keywords: Identification, Structural Vector Autoregressions, Open economy, Monetary policy shock, Foreign Exchange Intervention, Endogenous monetary policy.
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1 Introduction

General equilibrium models often produce dissimilar stylized facts about the effects of monetary policy. It is therefore essential for both theorists and policy makers to learn which model best represents each particular economy. In the last twenty years, a growing body of research has produced empirical evidence to improve the basis for model selection. While great advances have been made within the closed-economy context, the issue remains widely uncharted for open economies. The contemporaneous interaction between the interest rate and the exchange has proved difficult to unravel. This paper proposes a structural specification that extends Bernanke and Mihovs [6] identification of the monetary policy innovation to account for the simultaneity between interest rate and exchange rate innovations of open economies. Moreover, the methodology allows for a separate treatment of two distinct monetary policies: open market operations and foreign exchange market intervention.

Early attempts to identify monetary policy in open economies consisted in including the exchange rate in a Vector Autoregression (VAR) in a simple, straightforward way. Dynamic response functions were calculated assuming some type of Wold causal ordering with the policy instrument typically allowed to have contemporaneous effects on the exchange rate (Sims [37], Eichenbaum and Evans [16]). On inspection, this type of identification strategies suffered from two inherent weaknesses. First, they implicitly assumed that exchange rate innovations are not taken into account on impact by the monetary authority when setting the stance of monetary policy, a claim very difficult to credit. What is more, proceeding the other way around would be as unsatisfactory: it would preclude the possibility of an impact effect of interest rate innovations on the exchange rate (Kim and Roubini [21]). Second, these identification strategies also implied that the exchange should be left out of consideration as a policy instrument per se. Yet, a growing body of research investigates the monetary authorities' participation in foreign exchange markets as a policy device on its own (see, e.g., Sarno and Taylor [34]).

Regarding the first shortcoming, a number of studies acknowledged the simultaneity between current developments in the exchange rate and the interest rate (Grilli and Roubini [17], Clarida and Gertler [11], Cushman and Zha [13], Kim and Roubini [21]). However, none of them considered policy-making through interventions in the foreign exchange market. On the contrary, in these studies monetary policy affects the exchange rate only indirectly, through its effect on what the authors consider the sole policy instrument, such as money supply (Cushman and Zha [13]), or a short-term interest rate (Grilli and Roubini [17], Clarida and Gertler [11], Kim and Roubini [21]). Somewhat different than these approaches, Smets [39] claims for a more active role of the exchange rate when measuring the stance of monetary policy. The monetary policy shock simultaneously affects the exchange rate and the domestic short-term interest rate. As a result, the depreciation rate contains valuable information about monetary policy actions. However, while this makes the case for taking into account exchange rate shocks to accurately measure monetary policy shocks, it still assumes that there is only one policy shock. Since central banks in open economies operate through both open market operations and interventions in the foreign exchange market, two different sets of structural policy shocks should correspond to each of these actions.

Kim [20] is, in effect, the first author to attempt considering these two types of policy actions in a unifying empirical framework. The proposal consists in incorporating in a structural VAR the Fed's net purchases of foreign currency. However, the specification fails to consider the private sector's supply of, and demand for, foreign currency. Insofar as identifying policy actions requires controling for policy reactions (Kim [20], p. 357), it is essential to account for the market conditions that the monetary authority faces. In fact, some of the empirical puzzles that the literature on monetary policy identification has come across have been attributed to falling short in the task of separating supply and demand (Leeper and Gordon [23]). For example, if the Fed purchases foreign currency amid a large current account deficit, the U.S. dollar would depreciate, whereas such a depreciation is less plausible were there an excess of foreign currency due to a current account surplus. What is so interesting about Bernanke and Mihov's [6] identification strategy is the attempt to disentangle supply and demand pressures in the market for bank reserves. By drawing on this simple idea, the methodology developed in this paper considers both open market operations and foreign exchange interventions as channels for monetary policy actions and reactions, while at the same time tackling the simultaneity between interest rate and exchange rate innovations.

To test its performance, the proposed identification strategy is then applied to Argentina during 2003-2008, a small and open economy where the central bank was regularly involved in open market operations and foreign exchange market intervention. In addition to studying the effects of monetary policy innovations, the present study sheds light on the endogenous component of monetary policy. The relatively low volatility of Argentina's exchange rate within the period covered in this paper, along with the accumulation of large amounts of international reserves, could suggest another case of "fear of floating" (Calvo and Reinhart [7]). The identification strategy to be outlined below involves specifying the structural reaction function of the monetary authority. As such, estimation of the parameters of this structural equation might provide a more comprehensive measure than the ones of Calvo and Reinhart [7] on how closely the operating procedure of the monetary authority resembles the one of a currency board regime.

The main findings of this case study can be summarized as follows. Unexpected purchases of foreign currency are systematically sterilized on impact, as the central bank issues bonds to absorb around one-third of the domestic currency against which the foreign exchange intervention takes place. The ensuing depreciation of the domestic currency provides evidence of a portfolio balance channel. As a result of exchange rate pass-through, inflation jumps after the shock, and the temporary increase in the rate of output growth can thus be thought in terms of price misperception models. Finally, while the real interest rate initially falls, it starts recovering around three months after the shock as nominal interest rates increase. Unexpected open market operations affect output growth with the expected sign, although it is not statistically significant at conventional significance levels. The results also prove to be free of the empirical anomalies previously found in the literature. There is no evidence of a *liquidity puzzle*; following a contractionary policy shock, interest rates rise. In addition, the *price puzzle* is also absent; inflation does not accelerate after the shock. Finally, the unexpected tightening produces an impact appreciation of the domestic currency, and there are thus no signs of an *exchange-rate puzzle*. Moreover, there is an ensuing depreciation of the domestic currency which shows that there is no evidence of a *forward discount bias puzzle*. Regarding the endogenous component of monetary policy, the paper finds that the central bank has not absorbed balance of payments shocks in a currency-board fashion, as the literature on fear of floating might suggest. The growing level of international reserves can be rationalized, instead, as the monetary authority's response to terms of trade, supply and domestic currency demand shocks.

The paper is organized as follows. Section 2 below provides a simple characterization of the problem of identifying structural VARs (SVARs). Section 3 develops an identification strategy that extends the Bernanke and Mihov's [6] proposal to open-economy settings, while section 4 puts forward the main caveats of this type of strategies. Section 5 presents the application to the Argentine economy. Finally, section 6 contains concluding remarks.

2 SVARs and the problem of identification

Here I will briefly outline the identification problem of SVARs. Formal treatments of this subject can be found, among others, in Christiano, Eichenbaum and Evans [9] and Rubio-Ramírez, Waggoner and Zha [31].

A VAR(p) representation of a k-dimensional vector of economic variables, Z_t, is given by:

$$Z_t = D_1 Z_{t-1} + \ldots + D_p Z_{t-p} + FX_t + u_t \tag{1}$$

where u_t is multivariate normal with $Eu_tu_t' = \Sigma_u$ and $Eu_tu_s' = 0$ for all $s \neq t$, and X_t is a vector of exogenous variables.

In this representation, contemporaneous relations between the variables in Z_t are *implicitly* allowed through u_t. In particular, non-zero off-diagonal elements in Σ_u imply such relations. *Explicitly* accounting for the latter demands a more comprehensive representation than (1). The SVAR representation of the vector Z_t is given by:

$$AZ_t = C_1 Z_{t-1} + \ldots + C_p Z_{t-p} + EX_t + Bv_t \tag{2}$$

which is usually referred to as the *AB model* (Amisano and Giannini [1]), as the relation between reduced form residuals and structural shocks is given by $Au_t = Bv_t$. In (2), any contemporaneous relation between the variables can be encompassed through the off-diagonal elements of A and B. Then, as is customary, we can further assume without loss of generality that the covariance matrix Σ_v of v_t is diagonal.

It is useful to think about the reduced-form residuals u as "news" of the economy for the current period. They are news relative to the history of the economy, as summarized by the lagged values of the vector Z, and to the exogenous variables included in X. Being news, these reduced-form residuals are observable. However, they are the result of unobservable underlying (orthogonal) innovations that took place in the current period. This unobservable innovations are the driving forces of the economy. Nevertheless, it might well be the case that each one of these unobservable innovations leaves its track in more than one of the observed "news." To the extent that the cross-correlations of the "news" are different from zero, the latter is certainly the case.

The problem of identification arises because the "news" in the economy can be the result of different sets of underlying shocks. That is, different sets of structural parameters in (2) might yield the same observable parameters in (1). Consider a SVAR model of the vector Z_t that is different from the one in equation (2):

$$\tilde{A}Z_t = \tilde{C}_1 Z_{t-1} + \ldots + \tilde{C}_p Z_{t-p} + \tilde{E}X_t + \tilde{B}v_t \tag{3}$$

It is easy to prove that if there exists an $k \times k$ orthogonal matrix P such that $A = P\tilde{A}$, $C_j = P\tilde{C}_j$ $(1 \leq j \leq p)$, $E = P\tilde{E}$ and $B = P\tilde{B}$, then the structural models of equations (2) and (3) are observationally *indistinguishable* from each other.[1] That is, both structural models yield the same reduced-form representation.

To see this, pre-multiply both sides of (2) by A^{-1} to obtain:

$$Z_t = A^{-1}C_1 Z_{t-1} + \ldots + A^{-1}C_p Z_{t-p} + A^{-1}EX_t + A^{-1}Bv_t \tag{4}$$

Since $A = P\tilde{A}$ and $C_j = P\tilde{C}_j$, then $A^{-1}C_j = (P\tilde{A})^{-1}P\tilde{C}_j = \tilde{A}^{-1}P^{-1}P\tilde{C}_j = \tilde{A}^{-1}\tilde{C}_j$. On the other hand, since $A = P\tilde{A}$ and $E = P\tilde{E}$, then $A^{-1}E = (P\tilde{A})^{-1}P\tilde{E} = \tilde{A}^{-1}P^{-1}P\tilde{E} = \tilde{A}^{-1}\tilde{E}$. As for the last term in equation (4), $A = P\tilde{A}$ and $B = P\tilde{B}$ imply that $A^{-1}B = (P\tilde{A})^{-1}P\tilde{B} = \tilde{A}^{-1}P^{-1}P\tilde{B} = \tilde{A}^{-1}\tilde{B}$. Taken together, these results, which only require P to be invertible, allow us to state that both structural models have reduced-form representations with identical first moments. Consider then the second moments of the reduced-form VAR of model (2):

$$\Sigma_u = A^{-1}B\Sigma_v B'A'^{-1} \tag{5}$$

Now, since $A = P\tilde{A}$ and $B = P\tilde{B}$, we have that

$$A^{-1}B\Sigma_v B'A'^{-1} = \tilde{A}^{-1}P^{-1}P\tilde{B}\Sigma_v\tilde{B}'P'P'^{-1}\tilde{A}'^{-1} \tag{6}$$

Orthogonality of P implies that the RHS of (6) reduces to $\tilde{A}^{-1}\tilde{B}\Sigma_v\tilde{B}'\tilde{A}'^{-1} = \tilde{\Sigma}_u$, and so $\Sigma_u = \tilde{\Sigma}_u$.

A SVAR is said to be globally identified if the only such orthogonal matrix P is the identity matrix. If this is the case, then there is only one set of structural parameters that can be deduced from the estimation of the reduced-form VAR. For a model to be identified, it is necessary to impose restrictions on its parameters. Thus, the task of the structural VAR literature consists in finding an appealing story that establishes how the underlying shocks build up to the observed news. One can think of two general principles to follow when building such a story. First, it must be so parsimonious as to provide enough restrictions for the model to be identified. The necessary and sufficient conditions for identification upon this paper relies are the ones given in Rubio-Ramírez et al. [31]. Second, and not less important, the identification strategy should not rest on any particular theoretical model. Otherwise, it would not be possible to provide a neutral "arena within which macroeconomic theories confront reality and thereby each other" (Sims [36]).

By far the most popular identification strategy consists in ordering the endogenous variables by their degree of "exogeneity." This allows the researcher to rest on the uniqueness of the Cholesky factorization, so that only one possible structural model can be behind a certain reduced-form covariance matrix. With the years, more sophisticated strategies where developed, allowing to deal with models where the claim of a

[1] Rubio-Ramírez et al. [31], p. 6, prove that the converse is also true.

Wold causal ordering could not be sustained.

The first building block of the identification strategy to be developed in the present study consists in representing the economy with two sub-vectors of variables that together conform the vector Z_t of endogenous variables: Y_t denotes the $l \times 1$ vector of variables of the production sector, whereas the $(k-l)\times 1$ vector P_t includes the variables of the transactions sector of the economy.[2]

Bernanke and Blinder [3] argue that there are two alternative assumptions that facilitate identification. Namely, one could assume either that there is no contemporaneous feedback from the production sector to the transactions sector or that shocks within the transaction sector do not affect the production sector contemporaneously. In both cases, A becomes a block triangular matrix and B a block diagonal matrix. The approach here follows Bernanke and Mihov [6], who assume that shocks in the transaction sector do not affect the production sector within the current period. In other words, we assume a sluggish production sector that responds to innovations in the transactions sector only with a lag (see, e.g., Kim [20]). If

$$Z_t = \begin{bmatrix} Y_t \\ P_t \end{bmatrix} \tag{7}$$

then we have that

$$A = \begin{bmatrix} A_{11} & 0 \\ A_{21} & A_{22} \end{bmatrix} \tag{8}$$

$$B = \begin{bmatrix} B_{11} & 0 \\ 0 & B_{22} \end{bmatrix} \tag{9}$$

where A_{11} and B_{11} are of size $l \times l$, A_{21} is of size $(k-l)\times l$, and A_{22} and B_{22} are of size $(k-l)\times(k-l)$. I will assume that A_{11} is lower triangular, and that B_{11} is an $l \times l$ identity matrix,[3] leaving the parameters in A_{21} unrestricted. Additionally, all equations will appear normalized using the corresponding dependent variable as numeraire.

With the aforementioned restrictions, it is still necessary to understand the contemporaneous relations between the variables included in the transactions sector of the economy, encompassed in A_{22} and B_{22}, in order to achieve identification. The next section presents an identification strategy that successfully deals with this task.

3 Identification in open economies: extending the Bernanke-Mihov approach

Instead of focusing directly on the interest rate and the exchange rate, this paper presents an identification scheme that builds on the items in the balance sheet of the monetary authority. In their analysis for the US economy, Bernanke and Mihov [6]

[2]Even when the taxonomy adopted here might be misleading, it seems more appropriate in the present case than the nomenclature usually adopted in the literature. Bernanke and Blinder [3] label the former the "nonpolicy variables," and the latter the "policy variables." In the model to be constructed below, however, P_t includes variables that are far from being controlled by the monetary authority.

[3]I have assumed that the structural shocks are orthogonal, but not necessarily of unit variance. Other authors assume that the structural shocks have unit variance, and instead leave the elements on the diagonal of B unrestricted.

focus only on the items of the Federal Reserve's balance sheet that link the monetary authority with the commercial banks, namely, borrowed and nonborrowed reserves. Understanding the context in which central banks in open economies carry out monetary policy calls for bringing into the analysis the evolution of international reserves.

Table 1 below presents the balance sheet of the central bank in an open economy, with its components coveniently grouped for the purposes of the present study.

Table 1. The Balance Sheet of the Central Bank in an Open Economy

Assets	**Liabilities and Net worth**
Net foreign assets (nfa)	Currency held by the public (cp)
	Commercial banks' domestic liquidity (li)
	Central Bank Bonds (mp)
	Other items, net (oi)

With the definitions provided in Table 1, it is straightforward to see that the following accounting identity in VAR-innovation form holds at any given point in time:

$$u_{nfa} = u_{cp} + u_{li} + u_{mp} + u_{oi} \tag{10}$$

As long as the terms of trade and domestic prices are included in the nonpolicy block of the VAR, and under the identifying assumption that the latter two affect contemporaneously the policy block (which will then require no reverse feedback), it is then possible to argue that the reference interest rate, the discount rate and the selected exchange rate are the only remaining price variables affecting the quantities in equation (10).

One-step-ahead forecast errors for each of these prices enter the innovation-form equations describing the markets for each of the items in the central bank's balance sheet. Following the literature, it is assumed that the innovation to the discount rate is zero. Given the interest in solving for the remaining two prices in terms of the underlying structural shocks, two equilibrium conditions are needed. In other words, we need an additional equilibrium condition besides the one provided by the monetary authority's balance sheet. Actually, relying on only one equilibrium condition led Bernanke and Mihov [6], who initially consider both the fed funds rate and the discount rate, to make the simplifying assumption that the innovation to the discount rate is zero.[4] For its crucial relevance in the determination of the exchange rate in general and its decisive influence on the monetary conditions faced by the economy in the particular case under study, the external sector conservation condition seems the most appropriate identity to overcome this obstacle. Therefore, the additional equilibrium condition proposed here is the balance of payments.

Note, however, that while the balance of payments summarizes the *flows* of funds between the country and the rest of the world, the balance sheet of the monetary authority, as any other balance sheet, provides information on *stocks*. Considering the first difference of the above balance-sheet items, then equation (10) turns into:

$$u_{\Delta nfa} = u_{\Delta cp} + u_{\Delta li} + u_{\Delta mp} + u_{\Delta oi} \tag{11}$$

[4]In the 1995 NBER version of their article, Bernanke and Mihov [5] explore the effects of considering nonzero discount rate innovations by including an additional reaction function for the Federal Reserve. Insofar as neither the reference short-term interest rate nor the exchange rate are variables unilaterally decided by the policy maker, such a shortcut is not at hand in the present study.

On the other hand, turning to the balance of payments, the following conservation condition holds for the residuals of a VAR that includes the external accounts of any given country:

$$u_{\Delta nfa} = u_{ca} + u_{ka} \tag{12}$$

where $u_{\Delta nfa}$ is the forecast error of the change in net foreign assets also included in equation (11), u_{ca} is the residual corresponding to the current account, and u_{ka} is the error attached to capital and financial accounts' transactions *excluding* the flows affecting the central bank's foreign-currency liabilities,[5] since the latter are included within net foreign assets. In other words, the claim is that fluctuations in international reserves are relevant for the behaviour of the other variables of the VAR to the extent that they do not have as an exact counterpart adjustments in items denominated in foreign currency in the central bank's balance sheet. In the event of a positive shock to the current account, this could imply, for instance, an increase in seignoriage affecting $u_{\Delta cp}$, later possibly sterilized through $u_{\Delta mp}$.

It is essential to rely on a structural VAR system to know in which precise sense the observable VAR innovations in equations (11)-(12) relate to the "primitive" orthogonalized shocks v, and therefore be able to recover (i.e., *observe*) the latter to trace their effects on the economy. The following simple model parsimoniously accounts for the behaviour of the external sector of the economy and the markets for the items in the central bank's balance sheet:

$$\begin{aligned}
u_{ca} &= \beta u_{er} + v_{ca} && (13)\\
u_{ka} &= \rho u_{ir} - \delta u_{er} + v_{ka} && (14)\\
u_{\Delta nfa} &= \phi_{ca} v_{ca} + \phi_{ka} v_{ka} + v_{\Delta nfa} && (15)\\
u_{\Delta cp} &= -\gamma u_{ir} - \tau u_{er} + v_{\Delta cp} && (16)\\
u_{\Delta li} &= -\eta (u_{ir} - u_{dr}) + \omega u_{er} + v_{\Delta li} && (17)\\
u_{\Delta mp} &= \theta_{\Delta cp} v_{\Delta cp} + \theta_{\Delta li} v_{\Delta li} + \theta_{\Delta nfa} u_{\Delta nfa} + v_{\Delta mp} && (18)\\
u_{\Delta oi} &= \psi_{\Delta nfa} v_{\Delta nfa} + \psi_{\Delta cp} v_{\Delta cp} + \psi_{\Delta li} v_{\Delta li} + \psi_{\Delta mp} v_{\Delta mp} + v_{\Delta oi} && (19)
\end{aligned}$$

where u_{ir}, u_{dr} and u_{er} stand for the innovations in the reference interest rate, the discount rate, and the selected exchange rate measure, respectively.

Equation (13) puts forward the behaviour of the current account. It states that innovations in current account flows depend positively on the exchange rate and a foreign-currency supply disturbance operating through the current account. The exchange rate response is justified by the behaviour of the trade balance in goods and services.

Equation (14) relates innovations in the capital and financial account (as defined above) to innovations in the reference interest rate, the exchange rate, and an autonomous shock. While the domestic interest rate is expected to affect positively the capital and financial account, the sign of the effect of the exchange rate is less clear. On the one hand, an unexpected depreciation could make the country more attractive for foreign direct investors. On the other hand, an unexpected depreciation might lead to a contraction in the demand for domestic currency, with the corresponding flight to

[5] In the Argentine case below, for example, checking accounts in foreign currency and obligations with IFIs.

quality. The latter effect probably dominates the former one, for it seems reasonable to think that FDI decisions are based on longer-term conditions rather than on monthly forecast errors.

Equation (15) captures the behaviour of the central bank regarding the external sector of the economy, indicating how the monetary authority responds to the developments of the market for foreign currency. According to (15), the central bank observes and responds to the contemporaneous foreign currency supply (or demand if negative) shocks.[6] The strength of the response is given by the coefficients ϕ_{ca} and ϕ_{ka}. For example, under a currency board regime, the central bank provides all the currency (foreign or domestic, depending on the case) that the external sector needs at every point in time at the fixed exchange rate. This amounts to the identifying assumption that $\phi_{ca} = \phi_{ka} = 1$.

Equation (16) is the currency demand function of the public. It states that interest rate and exchange rate innovations affect negatively the change in the public's holdings of domestic currency. The expected relation with the exchange rate addresses the aforementioned aspect regarding the confidence in the domestic currency in the event of an unexpected depreciation.

Equation (17), in turn, is the liquidity demand by commercial banks, expressed in innovation form. As in Bernanke and Mihov [6], we will relate this variable to the reference interest rate and the discount rate. I expect the change in liquidity to depend *negatively* on the difference between the reference interest rate (the rate at which liquidity can be lent in the market) and the discount rate (the rate at which the central bank offers to withhold the liquidity). Consistent with the assumed relation between the exchange rate and the demand for domestic currency by the public, the positive relation between the change in liquidity and exchange rate innovations captures the precautionary liquidity hoarding commercial banks might incur when facing an unanticipated depreciation, thereby preparing themselves for potentially large deposit withdrawals. Finally, $v_{\Delta li}$ is a disturbance to the liquidity function.

Equation (18) describes the behaviour of the monetary authority in the markets where transactions denominated in local currency take place. That is, I assume that the central bank observes and responds to both public and commercial banks' contemporaneous liquidity shocks. Furthermore, the central bank reacts to the result of its own contemporaneous intervention in the foreign exchange market, $u_{\Delta nfa}$. For example, a central bank absorbing all the excess supply of foreign currency in an economy with a large external surplus (thereby avoiding an exchange rate appreciation) might at the same time decide to sterilize the domestic currency that it deems to be in excess of the transactionary requirements of the economy. In such a situation, one should expect $\theta_{\Delta nfa}$ to be close to one.

Last, equation (19) shows that the remaining items in the central bank's balance sheet are allowed to be contemporaneously affected by the developments in net foreign assets, currency held by the public, commercial bank's liquidity and the net bonds' holdings of the central bank. In this sense, these items are assumed to be the most endogenous ones, accomodating to the resulting interaction of the main monetary ag-

[6]In Argentina, all foreign-exchange transactions are made through the central bank, and so the assumption that it observes these shocks is straightforwardly sustained in the example to be carried out below.

gregates.

Following the literature, the innovation to the discount rate u_{dr} is assumed to be zero. Therefore, equations (11) and (12) allow to solve the system (13)-(19) in terms of innovations to the current account, change in net foreign assets, change in currency held by the public, change in liquidity, change in central bank's net bonds holdings, the reference interest rate and the exchange rate measure. In matrix form, the system that involves A_{22} and B_{22} becomes[7]:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & -\beta \\ -1 & 1 & 0 & 0 & 0 & -\rho & \delta \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & \gamma & \tau \\ 0 & 0 & 0 & 1 & 0 & \eta & -\omega \\ 0 & -\theta_{\Delta nfa} & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & -1 & -1 & -1 & 0 & 0 \end{bmatrix} \begin{bmatrix} u_{ca} \\ u_{\Delta nfa} \\ u_{\Delta cp} \\ u_{\Delta li} \\ u_{\Delta mp} \\ u_{ir} \\ u_{er} \end{bmatrix} =$$
$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ \phi_{ca} & 1 & 0 & 0 & 0 & \phi_{ka} & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & \theta_{\Delta cp} & \theta_{\Delta li} & 1 & 0 & 0 \\ 0 & \psi_{\Delta nfa} & \psi_{\Delta cp} & \psi_{\Delta li} & \psi_{\Delta mp} & 0 & 1 \end{bmatrix} \begin{bmatrix} v_{ca} \\ v_{\Delta nfa} \\ v_{\Delta cp} \\ v_{\Delta li} \\ v_{\Delta mp} \\ v_{ka} \\ v_{\Delta oi} \end{bmatrix} \tag{20}$$

While section 2 emphasized the fact that the observable error terms come as a result of the underlying structural shocks, it is now of interest to see how this unobservables forces could be empirically deduced from the former observable forecast errors. It follows from the previous discussion that in the open-economy setting under study we have not only one, but two simultaneous monetary policy shocks. One of them operates in the foreign exchange market, where the central bank also reacts to the demand for domestic and foreign currency. The other one can be found by appropriately filtering the one-step-ahead forecast error for the change in the central bank's net bonds holdings from the result of the external sector and the policy reaction to the public and commercial bank's liquidity demand shocks.[8] From (20) it is easy to see that:

$$\begin{aligned} v_{\Delta nfa} &= (\phi_{ka} - \phi_{ca})u_{ca} + (1 - \phi_{ka})u_{\Delta nfa} \\ &\quad + \rho\phi_{ka}u_{ir} + (\beta\phi_{ca} - \delta\phi_{ka})u_{er} \end{aligned} \tag{21}$$

$$\begin{aligned} v_{\Delta mp} &= -\theta_{\Delta nfa}u_{\Delta nfa} - \theta_{\Delta cp}u_{\Delta cp} - \theta_{\Delta li}u_{\Delta li} \\ &\quad + u_{\Delta mp} - (\eta\theta_{\Delta li} + \gamma\theta_{\Delta cp})u_{ir} + (\theta_{\Delta li}\omega - \tau\theta_{\Delta cp})u_{er} \end{aligned} \tag{22}$$

Unsurprisingly, under the currency board example ($\phi_{ca} = \phi_{ka} = 1$) neither the

[7] Appendix A shows that the model satisfies both the necessary order condition for identification and, based on Rubio-Ramírez et al. [31], a sufficient rank condition for global identification.

[8] Note that while for the U.S. monetary policy is often associated with innovations in the monetary target (i.e. the Fed Funds rate), Schabert [35] also proposes to identify monetary policy via changes in open market operations.

current account nor the capital account forecast errors play any role whatsoever when deducing the monetary policy shock on the external sector. In this case, this policy shock becomes $v_{\Delta nfa} = \rho u_{ir} + (\beta - \delta)u_{er}$. On the other hand, to the extent that the monetary authority reacts to contemporaneous shocks to its balance sheet (i.e., $\theta_{\Delta j}$ for some $j = cp, li, nfa$), to obtain the local-currency policy shock it is necessary to consider the news provided by additional forecast errors other than $u_{\Delta mp}$ itself.

4 Caveats

The above proposal for identification is subject to a number of criticisms that should not stay unmentioned. The most popular one comes as a response to Sims' [36] arguments against non-credible identification restrictions. A common interpretation of Sims' article is that the fear of placing the wrong restrictions should be enough incentive to leave the model as unrestricted as possible. In the present case, we have a reduced-form covariance matrix that will provide us with $\frac{k(k+1)}{2} = 55$ different restrictions, while we have only 49 unknown parameters (39 coefficients and 10 variances, one for each orthogonalized shock). Thus, it can be argued that, by dropping some of the restrictions, we would have an overall more credible identification structure.[9]

A more profound critique, nonetheless largely neglected in most of the literature, is the one that warns about the implications of forward-looking behavior for the credibility of zero restrictions as identification assumptions. The decision rules of forward-looking economic agents depend on the subjective *conditional* probability distributions that sthey have regarding what is unknown to them of the future. Thus, we are likely to face a misspecified equation if, after asserting that agents form their expectations conditional on all available information, we state, for instance, that contemporaneous changes in net foreign assets do not affect decisions that are eventually reflected in the capital account. On the contrary, the literature on currency crises that starts with Krugman [22] is precisely concerned with agents minding the level of international reserves in order to decide their domestic/foreign currency holdings.

Interestingly, Sims [36] himself stressed how "deeply subversive of identification" (p. 7) the rational expectations hypothesis is, even though later in that same article he turned to zero restrictions for identification. Since dealing with all of his critiques at once was "a [research] program which is so challenging as to be impossible in the short run" (Sims [36], p. 11), it is possible to justify Sims procedure as a first step towards improved estimation of macroeconomic models. The first caveat mentioned above can indeed be better understood from this perspective. As long as each additional *zero restriction* is regarded as a further departure from appropriately accounting for forward-looking behavior, one should leave as many parameters unrestricted as possible.[10] This leads to the conclusion that it is not overidentification per se that should be frown upon, but overidentification through zero restrictions. If, on the contrary, forward-looking behavior is appropriately accounted for, then whether the structural model is

[9] Of course, the counting exercise above leads only to a necessary condition for identification. It does not follow, then, that by dropping any one of the restrictions identification would necessarily be preserved.

[10] It is not surprising, then, that Sims [36] uses the just-identified Cholesky factorization.

overidentified or not ceases to be an issue.[11]

A number of reasons support overidentification in the present case. The first one relates to the appropriate procedure for selecting which restriction to drop. Christiano et al. [9] have criticized Bernanke and Mihov's [6] test for selecting among different identification schemes, which consists in imposing an additional, maintained, restriction, to then use standard likelihood ratio methods for testing the alternative identification assumptions. Christiano et al. [9] point that, unless there are "overwhelimingly sharp priors" that support the maintained restriction, these procedure is not useful.

Second, there is a pragmatical advantage derived from using an overidentified model. Based on the bootstrap confidence intervals of the impulse response functions, it is possible to learn how much information the data provide for unveiling the effects of the structural shocks. The smaller the sample size, the more difficult it is to accurately estimate the effects of a certain shock, even more so for those shocks that explain only a small portion of the variability in the data (Christiano, Eichenbaum and Vigfusson [10]).[12] Overidentification allows to narrow bootstrap confidence intervals in spite of having a relatively small sample.

Additional pitfalls in the VAR literature come from the fact that the information set the econometrician assigns to the central banker does not match their actual information set. In fact, it is possible to argue that neither of these sets is included in the other one. On the one hand, the block diagonal structure adopted here implies that the monetary authority observes and responds to final, revised data on terms of trade, output and prices. Rudebusch [32] shows that if data revisions by statistical agencies do more than simply adding noise to the preliminary figures, then by the classic result from the errors-in-variables model, estimates of the parameters in the monetary authority's reaction function are biased.[13] The problem with the opposite ordering, however, is that certain behavioral equations become certainly controversial. For instance, with the transactions block ordered first, money demand cp would not have current output or prices as arguments.

On the other hand, the decision maker is likely to react to variables not included in the econometrician's data set, such as the trade balance, the stance of fiscal policy and political pressures (Khoury [19], cit. in Rudebusch [32]). Doubts cast on the estimated reaction functions due to this type of concerns has led several authors to focus on the dynamic response of the system to the estimated shocks rather than on the estimated systematic component of monetary policy (Sims [38], Christiano et al. [9]).

In his critique to VAR measures of monetary policy, Rudebusch [32] also emphasizes the possibility of misspecification due to the use of a linear structure in the monetary authority's reaction function. This could be the case if the policy reaction function is a nonlinear function of the information set of the policy-maker, or if the decision rule of the latter involves moving the policy instrument by discrete amounts (Eichenbaum

[11] The most appropriate alternative to zero restrictions goes back to Sargent [33], who estimates a permanent-income model with cross-equations restrictions. This notwithstanding, it has been argued that the type of short-run restrictions used here seems to be the most appropriate to identify two type of policies (Kim, [20], p. 357).

[12] Once detected, there are no solutions for large confidence intervals but to "impose additional indentifying restrictions (i.e., use more theory) or obtain better data" (Christiano at al. [10], p. 40).

[13] For an empirical analysis of the importance of data revisions using U.S. data, see Croushore and Evans [12].

and Evans [16]). This type of misspecification is not investigated here, both because it would not be clear the precise source of nonlinearity (Eichenbaum and Evans [16]), and because a linear model could provide accurate results even when the structure of the economy is nonlinear (Sims [38]).

5 Measuring monetary policy in Argentina

To evaluate its performance, this section applies the methodology developed in section 3 to the case of Argentina. The first subsection presents the variables included in the model and the specification to be used. The second subsection presents and discusses the estimation results.

5.1 Data and specification

Estimation is conducted employing monthly data from 2003:4 through 2008:9.[14] Based on the discussion of the previous sections, the variables in the VAR are constructed according to the following description. All stocks are as of the end of the corresponding period.

- Terms of trade growth (tot). Monthly variation of the terms of trade index, interpolated from the National Institute of Statistics and Censuses (INDEC) statistics (see Appendix B).
- Output growth (g). Monthly variation of the seasonally-adjusted real gross domestic product, interpolated from INDEC national accounts statistics (see Appendix B).
- Inflation (p). Monthly variation of the GDP deflator, monthly series, interpolated from INDEC national accounts statistics (see Appendix B).
- Net foreign assets (nfa) consists of gross international reserves net of checking accounts in foreign currency and obligations with IFIs.
- Current account (ca) data were collected from the foreign exchange market statistics of the Central Bank of the Republic of Argentina (BCRA henceforth, by its initials in Spanish).[15] The series is expressed in Pesos using the average reference exchange rate released by the BCRA.

[14] Argentina abandoned its currency-board regime on January 6, 2002. I leave 2002 and the first months of 2003 out of the sample because of the turmoil affecting the financial system during that period.

[15] The data come from the "Mercado Único Libre de Cambios". There are multiple reasons that justify this decision, among them the fact that the balance of payments computes trade in goods at the time of embarkment while the exchange market computes it when the foreign-currency transaction is liquidated, and because the latter is calculated on a cash basis rather than on a accrued basis, and thus appropriately captures the transactions that influence the exchange rate within each period of time. Fortunately, foreign exchange market statistics are available at a monthly frequency (as opposed to the quarterly data provided by National Accounts statistics). For the differences between the balance of payments statistics released by the Direction of National Accounts and the data used here from the foreign exchange market elaborated by the BCRA, see `http://www.bcra.gov.ar/pdfs/estadistica/diferencias.pdf` (in Spanish).

- Currency held by the public (cp) includes both Pesos and quasi-monies held by the public, seasonally adjusted. Quasi-moneis, which rescue finished in March 2004, had been issued by different provinces since 2001. By including them within cp, however, we are assuming that they constitute a (contingent) liability of the central bank.

- Bonds (mp) includes only BCRA Peso-denominated bonds. Peso-denominated bonds issued by Argentina's Treasury held by BCRA are set aside from this definition, since variations in this item could well respond both to quantities (open market operations) or prices, and the latter are particularly volatile for the country under study. Thus, Public bonds in Table 1 go within other items.

- Commercial banks' liquidity (li) includes checking accounts in Pesos at BCRA, domestic currency held by banks (i.e., cash in vaults), and reverse repos net of (i) repos and (ii) iliquidity rediscounts.[16]

- The interest rate (ir) is the average interest rate for loans between domestic financial institutions (period average) released by BCRA.

- The exchange rate (er) is BCRA's reference exchange rate (period average).

Since identification in (20) is achieved by exploiting linear relationships, it is not possible to resort to log levels for normalization (Strongin [40]). Monetary stock variables and ca are therefore normalized by the lag of a 36-month moving average of cp.[17] Normalized series are plotted in Figure 4 (Appendix C).

Specification tests are presented in Appendix C. In a nutshell, the AIC suggests one should prefer the model with three lags to the one with two lags, and the latter to the one with only one lag, while based on the other information criteria the preference relation is reversed. The model with two lags should be preferred in terms of compliance with both the assumption of no serial autocorrelation and of normality of the residuals. On the contrary, these two assumptions and the one of homoskedasticity seem to be violated in the specification wih only one lag. On the other hand, the VAR(3) specification conforms slightly better to homoskedasticity than the VAR(2). In light of these considerations, we are inclined to present the results obtained with the model with two lags. For the sake of robustness, however, all estimates presented here were compared

[16] Note that the supply of net reverse repos is not taken into account within mp. Behind this choice stands the claim that the supply of net reverse repos is perfectly elastic, their quantity being determined solely by the demand of commercial banks. It must be noted, however, that this is not justified on the grounds of there being 'implicit costs' (Nakashima [27]) in discount-window borrowing that discourage commercial banks from borrowing infinite quantities when the discount rate is below short-term interest rates. Contrary to the case of the United States, for the period under analysis commercial banks in Argentina were net discount-window *lenders* to the monetary authority. The underlying assumption is, then, that the fact that the BCRA passively accommodates to the excess liquidity the banks wish to collocate in reverse repos in the short run. The same reasoning applies to Iliquidity rediscounts, which were a major source of liquidity during the first years of the period under analysis, when they were used to face the deposit withdrawals that followed the pesification of the latter. While the BCRA had established a schedule for the cancellation of these rediscounts, the bulk of them was cancelled in advance of that schedule.

[17] Strongin [40], Bernanke and Mihov [6] and others normalize U.S. data by a moving average of total reserves. In the present study, the closest analogue of total reserves is li. However, this last variable remains negative until 2004.

to the ones of the model with three lags. These were not not qualitatively different from the ones presented here, and are available from the author upon request.[18]

5.2 Estimation and results

The structural model is estimated via full information maximum likelihood. 95 % confidence intervals for impulse response functions are computed using the bootstrap procedure described in Christiano et al. [9],[19] represented by the dashed lines in the figures to be introduced below.

5.2.1 What happens after both monetary policy shocks?

Figure 1 presents the response of the different variables to monetary policy shocks. A remarkable dynamic feature produced by the estimated SVAR regarding foreign exchange intervention is that the central bank's unexpected purchase of foreign currency is not even nearly mirrored by an increase in the monetary base on impact. And this fact can only be partially explained by the systematic sterilization component of the intervention: on impact the central bank absorbs only one third of the shock (33.8%, nearly significant at the 5% level). It follows then that some of the components within "Other items, net" (*oi*, see Table 1) must *necessarily* be affected by this shock. Notably, this might mean that the unexpected foreign exchange purchase partially corresponds itself with the reduction of a Treasury liability to the central bank (a central bank asset). It is possible to think of a situation in which, upon running a surplus, the Treasury cancels transitory advances lent by the monetary authority, to then have the latter purchasing foreign currency so that the monetary base remains unaffected (as the fiscal surplus was raised from the private sector in the first place). This would open the way to the possibility, unexplored in the literature, that monetary policy shocks be indeed partially driven by fiscal shocks.[20]

The foreign exchange intervention shock causes a depreciation of the domestic currency. For the most part, this observed depreciation can be explained by the systematic sterilization of intervention. According to portfolio balance models, the increase in Peso-denominated assets in the portfolio of the private sector requires a fall in the price

[18]With $T = 66$, we are left with only 43 and 32 degrees of freedom in the VAR(2) and VAR(3) specifications, respectively. This notwithstanding, Bernanke and Mihov [6] rely on a similar amount of degrees of freedom for their short sub-sample 1988-1996. Their 100-observations sample is further reduced because of using a maximum lag of 11. The remaining 89 observations are used to estimate a VAR with an intercept and lags 1 to 6, 8, 10, and 11. This leaves them with as many as 34 degrees of freedom, notably lower than the ones left in other sub-samples, ranging from 100 to 305 for the whole sample, although parameter stability is a problem when the whole sample is used (see Bagliano and Favero [2]).

[19]First, the following procedure is repeated 200 times: (i) from the residuals of the estimated model, draw a random sample of size equal to the sample size T, with replacement; (ii) based on this new set of residuals, construct the series included in the model using the estimated coefficients and the historical initial conditions; (iii) then re-estimate the VAR using this artificially generated sample, and calculate its IRFs. Then, for each lag, order the 200 impulse responses from smallest to largest. The lower and upper boundaries are the corresponding percentiles in this ordering. See Christiano et al. [9], p. 22, footnote 23.

[20]Of course, one could also think of a central bank demanding resources from the Treasury to enable the latter to buy foreign currency. The question of whether there is fiscal or monetary dominance clearly raises an identification issue.

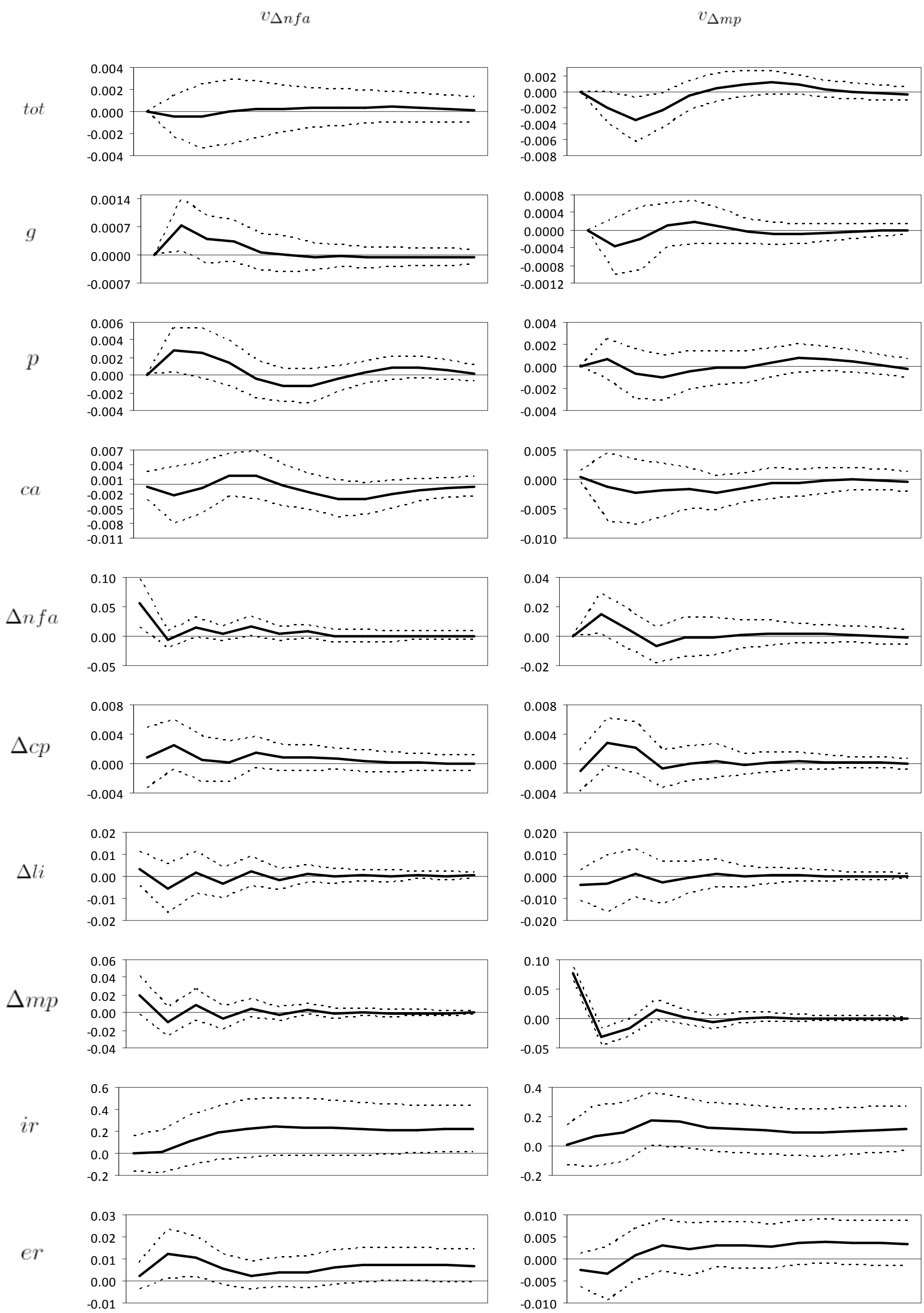

Figure 1: What happens after both monetary policy shocks?

of these assets relative to the price of foreign assets (e.g., Obstfeld [28], Dominguez and Frankel [14]).[21] This would induce the persistent depreciation observed in the estimated impulse-response function, there also being evidence of a mild overshooting during the first few months after the impact. On the contrary, the evidence here rejects the possibility that the exchange rate depreciation is ultimately grounded on the unexpected purchase of foreign currency conveying a signal of a less tight monetary policy in the future (e.g., Lewis [25], Kaminsky and Lewis [18], Payne and Vitale [29]). If that were the case, then the central bank should systematically pursue expansionary open market operations some time after the impact. However, the estimated model shows how this policy reaction is far from being statistically significantly different from zero one month after the impact, to then rapidly die out.

While the literature on foreign exchange intervention has traditionally been confined to the question on whether or not it is effective in influencing exchange rates (see, e.g., Sarno and Taylor [34]), the present analysis is wider in its scope.[22] It is thus possible to gauge the effects of this type of monetary policy shock on the rest of the economy. In that regard, the estimated model features a significant, temporary acceleration in inflation one month after the impact, alongside a temporary increment in the rate of growth. The jump in the inflation rate can be rationalized straighforwardly as exchange-rate pass-through. Interestingly, the response of output is thus consistent with Lucas' [30] model of price misperceptions, a transmission mechanism largely discarded in studies using U.S. data and which focus on only one possible policy shock (Christiano, Eichenbaum and Evans [8]). Finally, while the real interest rate initially falls, it starts recovering around three months after the shock as nominal interest rates increase.

As for the effects of the other monetary policy shock, an unexpected open market operation produces a significant slowdown in the rate of terms of trade growth. This fact reappears here as surprisingly as was first found out by Sims [37].[23] The response of output growth, on the other hand, is of the expected sign, although it is not statistically significant at conventional significance levels.[24] The contractionary monetary policy shock also produces an increase in interest rates, consequently there being no evidence of a *liquidity puzzle* (Leeper and Gordon [23]). In addition, the shock has no significant effects on the price level. That inflation does not accelerate after the contractionary monetary policy shock indicates that the identification strategy also overcomes

[21]For this to be true, the private sector should not be providing foreign currency to the Argentine central bank by selling foreign bonds. If that were the case, there would be no excess demand for foreign currency in the event of a fully sterilized intervention. The argument above thus rests on the assumption that Argentine and non-Argentine assets are not perfect substitutes.

[22]An exception in the theoretical literature is Vitale [41], who proposes a model with foreign exchange intervention as a signalling device that, in equilibrium, reduces the volatility of the employment level.

[23]Upong finding that a contractionary monetary policy shock reduces commodity prices in all but one of the countries studied, Sims argues that "[t]he only caveat is that it is perhaps surprising that four of these five countries' monetary policies could all independently have such strong influences on a single international commodity price index." (op. cit., p. 988)

[24]In the model with three lags, which impulse-response functions are not reported here, one and two months after the monetary policy shock output growth does fall significantly. The point estimate of the slowdown is of -0.79% and -0.72% annualized, respectively. The 95% confidence interval for the deceleration one month after the perturbation indicates that output growth is estimated to fall from 0.1% to 1.5% annualized. This model also displays a bounce-back effect in output growth around 5 months after the shock.

the *price puzzle* (Sims [37], Eichenbaum [15]). That there is no evidence of the shock generating deflationary pressures, on the other hand, suggests that the deceleration in output growth could be rationalized by sticky-prices or limited participation models (Christiano et al. [8]).

On impact, the contractionary monetary policy shock produces an appreciation of the exchange rate, as has been found elsewhere in the literature for other small and open economies (Zettelmeyer [42]), and there is thus no evidence of an *exchange-rate puzzle* in which a monetary tightening leads to an impact depreciation (Sims [37], Grilli and Roubini [17]). The ensuing depreciation of the domestic currency, although not significant at convetional significance levels, is consistent with the uncovered interest parity condition (UIPC). Under this condition, an increase in domestic interest rates relative to foreign interest rates should be followed after the impact appreciation by a persistent depreciation of the domestic currency.[25] As found by Kim and Roubini [21] for major industrialized countries, the rapid reversal of the impact appreciation is indeed evidence of no delayed overshooting and that the UIPC might hold. In other words, there is no evidence of a *forward discount bias puzzle* (Eichenbaum and Evans [16], Grilli and Roubini [17]).

It is also interesting to note that in both specifications the response of the central bank's net foreign assets holdings almost mimics the response of the demand for currency by the public. Even when it might be puzzling that a contractionary monetary policy shock is followed one month later by an increased demand for local currency, impulse response functions show very clearly that the monetary authority is constantly accomodating to these changes. Thus, when the demand for domestic currency increases, the central bank exchanges it for foreign currency, and vice versa. As a result of this accomodative policy, the exchange rate barely moves through time, with only a slight depreciation one quarter after the shock.

5.2.2 The response to current developments in the economy

Table 2 reports the point estimates and 95% confidence intervals of the parameters in the monetary authority's reaction functions (equations (15) and (18)). The most surprising results are the ones related to the provision of foreign and domestic currencies by the central bank. In both specifications the BCRA absorbs less than 3% of the current account shocks. More striking is the finding that, albeit small, the response to capital and financial account shocks ranges from statistically insignificant in the SVAR(3) specification to negative in the SVAR(2) specification. In other words, as far as the contemporaneous response to shocks is concerned, the reaction function of the central bank for the period under study does not resemble the one of a currency board.

The provision of liquidity through open market operations also yields interesting results. Estimates indicate that the Argentine central bank does not accommodate neither to currency demand shocks by the public nor to liquidity shocks by commercial banks. On the contrary, both specifications yield a significant and sizeable contemporaneous accomodation of the BCRA to the results of its own intervention in the foreign exchange market. The 95% confidence intervals suggest that the Argentine central bank is likely

[25] We sensibly assume that Argentina is an economy small enough so as not to affect foreign interest rates, and so the latter can be assumed to remain constant. Kim and Roubini [21] find that only Japan and Germany, among all non-U.S. G-7 countries, are large enough to affect world interest rates.

to sterilize in a range from 5.8% to 65.3% its intervention in the foreign exchange market within the same month. In the case of a positive current or capital account, this means that the Argentine central bank systematically repurchases (in exchange for bonds) a fraction of the monetary base it initially sold to accommodate to the demand for local currency.

Table 2. Contemporaneous response to shocks

	SVAR(2)			SVAR(3)		
	Coef.	95% conf. int.		Coef.	95% conf. int.	
ϕ_{ca}	0.0109	-0.0003	0.0221	0.0209*	0.0083	0.0335
ϕ_{ka}	-0.0199*	-0.0321	-0.0078	-0.0120	-0.0247	0.0007
$\theta_{\Delta cp}$	-0.0050	-0.0245	0.0145	-0.0106	-0.0294	0.0083
$\theta_{\Delta li}$	0.0002	-0.0207	0.0212	0.0055	-0.0134	0.0244
$\theta_{\Delta nfa}$	0.3376*	0.0578	0.6174	0.3884*	0.1235	0.6533

* statistically significant at the 5% level.

Besides looking at its contemporaneous accomodation to shocks, impulse response functions allow us to assess the evolution of endogenous monetary policy-making through time. As in the previous subsection, only estimated impulse-response functions of the model with two lags will be discussed here. Figures 2 and 3 present the systemic response to non-policy shocks. Estimates show that two to three months after a terms-of-trade shock net foreign assets increase. The sharp improvement in the central bank's external position prevents the currency from appreciating and interest rates fall two months after the impact. Interest rates might not fall initially due to the central bank's counter-cyclical open market operations the month following the shock, with BCRA bonds increasing in a nearly significant way.

A supply shock causes net foreign assets to increase in the second and third months after that shock takes place, a fact that might explain why the exchange rate does not appreciate significantly. Overall, open market operations appear to be neutral when facing this shock, which points to a pro-cyclical monetary stance, with interest rates remaining broadly stable. Similarly, as a response to an inflationary shock net foreign assets and central bank bonds are reduced, especially one month after the perturbation. Again, the intuition suggests that without this type of response interbank interest rates, which rise alongside the fall in commercial bank's liquidity, would experience a significant increase.

Dynamic response functions show that current account innovations are not absorbed further than what Table 2 indicates for the month within the impact. However, an important remark is that all the responses of the system to current account shocks are estimated very imprecisely. Given that the data do not provide evidence that current account shocks significantly affect the system, this motivates looking for alternative methodologies that enable the use of longer time series.

Responses to domestic currency demand innovations also appear to be subject to substantial sampling uncertainty. This notwithstanding, there is evidence that the BCRA accommodates to this shock by buying foreign currency, without sterilization, although this does not prevent the appreciation of the Peso two months after the innovation took place. More puzzling is the response of the BCRA to a liquidity demand shock. One month after the shock the central bank issues additional bonds, putting more pressure on the liquidity market. Only two months after the initial impulse the

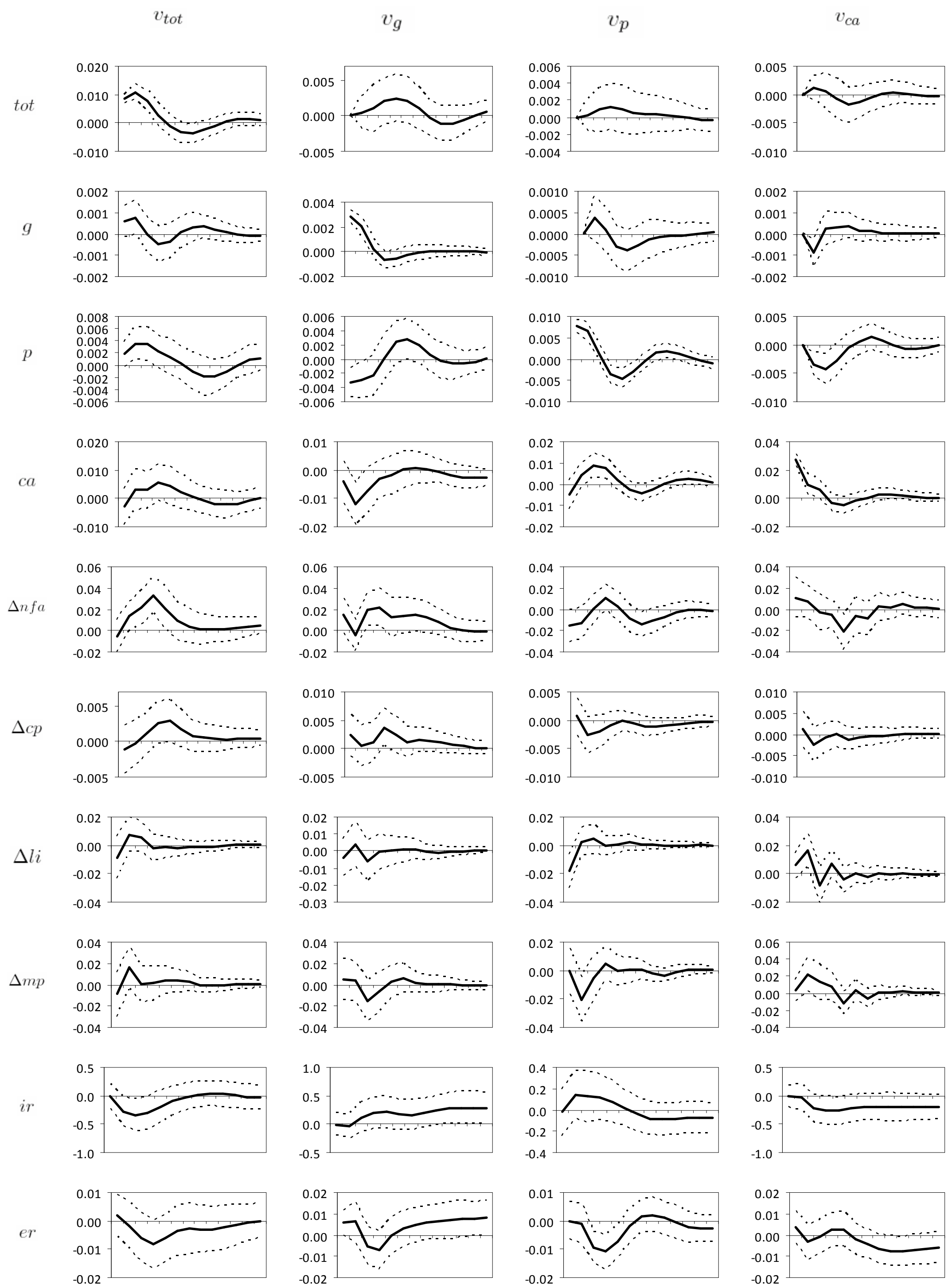

Figure 2: Systemic response to non-policy shocks

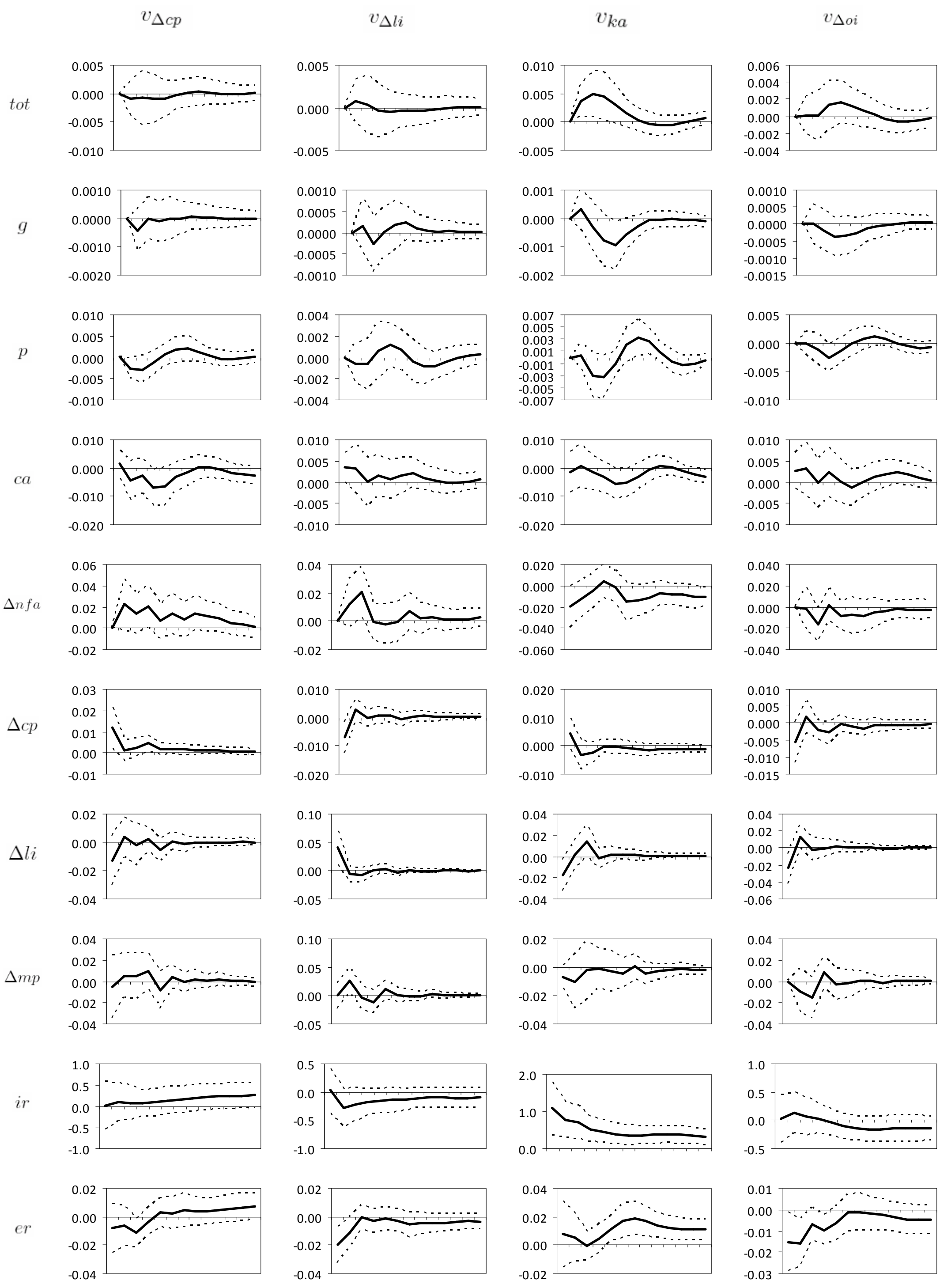

Figure 3: Systemic response to non-policy shocks (continued)

central bank eases the pressure by buying foreign currency, as the increased demand for domestic liquidity produces a contemporaneous appreciation of the local currency. Again, the stability of interest rates throughout this process may in fact reflect the pervasive effects of sampling uncertainty. Finally, impulse response functions find no significant response of the BCRA to capital account shocks, even when there is evidence that interest rates rise within the first half of the year after the shock and the exchange rate depreciates henceforth.

5.2.3 Overall assessment

It has been argued that a basic test that an identification strategy should pass is to yield "reasonable" results. Indeed, Christiano et al. [9] propose to reject a particular identification scheme if there is no coherent model that can account for its impulse response functions. A broader, and epistemologically less debatable, interpretation of the argument suggests that a particular identification strategy should be discarded if its impulse response functions were at odds with basic intuitions regarding monetary policy. That is, we should reject impulse response functions that are "inconsistent not only with existing models but also with views that have been held by actual policy makers for many decades – indeed, for over a century" (McCallum [26], p. 121, cit. in Cushman and Zha [13], p. 435).

In this sense, the proposed identification strategy features many results that are broadly supported by conventional economic wisdom. Terms of trade shocks induce a temporary acceleration of output growth and inflation, particularly within the first two months, a temporary (though not significant) improvement of the current account one to three months after the shock, a significant increase in net foreign assets two and three months after the shock, an increased demand for local currency, and an appreciation of the domestic currency two to three months after the shock. Output shocks, which are also subject to considerable inertia, imply a temporary reduction in inflation, a deterioration of the current account during the month following the shock, an improvement in the central bank's external position only after the deterioration of the current account, a rise in the demand for local currency two to three months after the perturbation, and a temporary depreciation of the currency that is later followed by an appreciation. The increase in interest rates due to the supply shock starts two months after the impact, although it is statistically insignificant.

An inflationary shock increases output growth one and two months later, albeit in a nonsignificant way. The improvement in the current account that follows this shock occurs because the GDP deflator also incorporates exports prices, and with a greater weight than imports prices. Additionally, the inflationary shock appears to have a positive impact on nominal interest rates. The decreased demand for domestic currency two months after the shock can be rationalized by agents adjusting their portfolios in light of the effects of inertial inflation on real cash balances.

Also conforming with general beliefs, a current account shock results in a fall in interest rates and an increased liquidity of commercial banks. Additionally, a positive shock in the demand for domestic currency leads to a nearly significant deceleration of inflation. The increased demand for local currency results in its appreciation vis-à-vis the U.S. dollar two months after the shock. As expected, a positive shock to the demand for liquidity by commercial banks results in a fall in the amount of currency held by the public, and in the rise of the dollar value of the currency. Finally, a foreign-currency supply shock operating through the capital and financial account leads to a temporary acceleration of growth that is then reversed.[26]

Notwithstanding the compliance of the aforementioned responses to conventional wisdom, some results turn out to be more puzzling. Less easy to rationalize is the response of output growth to a current account shock. A foreign-currency supply shock operating through the current account leads to a fall in GDP growth during the month after the shock took place.[27] Also puzzling is the response of some of the variables to a capital account shock. In particular, it is somewhat difficult to explain that a capital account shock simultaneously (i) increases terms of trade growth, (ii) increases interest rates, and, a few months later, (iii) depreciates the currency.

Overall, however, the estimated model seems to fit relatively well generally accepted views regarding the effects of non-policy shocks.

6 Concluding remarks

Identification of monetary policy shocks in open economies has been dealt with diverse approaches, although without reaching a consensus about the dominant one. This paper extended a popular identification strategy originally developed for the U.S. relatively closed economy so that it could account for the simultaneity between interest rate and exchange rate innovations present in any open economy. Moreover, the methodology allows a separate treatment of two distinct monetary policy shocks, namely, the one that operates through open market operations, and the one that takes place through interventions in the foreign exchange market. In doing so, it attempts to disentangle the pressures stemming from the markets for domestic and foreign liquidity from the central bank's response to these pressures.

The strategy is implemented to the Argentine economy over the period 2003-2008. Although the methodology is subject to a number of long-standing (some often neglected) critiques raised in the literature, the dynamic features of the estimated model are broadly supported by conventional economic wisdom. Estimation results should thus serve both to confront theoretical models against reality, and to shed light on the way central banks operate in open economies.

Dynamic responses of the system to a typical, unexpected purchase of foreign currency indicate that the central bank issues bonds to absorb around one-third of the domestic currency against which the foreign exchange intervention takes place. The ensuing depreciation of the domestic currency provides evidence of a portfolio balance channel. As a result of exchange rate pass-through, inflation jumps after the shock, and the temporary increase in the rate of output growth can thus be thought in terms of price misperception models. Finally, while the real interest rate initially falls, it starts recovering around three months after the shock as nominal interest rates increase. On the other hand, unexpected open market operations affect output growth with the expected sign, although it is not statistically significant at conventional significance levels.

[26] I will not focus on the response of the system to $v_{\Delta oi}$ shocks, as there are no conventional priors to have in this regard.

[27] In the model with three lags, there is a significative bounce-back effect in the third month after the impulse.

The results also prove to be free of the empirical anomalies previously found in the literature. There is no evidence of a *liquidity puzzle*; following a contractionary policy shock, interest rates rise. Moreover, the *price puzzle* is also absent; inflation does not accelerate after the shock. Finally, the unexpected tightening produces an impact appreciation of the domestic currency, and there are thus no signs of an *exchange-rate puzzle*. Moreover, there is an ensuing depreciation of the domestic currency which shows that there is no evidence of a *forward discount bias puzzle*.

Regarding the systematic component of monetary policy, this paper finds that, notwithstanding the relative stability of the exchange rate and the accumulation of large amounts of international reserves, the central bank in Argentina has been far from absorbing balance of payments shocks in a currency-board fashion. The growing level of international reserves can be rationalized, instead, as the monetary authority's response to shocks to the terms of trade, supply shocks, and innovations in the demand for domestic currency, both by the public and by commercial banks.

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APPENDIX A

This appendix draws entirely from the identification theory by Rubio-Ramírez et al. [31] (RWZ henceforth). It is beyond the scope of the present study to develop this theory here. Thus, the reader is referred to RWZ to understand the procedure below. To facilitate this task, this appendix adopts RWZ's convention of writing the VAR model with the endogenous variables as a *row* vector (see RWZ, p. 5, eq. (1)). Hence, matrices A and B will appear transposed.

To apply the identification theory of RWZ, first it is necessary to drop the normalizations adopted in the previous sections. Second, we also need consider the identification of those parameters that do not appear in matrix A or matrix B, namely the variances of the structural shocks. If we assume that the structural shocks are not only orthogonal, but also of unit variance, then we can accommodate matrix B to have unrestricted coefficients where it had ones. For example, instead of being an identity matrix, B_{11} becomes:

$$B_{11} = \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}$$

so that, for instance, the variance of the terms of trade (which is ordered first) structural shock is simply $VAR(b_{11}\breve{v}_{11}) = b_{11}^2 VAR(\breve{v}_{11}) = b_{11}^2$, where $\breve{v}_{11}$ is the unit-variance orthogonal terms of trade shock.

With these considerations taken into account, the function $f(A_0, A_+)$ of transformed structural parameters is the 20×10 matrix that results from the vertical concatenation of the non-normalized versions of A' and B':

$$f(A_0, A_+) = \begin{bmatrix} a_{11} & a_{21} & a_{31} & a_{41} & a_{51} & a_{61} & a_{71} & a_{81} & a_{91} & a_{10,1} \\ 0 & a_{22} & a_{32} & a_{42} & a_{52} & a_{62} & a_{72} & a_{82} & a_{92} & a_{10,2} \\ 0 & 0 & a_{33} & a_{43} & a_{53} & a_{63} & a_{73} & a_{83} & a_{93} & a_{10,3} \\ 0 & 0 & 0 & a_{44} & -a_{55} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & a_{55} & a_{65} & 0 & 0 & -\tilde{\theta}_{\Delta nfa} & a_{10,5} \\ 0 & 0 & 0 & 0 & 0 & 0 & a_{76} & 0 & 0 & -a_{10,5} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & a_{87} & 0 & -a_{10,5} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & a_{98} & -a_{10,5} \\ 0 & 0 & 0 & 0 & -\tilde{\rho} & 0 & \tilde{\gamma} & \tilde{\eta} & 0 & 0 \\ 0 & 0 & 0 & -\tilde{\beta} & \tilde{\delta} & 0 & \tilde{\tau} & -\tilde{\omega} & 0 & 0 \\ b_{11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 & \tilde{\phi}_{ca} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & b_{65} & 0 & 0 & 0 & \tilde{\psi}_{\Delta nfa} \\ 0 & 0 & 0 & 0 & 0 & 0 & b_{76} & 0 & \tilde{\theta}_{\Delta cp} & \tilde{\psi}_{\Delta cp} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & b_{87} & \tilde{\theta}_{\Delta li} & \tilde{\psi}_{\Delta li} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & b_{98} & \tilde{\psi}_{\Delta mp} \\ 0 & 0 & 0 & 0 & b_{59} & \tilde{\phi}_{ka} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & b_{10,10} \end{bmatrix} \quad (23)$$

The tilde above each structural parameter of equation (20) indicates that the parameter is not normalized.

There are ten 20×20 Q_j matrices, one for the restrictions on each of the columns of (23). Each matrix Q_j is of rank q_j. The policy block in section 3 has been constructed so as to comply with RWZ's ([31], p. 10) convention that $q_j \geq q_i$ if, and only if, $j \geq i$.[28] Since $\sum_j q_j = 140 \geq 45 = k(k-1)/2$, the necessary condition for identification is met.

We can then proceed to construct the ten $M_j(f(A_0, A_+))$ matrices (see RWZ [31], p. 14). Since there exist values for the elements in (23) such that M_j has rank $k = 10$ for $j = 1, \ldots, 10$, we have that the model is globally identified almost everywhere in the structural parameter space where the identifying restrictions are satisfied.

The Maxima code with the entire set of rank checks is available from the author upon request.

APPENDIX B

National accounts statistics and terms of trade data are released on a quarterly basis by INDEC. Instead of turning to monthly indicators such as the overall activity index in the case of economic activity and the CPI in the case of the price level, here the choice was the interpolation of quarterly variables, whose impulse response functions are more easily interpretable.[29]

Interpolation is through state space methods. Let y_t be the monthly unobservable variable (e.g., monthly GDP) we want to recover from the data, and consider a set of s related series that are believed to provide information of within quarter movements of the series to be recovered. Defining then the state vector as $\xi_t = (y_t \quad y_{t-1} \quad y_{t-2})'$, our state equation becomes:

$$\xi_{t+1} = \mathbf{d} + \mathbf{F}\xi_t + \mathbf{G}x_{t+1} + \mathbf{w}_{t+1} \tag{24}$$

where $\mathbf{d}$ is a 3×1 vector, $\mathbf{F}$ is a 3×3 matrix, $\mathbf{G}$ is a $3 \times s$ matrix, x_t is a $s \times 1$ vector of stacked related series, and $\mathbf{w}_t$ is a vector of disturbances. Under the hypothesis that the monthly series follows a random walk process,[30] $\mathbf{F}$ is simply:

$$\mathbf{F} = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

so that the first row in equation (24) becomes

$$y_{t+1} = d_1 + y_t + g_{11}x_{1,t+1} + \cdots + g_{1s}x_{s,t+1} + w_{1,t+1} \tag{25}$$

[28] We have that $q_1 = 18$, $q_2 = 17$, $q_3 = 16$, $q_4 = 14$, $q_5 = q_6 = q_7 = q_8 = 13$, $q_9 = 12$, $q_{10} = 11$.

[29] Bernanke, Gertler and Watson [4] and Bernanke and Mihov [6] are among the authors that rely on interpolated data obtained using a similar procedure than in the present study. Leeper, Sims and Zha [24], among others, use the Chow-Lin procedure. Other authors, on the other hand, simply use monthly available indicators. For instance, in order to check the robustness of their results, Christiano at al. [9] replace aggregate output with nonfarm payroll employment and the GDP deflator with the implicit deflator for personal consumption expenditures. Since January 2007 several monthly indexes produced by INDEC have been widely contested by private analysts, providing an additional reason to avoid the use of monthly indicators.

[30] The null of unit root could not be rejected in any of the quarterly series. Since the low power of the unit root tests might have severe implications for the short samples used (63 observations), interpolation was also done without imposing that the AR coefficient be equal to one. Results proved to be unsensitive to this modification.

allowing for the possibility of the monthly series to have a drift (i.e., d_1 is not restricted to zero). The second and third rows in equation (24) are mere identities, so that $\mathbf{d}$, $\mathbf{G}$ and $\mathbf{w}_{t+1}$ are:

$$\mathbf{d} = \begin{bmatrix} d_1 \\ 0 \\ 0 \end{bmatrix}$$

$$\mathbf{G} = \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1s} \\ 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 \end{bmatrix}$$

$$\mathbf{w}_{t+1} = \begin{bmatrix} w_{1,t+1} \\ 0 \\ 0 \end{bmatrix}$$

Each three months we observe a signal $y_t^{\diamond}$ of what happened within quarter, e.g., the quarterly GDP. The signal equation thus becomes the following simple average constraint:

$$y_t^{\diamond} = \mathbf{h}'\xi_t \tag{26}$$

where $\mathbf{h} = (1/3 \quad 1/3 \quad 1/3)'$.[31]

Assuming that the disturbance $w_{1,t+1}$ has a standard normal distribution, parameters are estimated by maximum likelihood. The sample goes from 1993:1 through 2008:9. Once the model (24)-(26) has been estimated, the state series is recovered by moment smoothing.

For the GDP, $s = 2$, with the "Indice General de Actividad" (IGA) from OJ Ferreres & Asociados and the "Indice de Producción Industrial" (IPI) from FIEL as related series. For the GDP deflator no related series were used. Finally, for the terms of trade $s = 5$, relying on the monthly average crude oil price, the average hard red winter wheat price, the average soybeans price, the average corn price, and the chapter of industrial commodities of the U.S. producer price index. The data source for terms of trade related series is World Bank's Global Economic Monitor. Interpolated monthly series are available from the author upon request.

APPENDIX C

Table 3 displays the standard statistics for lag order selection. The Akaike statistic suggests the use of three lags. With a larger penalization for lack of parsimony than the AIC, the Hannan-Quinn and the Schwarz criteria suggest the use of the model with only one lag.[32] Based on the LR test, on the other hand, it is possible to reject the

[31]Note that we have worked with this average constraint for all three series (GDP, GDP deflator and terms of trade). It could be argued that for the GDP, the add-up constraint that results from setting $\mathbf{h} = (1 \quad 1 \quad 1)'$ is more appropriate. I chose to work with the average constraint because it complies with the fact that quarterly GDP figures released by INDEC are annualized. Additionally, the average constraint makes the interpolated series easier to interpret for those who are familiar with Argentine GDP data.

[32]More specifically, let k be the number of parameters to be estimated and T denote the sample size. The penalization is equal to $2k/T$, $2k \cdot ln(ln(T))/T$ and $k \cdot ln(T)/T$ for the AIC, the HQIC and the SBIC, respectively. With 66 observations, the penalization factor for each additional parameter is of 0.0303, 0.0434 and 0.0635 for the AIC, the HQIC and the SBIC, respectively.

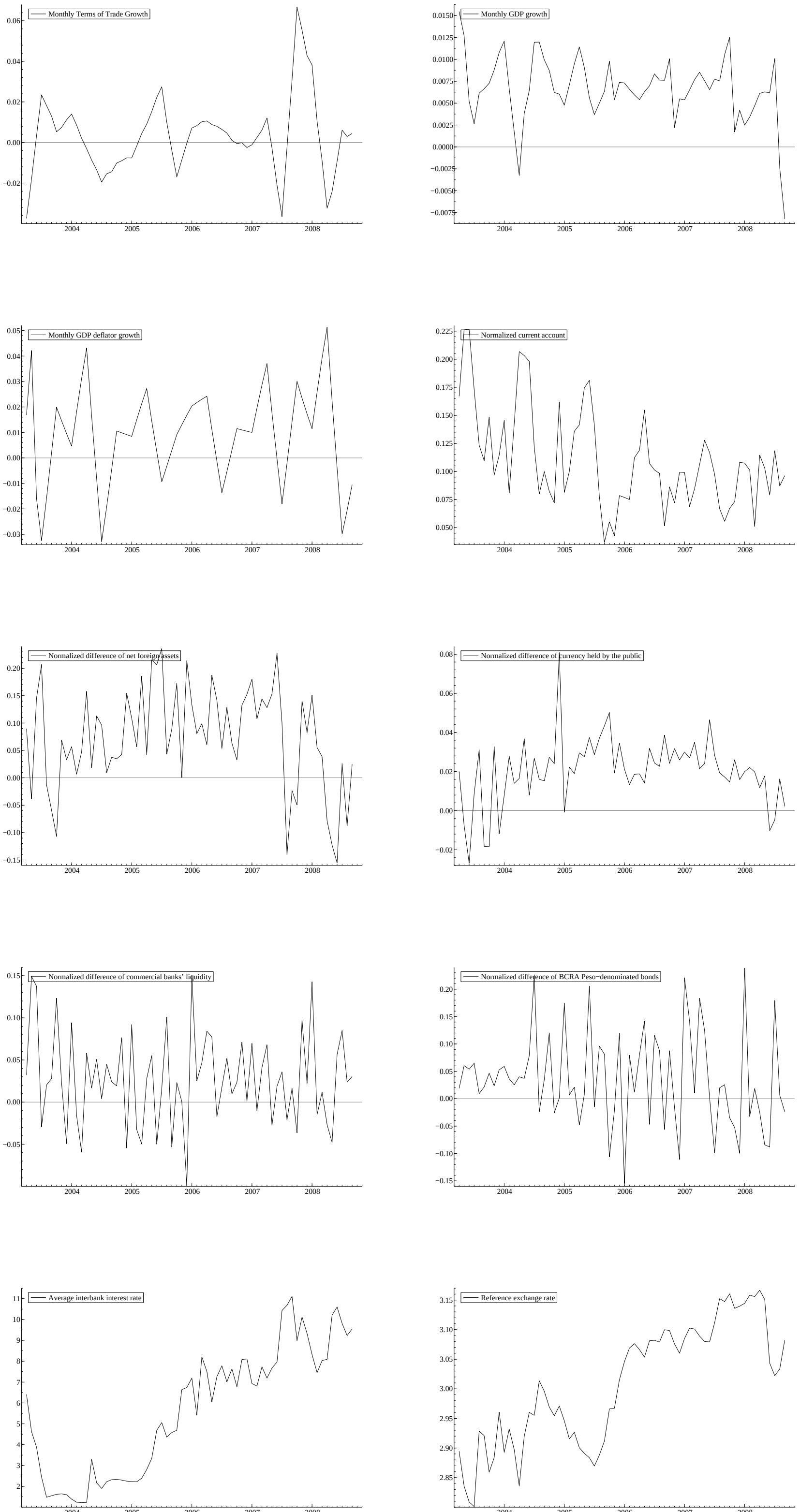

Figure 4: Variables included in the model

hypothesis that the parameters associated with the second and third lags are jointly zero.[33]

Table 3. Lag length selection criteria

Lag	AIC	HQIC	SBIC	LR
0	-34.04	-33.91	-33.7	
1	-39.79	-38.31^{*}	-36.04^{*}	562.0
2	-40.98	-38.17	-33.84	275.3
3	-41.19^{*}	-37.05	-30.65	213.5^{*}

* indicates optimal lag order.

In section 3 $v_{\Delta nfa}$ and $v_{\Delta mp}$ were the monetary policy shocks we want to be identified. As such, they reflect changes in the "personalities" involved in the decision process of the Central Bank, political factors, errors made by the policy makers in the measurement of current economic conditions, etc. However, it is necessary to recognize the possibility that the identified shocks partially reflect misspecification (Eichenbaum and Evans [16]). In light of this consideration, I follow Bagliano and Favero's [2] sensible procedure of performing a number of specification tests on the reduced form VAR, which is always consistently estimated equation-by-equation using OLS.

Moreover, insofar as the standard statistics for order selection yield ambiguous results, it is worth testing whether the different models comply with the assumptions regarding the vector of reduced VAR residuals u_t. First, it is important to see if with only one lag the assumption of no serial autocorrelation is not rejected. As it can be readily seen in Table 4, at conventional significance levels (5% or 10%) the specification with two lags outperforms the other two specifications in terms of absence of autocorrelation.

Table 4. LM autocorrelation test (p-values)

Model	1	2	3	4	5	6	7	8	9	10	11	12
VAR(1)	0.00	0.53	0.44	0.73	0.68	0.16	0.12	0.45	0.59	0.87	0.24	0.23
VAR(2)	0.12	0.15	0.22	0.32	0.83	0.54	0.40	0.42	0.41	0.93	0.45	0.66
VAR(3)	0.14	0.44	0.04	0.19	0.78	0.04	0.21	0.50	0.64	0.99	0.19	0.14

As a second step, we proceed to investigate if the residuals of the alternative specifications could be considered to be normally distributed. The second column in Table 5 shows substantial departures from normality in the VAR(1) model. On the other hand, the VAR(2) specification performs better than the VAR(3). With two lags, normality of the residuals of the equation for Δcp can be rejected at a 5% level, but not at a 1% level (p-value of 0.0196).

Table 5. Normality test χ^2

	VAR(1)	VAR(2)	VAR(3)
u_{tot}	4.66	0.37	2.28
u_g	10.41^{*}	3.57	0.28
u_p	13.07^{*}	2.43	0.78
u_{ca}	0.69	0.49	0.11

[33]The LR statistic has been adjusted to account for small-sample bias (see Sims [36], pp. 17-8). This is easily achieved by multiplying the large-sample statistic by $\frac{T-k}{T}$, where T is the number of observations and k is the number of estimated parameters per equation.

	VAR(1)	VAR(2)	VAR(3)
$u_{\Delta nfa}$	6.53*	1.39	5.23*
$u_{\Delta cp}$	9.29*	7.87*	16.10*
$u_{\Delta li}$	0.27	0.06	2.00
$u_{\Delta mp}$	1.95	2.80	0.39
u_{ir}	5.00	2.45	1.23
u_{er}	0.50	0.66	0.31

* indicates rejection of normality at the 5% level.

Finally, we test if the maintained assumption of homoskedasticity of the VAR residuals could be rejected. Table 6 shows the resulting p-values of performing Engle's LM test of autoregressive conditional heteroskedasticity (ARCH), where the null hypothesis of no ARCH effects is tested against the alternative of ARCH effects of order p. There are clear signs of heteroskedasticity in the VAR(1) residuals of the equations of tot, g, er, and, to a smaller extent, p and Δmp. With the exception of the alternative of ARCH(3) effects in tot for the case of the VAR(2), in the other two specifications it is not possible to reject the null at a 5% significance level.

Table 6. ARCH test $\chi^2(p)$ for different p's (p-values)

		1	2	3	4	5	6
u_{tot}	VAR(1)	0.00	0.00	0.00	0.01	0.01	0.01
	VAR(2)	0.71	0.09	0.05	0.10	0.17	0.07
	VAR(3)	0.89	0.44	0.43	0.27	0.40	0.49
u_g	VAR(1)	0.00	0.00	0.00	0.00	0.00	0.00
	VAR(2)	0.07	0.23	0.31	0.46	0.32	0.25
	VAR(3)	0.35	0.53	0.46	0.63	0.59	0.39
u_p	VAR(1)	0.01	0.41	0.57	0.10	0.09	0.14
	VAR(2)	0.37	0.61	0.66	0.76	0.79	0.87
	VAR(3)	0.11	0.22	0.36	0.39	0.51	0.50
u_{ca}	VAR(1)	0.90	0.88	0.79	0.58	0.76	0.70
	VAR(2)	0.84	0.98	0.67	0.74	0.53	0.33
	VAR(3)	0.63	0.63	0.25	0.33	0.40	0.52
$u_{\Delta nfa}$	VAR(1)	0.39	0.47	0.82	0.74	0.83	0.57
	VAR(2)	0.47	0.35	0.53	0.33	0.28	0.24
	VAR(3)	0.64	0.76	0.64	0.80	0.89	0.84
$u_{\Delta cp}$	VAR(1)	0.25	0.50	0.69	0.78	0.78	0.91
	VAR(2)	0.07	0.18	0.34	0.49	0.39	0.67
	VAR(3)	0.40	0.63	0.42	0.47	0.61	0.71
$u_{\Delta li}$	VAR(1)	0.68	0.69	0.77	0.87	0.81	0.98
	VAR(2)	0.80	0.66	0.88	0.77	0.93	0.95
	VAR(3)	0.65	0.80	0.84	0.95	0.94	0.96
$u_{\Delta mp}$	VAR(1)	0.02	0.05	0.11	0.20	0.08	0.07
	VAR(2)	0.84	0.11	0.21	0.31	0.44	0.58
	VAR(3)	0.83	0.13	0.24	0.28	0.44	0.44
u_{ir}	VAR(1)	0.83	0.71	0.74	0.76	0.79	0.90
	VAR(2)	0.71	0.76	0.88	0.96	0.99	0.98
	VAR(3)	0.12	0.08	0.12	0.12	0.18	0.18
u_{er}	VAR(1)	0.16	0.19	0.32	0.01	0.01	0.02
	VAR(2)	0.87	0.99	0.94	0.78	0.88	0.88
	VAR(3)	0.21	0.37	0.52	0.35	0.44	0.46

Tables 7 and 8 display the correlation matrices of the residuals of the VAR(2) and VAR(3) specifications, respectively.[34] There are two important features to note from the observation of these matrices. First, the fact that several off-diagonal elements are very large in absolute value underscores the importance of the task of identification. Second, since in most cases correlations do not differ significantly across specifications, it should not be surprising to find that both yield qualitatively similar results.

Table 7. Correlations of VAR(2) residuals

	u_{tot}	u_g	u_p	u_{ca}	$u_{\Delta nfa}$	$u_{\Delta cp}$	$u_{\Delta li}$	$u_{\Delta mp}$	u_{ir}	u_{er}
u_{tot}	1.00									
u_g	0.20	1.00								
u_p	0.21	-0.34	1.00							
u_{ca}	-0.10	-0.16	-0.11	1.00						
$u_{\Delta nfa}$	-0.09	0.22	-0.27	0.33	1.00					
$u_{\Delta cp}$	-0.05	0.12	-0.07	-0.07	0.21	1.00				
$u_{\Delta li}$	-0.17	-0.09	-0.26	0.15	0.13	-0.42	1.00			
$u_{\Delta mp}$	-0.11	0.04	-0.04	0.13	0.23	-0.12	0.05	1.00		
u_{ir}	0.05	-0.05	-0.19	-0.14	-0.20	0.22	-0.22	-0.36	1.00	
u_{er}	0.08	0.21	-0.11	-0.07	0.09	0.39	-0.29	-0.14	0.19	1.00

Table 8. Correlations of VAR(3) residuals

	u_{tot}	u_g	u_p	u_{ca}	$u_{\Delta nfa}$	$u_{\Delta cp}$	$u_{\Delta li}$	$u_{\Delta mp}$	u_{ir}	u_{er}
u_{tot}	1.00									
u_g	0.28	1.00								
u_p	0.23	-0.41	1.00							
u_{ca}	-0.01	-0.22	0.01	1.00						
$u_{\Delta nfa}$	-0.15	0.10	-0.24	0.43	1.00					
$u_{\Delta cp}$	-0.13	0.13	-0.16	0.00	0.16	1.00				
$u_{\Delta li}$	-0.22	-0.08	-0.25	0.10	0.17	-0.29	1.00			
$u_{\Delta mp}$	-0.01	-0.12	0.11	-0.04	0.11	-0.20	0.05	1.00		
u_{ir}	0.10	-0.01	-0.47	0.03	-0.10	0.12	0.09	-0.33	1.00	
u_{er}	0.05	0.23	-0.04	0.01	0.13	0.48	-0.34	-0.20	0.17	1.00

[34]Covariance matrices are estimated using a small-sample adjustment, where $1/(T - \bar{m})$ is used instead of $1/T$, being $\bar{m}$ the average number of parameters across the different equations of the VAR. This adjustment becomes relevant when estimating the structural parameters, as the covariance matrix is an argument of the likelihood function.