Essays on optimal experimentation

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Chapter 4

Using Dollarized Countries to Analyze the Effects of US Monetary Policy Shocks

4.1 Introduction

Since monetary policy is typically not executed in an erratic fashion, identifying random disturbances to the monetary instrument (the so-called "monetary policy shocks") is difficult. For this reason, the present paper has a different focus than the standard VAR exercise. Instead of trying to find the perfect shock identification scheme, this paper starts by asking: if shock identification is so difficult, can't we find a natural setting that *reduces the consequences* of the almost inevitable misidentification of monetary shocks?

The natural setting I exploit is the existence of dollarized countries. These countries import US monetary policy, but, as I will argue below, they are not perfectly integrated with the US economy. Non-monetary US shocks therefore do not survive the transmission process to these client economies undamaged. Consequently, the setting works a bit like an ideal filter that reduces the effects of any mistakenly included non-monetary shocks on dollarized country variables, while leaving the effects of the true monetary shocks untouched.

The fact that shock identification is difficult might explain the presence of

[0] The Appendix accompanying this paper is available on my website.

some ongoing debates in the structural VAR literature. Next to the fact that there is no consensus on the effects of monetary shocks on output, many studies find that prices *increase* after a monetary contraction, which goes against the predictions of most standard macroeconomic theories (such as the New Keynesian one). Even though this price response can be rationalized through the working capital channel,[1] it is generally referred to as "the price *puzzle*".

Currently, there are three popular explanations for the positive response of prices to an interest rate increase. First, some have argued that the working capital channel indeed is important and that prices do go up after a monetary tightening. If this is true, then the price puzzle is not a puzzle and incorporation of the cost channel into standard macroeconomic models seems desirable.[2]

Second, it has been argued that the price puzzle reflects the fact that the estimated VAR contains less information than available to the monetary authority. The idea is that when the monetary authority knows that inflation is about to arrive and contracts in response, prices will still rise, but by less than they would have without the contraction. Sims (1992) tries to correct for this by adding a commodity price index to the VAR and shows that this decreases the puzzle. Recently, however, this solution has been questioned. Hanson (2004) for example fails to find a correlation between the ability of variables to forecast inflation and the ability to reduce the price puzzle. Moreover, Hanson shows that including commodity prices in the VAR does not work for an early sample period, running from 1959 to 1979. These findings thus suggest that either the price puzzle is not a puzzle (it is just the working capital channel at work), or that there is a different problem.

In this light, it might also be the case that the necessary identifying restrictions are not met in practice and play a distorting role. A popular way of identifying VARs is to assume that some variables do not respond to certain shocks within the period. But as for example argued in Canova and Pina (2005) and Carlstrom,

[1] With a working capital channel in place, firms need to borrow funds in order to be able to pay for their production factors. Consequently, the interest rate becomes a determinant of real marginal costs. *Cf.* Van Wijnbergen (1983), who obtained the price puzzle - *avant la lettre* - in such a model.

[2] This development has actually started already: Barth and Ramey (2001, p. 199-200) state that "cost-side theories of monetary policy transmission deserve more serious consideration". Christiano, Eichenbaum and Evans (2005) did this by adding a working capital channel to their model. Ravenna and Walsh (2006) discuss how the cost channel affects the optimal monetary policy.

Fuerst and Paustian (2009), these inertial restrictions may not hold in reality as a result of which shocks can be misidentified and resulting IRFs (such as the one for prices) can get the wrong sign.

This paper focuses at this last problem. Hereby, it tries to shed light on the question whether economic theory should take the price puzzle seriously, or whether it is just an artifact of shock misidentification. As I acknowledge the potential of the working capital channel to explain the price puzzle, I do not take a prior position on what the price effects of monetary policy shocks *should be*. This distinguishes my approach from the sign restriction procedure employed by for example Uhlig (2005). That approach dismisses the cost channel and identifies a contractionary monetary shock as a shock that (among other things) does not increase prices.

To circumvent the use of sign restrictions, this paper takes advantage of a convenient natural setting: it uses output and price data from dollarized countries (all located in Latin America). By unilaterally adopting the US dollar, these countries have established a so-called "informal monetary union" with the US. From a monetary perspective, the client countries are therefore not that different from genuine US states as they import US monetary shocks just as normal US states do (*cf.* Stockman (1993): he constructs a two-country model of international transmission of monetary shocks and shows that there is a perfect spillover if there is no flexible exchange rate between the two countries, which is intuitive). After all, dollarized countries also use the US dollar as legal tender (just like, say, Idaho does), without having the possibility to deviate from US monetary policy, as there is no local currency to de- or revalue. Consequently, these countries rapidly import US monetary shocks (primarily via the financial channel; see Canova (2005)), while there are no exchange rate considerations at play. Hence, from this paper's perspective, dollarized countries can be seen as US states that are not represented in the Federal Reserve System. The fact that the monetary union is only "informal" (thereby contrasting with formal monetary unions, such as the euro zone), does not matter in this respect.

Taking this geographical detour has three advantages. Firstly, the resulting econometric restrictions enable one to analyze the effects of US monetary shocks in the client economies, without imposing inertial or sign restrictions on the variables of interest.

Secondly, the working capital channel is believed to be more important for dollarized countries than it is for the US (as short-term bank financing typically plays a bigger role in the former). Consequently, dollarized countries are a good candidate to test whether this channel is really capable of generating a price increase after a monetary tightening. If we would find that these countries are free of the price puzzle, this would therefore be a strong result.

Finally, and most importantly, basing conclusions upon the responses of variables in dollarized countries makes this paper's findings less prone to the major concern any structural VAR exercise has to face: misidentification of the US monetary shock. This is the case because the dollarized countries that are going to be considered (Ecuador, El Salvador and Panama) are only imperfectly integrated with the US economy. In particular, the economies of Ecuador and El Salvador are only moderately open in terms of trade-to-GDP ratios,[3] which is probably a result of the fact that these countries were rather late with decreasing their trade barriers (Sachs and Warner, 1995). In addition, to the extent that these dollarized economies do trade internationally, most of it takes place with other countries than the US.[4] Consequently, non-monetary US shocks can be expected to produce only rather limited output- and price fluctuations in these countries - especially at short horizons.[5]

Lindenberg and Westermann (2010) investigated this issue empirically and they indeed find that Latin America does not share its business cycle with the US.[6] This suggests that these cycles are not driven by the same shocks, or that

[3] As reported by the CIA World Factbook, the ratio of exports (imports) to GDP equaled 0.250 (0.249) for Ecuador in 2009. For El Salvador, these numbers are 0.183 and 0.318 and for Panama they equal 0.441 and 0.523. To compare: for a textbook open economy, such as Singapore, these ratios are 1.550 and 1.358, while the corresponding US numbers equal 0.073 and 0.110.

[4] According to the Factbook, 66 percent of Ecuadorian exports (73 percent of their imports) went to (came from) other countries than the US in 2009. For El Salvador, these numbers are 56 percent for exports and 70 percent for imports. Finally, Panama exported 82 percent (imported 88 percent) of their total to (from) non-US trading partners.

[5] Non-monetary shocks are typically transmitted through the time-consuming trade channel, as a result of which they need a while to arrive at a different region. Monetary shocks, on the other hand, are transmitted fully and quickly through financial markets. This idea has a long-standing tradition in international economics, going back to at least Dornbusch (1976), and is confirmed in the empirical exercise by Canova (2005).

[6] Lindenberg and Westermann (2010) report that the correlation in growth rates between the US and El Salvador (Panama) equals only 0.23 (0.12). Ecuador is not included in their study, but in own calculations this correlation equals 0.30. To compare: for Canada and Mexico the correlations with US growth rates equal 0.77 and 0.73, respectively. A similar result is reported by Alesina, Barro and Tenreyro (2002): they also show that output comovement between the US

the shocks are only transmitted with a delay. By looking at the already dollarized economies of El Salvador and Panama, they are also able to reject the hypothesis that business cycle synchronization is "endogenous", as they find that the business cycles of these countries do not show a bigger comovement with the US cycle than those of non-dollarized countries. In line with this, Canova (2005) even finds that non-monetary US shocks do not tend to produce significant output or price fluctuations in Latin America at all.

So all this suggests that even if the identified "monetary policy shock" includes some non-monetary US components, the consequences of this mistake are contained in the dollarized countries, as the transmission of these non-monetary US disturbances to Latin America is not instantaneous and perfect. Although this approach is certainly not flawless (for that one needs to find a dollarized economy that is *fully* shielded from non-monetary US shocks, which the countries I look at probably aren't), it works at least a bit like an ideal filter, as it reduces (or at the very minimum: delays) the effects of any non-monetary US shocks on client country variables, while leaving the effects of true monetary shocks unaffected.

The results of this exercise are univocal: when one analyzes the effects of a contractionary US monetary shock through dollarized economies, prices in all client countries fall quickly and significantly - so the price puzzle disappears. Quantitatively, the data suggest that prices in the economies considered were pretty flexible over the sample period. Output does not show a clear response, so monetary neutrality cannot be rejected.

4.2 Identifying monetary policy shocks

To identify structural shocks, one has to start with the estimation of a reduced form VAR with p lags for a vector of variables Z_t:[7]

$$Z_t = \sum_{i=1}^{p} B_i Z_{t-i} + u_t, \tag{4.1}$$

with $Z_t = \left(X'_{1,t}, R_t, X'_{2,t}\right)'$. Here, $X'_{1,t}$ is a $(k_1 \times 1)$-vector whose contemporaneous values are assumed to be in the information set of the central bank. $X'_{2,t}$ (of

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and the dollarized countries under consideration is not that high.

[7] This section draws upon Christiano, Eichenbaum and Evans (1999).

dimension ($k_2 \times 1$)) on the other hand contains those variables whose contemporaneous values are not in the information set of the monetary authority (its lags are though).

The B-matrices in equation (1) can be estimated by OLS, after which one can calculate the reduced form errors u_t, with $\mathbb{E}u_t u_t' = \Sigma$. However, there is nothing that ensures that the residuals are contemporaneously uncorrelated, as a result of which we cannot give them a structural economic interpretation. We can do this once we have transformed the variance-covariance matrix of the residuals into a diagonal one.

This can be achieved by premultiplying the reduced form (equation (1)) with A_0, a $(k \times k)$-matrix that captures the contemporaneous relations between the variables in Z_t. This gives us the structural form representation of (1):

$$A_0 Z_t = \sum_{i=1}^{p} A_i Z_{t-i} + \varepsilon_t, \tag{4.2}$$

with $A_i = A_0 B_i,\ i = 1, ..., p$, and $\varepsilon_t = A_0 u_t$. ε_t is a $(k \times 1)$-vector of structural (that is: uncorrelated) shocks with $\mathbb{E}\varepsilon_t \varepsilon_t' = I$. It then follows that $\Sigma = A_0^{-1}\left(A_0^{-1}\right)'$.

As shown in Christiano, Eichenbaum and Evans (1999, henceforth CEE), it is possible to identify the monetary policy shock (under certain assumptions, to be discussed below) by assuming that A_0 has the following, lower-triangular structure:

$$A_0 = \begin{bmatrix} \underset{(k_1 \times k_1)}{A_{0,11}} & \underset{(k_1 \times 1)}{\mathbf{0}} & \underset{(k_1 \times k_2)}{\mathbf{0}} \\ \underset{(1 \times k_1)}{A_{0,21}} & \underset{(1 \times 1)}{A_{0,22}} & \underset{(1 \times k_2)}{\mathbf{0}} \\ \underset{(k_2 \times k_1)}{A_{0,31}} & \underset{(k_2 \times 1)}{A_{0,32}} & \underset{(k_2 \times k_2)}{A_{0,33}} \end{bmatrix} \tag{4.3}$$

A matrix that has this form, is the Choleski decomposition of Σ.

Next to the fact that the structure imposed by (3) is consistent with the informational assumption made about the central bank before, it also implies that the monetary policy instrument R_t (taken to be the federal funds rate, as in Bernanke and Blinder (1992)) has no contemporaneous impact on the variables in $X_{1,t}$: it can only affect these variables with a lag. Any variables in $X_{2,t}$ on the other hand, can be affected within the period.

A popular way to identify monetary policy shocks, employed by CEE (1999), is to assume that $X_{1,t}$ includes output and prices, while the $X_{2,t}$-vector is either assumed to be empty or contains monetary aggregates. Economically, this implies that the monetary authority is able to react to changes in output and prices within the period, while the output and price effects of monetary shocks can only show up after one period.

Alternatively, one can also go down the lines of Sims and Zha (2006) and assume the opposite by allowing for impact effects of monetary shocks, but assuming that contemporaneous values of output and prices are not in the Fed's information set. This assumption is motivated by the fact that gathering and processing the necessary data takes time, as a result of which monetary policy may not be able to respond to changes in these variables within the period.

The degree of realism of both restrictions can however be questioned: the majority of existing theoretical models imply that output and prices already respond on impact of a shock (which the CEE-scheme does not allow for), while the availability of now- and forecasts makes the Sims-Zha approach debatable. As Canova and Pina (2005) show, the imposition of both of these type of restrictions may lead to shock misidentification, as a result of which IRF coefficients can get the wrong sign (which may remind some of the price puzzle).

Summarizing, there thus seems to exist a trade-off: on the one hand, one could use the CEE-scheme, which gives the monetary authority the most realistic information set, but this comes at the cost of having to assume that other variables in the VAR cannot respond to these shocks within the period. On the other hand, one could also follow the Sims-Zha approach (which does allow for impact effects of monetary shocks) but this comes at the expense of having to restrict the monetary authority's information set.

As will be argued in the following section, dollarized countries can offer a solution to this conundrum by essentially allowing us to combine the best of both approaches.

4.3 Dollarized countries to the rescue

To address the issues set out in the previous section, this paper does not look at the responses of US output and US prices to federal funds rate shocks (henceforth referred to as Y^{US}, P^{US} and R^{US}, respectively), but uses their counterparts from dollarized countries instead (Y^D and P^D). Econometrically speaking, this approach has two advantages. First, it allows us to combine the dominant existing approaches in a convenient way: we can identify US monetary shocks in the US block of the system (with the contemporaneous values of Y^{US} and P^{US} in the Fed's information set), while we can analyze the impact of these shocks by looking at the responses of output and prices in the dollarized economies, *without* imposing inertial or sign restrictions on these variables of interest.

Second, inferring from responses of dollarized country variables makes the procedure less vulnerable to possible misidentification of the monetary shock in the US block of the system. As Canova (2005) reports, the transmission of non-monetary US shocks to Latin American countries is far from perfect. This implies that if the identified "monetary policy shock" contains a non-monetary component in the US block of the system (for example because the imposed inertial restrictions are not met in practice), that non-monetary component does not survive the transmission process to the client country undamaged and, ideally, only the effects of the true monetary shock remain. In this sense, the present paper thus rests with the idea that perfect shock identification is probably not possible, and moves on to the exploitation of a natural setting that reduces the consequences of shock misidentification instead.

Related to this, the setting considered also has the ability to "convert" endogenous policy responses to non-monetary disturbances, into monetary policy shocks. To see this, consider the following example:[8] say that the US is hit by a non-monetary shock, in response to which the Fed immediately raises the interest rate. At this stage, US variables are moved by both the direct effect of the non-monetary shock, as well as by an indirect effect, being the endogenous response of the monetary authority. But as this response took place within the period, the sum of the two effects will look like a monetary policy shock to the observer in standard VAR-specifications, which is wrong as there never was a monetary shock in reality (only the endogenous response to the non-monetary shock). However, output and prices in dollarized countries are unlikely to be moved within the period by the non-monetary US shock. Hence, the direct effect gets killed in the transmission process and the full, unexpected interest rate increase is a true monetary policy shock from the perspective of the dollarized countries. So where

[8] I owe this example to Wouter den Haan.

standard VAR exercises need random variations in the monetary policy instrument, the current setting is able to provide us with monetary shocks (through the eyes of the client countries) even if the Fed just responds in a perfectly predictable way to unpredictable US developments (under the proviso that the latter are not immediately transmitted to the dollarized economies).

As noted before, I am aware that the client economies considered are probably not fully insulated from non-monetary US shocks (especially at longer horizons), and that next to those, there may also be aggregate world-wide shocks affecting both the client countries and the US simultaneously. To address the latter point, the Appendix shows that results are robust to the inclusion of a commodity price index, which could be seen as an indicator of aggregate economic conditions. More generally, it seems reasonable to assume that the exploited setting at least reduces the consequences of shock misidentification somewhat (a conjecture that will be investigated in greater detail in Section 5).

Another point of potential concern is the fact that the client countries considered were affected by idiosyncratic factors over the sample period, while they have also followed different fiscal policies. These issues however also apply to standard VAR exercises performed on the US or the euro area (*cf.* the differences in fiscal policy between Northern and Southern Europe, while every euro area country/US state is also hit by idiosyncratic shocks), so these concerns are not unique to the alternative route taken by this paper.

When estimating the system, this paper exploits the fact that the US economy can be taken to be exogenous to the dollarized economies (as the latter are all small). In particular, one can make use of the fact that the Fed does not pay any attention to economic conditions in these client countries when designing its monetary policy. Building upon Lastrapes (2005), the remainder of this section sets out an estimation and identification strategy that exploits this convenient natural setting.

4.3.1 Estimation

Let Q_t be a vector stochastic process that is assumed to be generated by:

$$C_0 Q_t = \sum_{i=1}^{q} C_i Q_{t-i} + \epsilon_t \tag{4.4}$$

Here ϵ_t is a normalized, white noise vector process such that $\mathbb{E}\epsilon_t\epsilon_t' = I$. To simplify notation, I suppress the constant and linear time trend that are also included in the analysis. Since the data on dollarized countries are not seasonally adjusted, I also include quarterly dummies in the client country block to remove any possible seasonality in these series.

The corresponding reduced form of this model is:

$$Q_t = \sum_{i=1}^{q} F_i Q_{t-i} + v_t, \tag{4.5}$$

with $F_i = C_0^{-1}C_i,\ i = 1, ..., q,\ v_t = C_0^{-1}\epsilon_t$ and $\mathbb{E}v_t v_t' = \Omega = C_0^{-1}\left(C_0^{-1}\right)'$.

In estimating the reduced form, I impose two over-identifying restrictions. First, regarding the absorption of shocks, I assume that the correlation between output and prices in the client countries is solely due to their joint dependence on the US variables.[9] This makes it possible to estimate the system efficiently by OLS (see Lastrapes (2005)). As one could debate the reasonableness of this assumption, I show in the Appendix that the results are robust to dropping this restriction (in which case one must estimate the system by seemingly unrelated regressions).

Second, with respect to the emission of shocks from dollarized countries, I assume that US variables are block exogenous with respect to the variables in the dollarized countries. That is: whatever happens in the client country is assumed to have no impact on the US economy, as the former is too small to affect the latter.

Econometrically, these assumptions amount to the following: organize Q_t such that $Q_t = \left(Q_t^D, Q_t^{US}\right)'$, where $Q_t^D = (Y_t^D, P_t^D)'$ and $Q_t^{US} = (Y_t^{US}, P_t^{US}, R_t^{US})'$.[10] Block exogeneity of Q_t^{US} with respect to Q_t^D then implies that all C-matrices will be upper-triangular. That is:

$$C_i = \begin{pmatrix} C_{i,11} & C_{i,12} \\ \mathbf{0} & C_{i,22} \end{pmatrix},\ \ i = 0, ..., q \tag{4.6}$$

[9] That is: the equation for Y^D (*in casu* P^D) only contains its own lags (and lags of Y^{US}, P^{US} and R^{US}, of course). So lagged values of P^D do not enter the equation for Y^D and vice versa.

[10] Note that the empirical results that are to follow are invariant to the ordering of the output and price variables within each block, as I am only going to look at a shock to R_t^{US}.

The assumption regarding the absorption of shocks implies that $C_{i,11}$ is diagonal.

Partitioning the VAR into a dollarized country- and a US-block gives:

$$\begin{pmatrix} Q_t^D \\ Q_t^{US} \end{pmatrix} = \sum_{i=1}^{q} \begin{pmatrix} F_{i,11} & F_{i,12} \\ \mathbf{0} & F_{i,22} \end{pmatrix} \begin{pmatrix} Q_{t-i}^D \\ Q_{t-i}^{US} \end{pmatrix} + \begin{pmatrix} v_{1,t} \\ v_{2,t} \end{pmatrix} \tag{4.7}$$

Equivalently, the associated variance-covariance matrix Ω can be partitioned into:

$$\Omega = \begin{pmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{12}' & \Omega_{22} \end{pmatrix}$$

As set out in Hamilton (1994, pp. 309-313), block exogeneity of Q_t^{US} with respect to Q_t^D implies that (7) can be re-parameterized and separated into two independent parts, least squares estimation of which is fully efficient:

$$\begin{aligned} Q_t^D &= \sum_{i=1}^{q} F_{i,11} Q_{t-i}^D + \sum_{i=0}^{q} G_i Q_{t-i}^{US} + e_t \\ Q_t^{US} &= \sum_{i=1}^{q} F_{i,22} Q_{t-i}^{US} + v_{2,t}, \\ \text{with} \quad G_0 &= \Omega_{12}\Omega_{22}^{-1} \\ G_i &= F_{i,12} - G_0 F_{i,22} \Leftrightarrow F_{i,12} = G_i + G_0 F_{i,22}, \; i = 1, ..., q \\ \mathbb{E} e_t e_t' &= \Omega_{11} - \Omega_{12}\Omega_{22}^{-1}\Omega_{12}' \end{aligned}$$

4.3.2 Identification

Once the system is estimated, one still has to identify the structural form (given by equation (4)). The vector moving average representation of the latter is:

$$Q_t = (C_0 - C_1 L - ... - C_p L^p)^{-1} \epsilon_t = \left(H_0 + H_1 L + H_2 L^2 + ...\right) \epsilon_t \tag{4.8}$$

Equivalently, the vector moving average representation of the reduced form (equation (5)) equals:

$$Q_t = (I - F_1 L - ... - F_p L^p)^{-1} v_t = (I + J_1 L + J_2 L^2 + ...) v_t \tag{4.9}$$

The goal now is to identify the H-matrices in equation (8), as these represent the system's impulse response functions ($H_k = \frac{\partial Q_{t+k}}{\partial \epsilon_t}$). This can be done as follows.

Using that $v_t = C_0^{-1}\epsilon_t$ in equation (9) and comparing with (8) shows us that:

$$H_0 = C_0^{-1} \tag{4.10}$$
$$H_k = J_k H_0, \; k = 1, 2, ... \tag{4.11}$$

By Hamilton (1994,p. 260) the solution to the inverted lag polynomial in (9) is:

$$J_0 = I \tag{4.12}$$
$$J_k = F_1 J_{k-1} + ... + F_p J_{k-p}, \; k = 1, 2, ... \tag{4.13}$$

Moreover, given the imposed restrictions, we know that $H_{0,11} = C_{0,11}^{-1}$ and that $H_{0,21} = \mathbf{0}$. Through equation (10) one then obtains that $\Omega = H_0 H_0'$. Partitioning this matrix as before (and using that $H_{0,21} = \mathbf{0}$) yields:

$$\begin{pmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{12}' & \Omega_{22} \end{pmatrix} = \begin{pmatrix} H_{0,11}H_{0,11}' + H_{0,12}H_{0,12}' & H_{0,12}H_{0,22}' \\ H_{0,22}H_{0,12}' & H_{0,22}H_{0,22}' \end{pmatrix} \tag{4.14}$$

From (14), one can fully identify H_0 - and hence H_k by using (11)-(13). Note that block exogeneity of Q^{US} implies that $H_{0,22}$ (which is where the US monetary policy shock lives) can be identified in isolation from the Q^D block. Consequently, one can copy the attractive feature of the CEE-approach and allow for contemporaneous values of US variables in the Fed's information set by assuming that $H_{0,22}$ is lower triangular. However, as set out in Section 2, this approach does not allow for a contemporaneous impact of US monetary shocks on US prices and output, which is hard to defend in reality. But this is where the dollarized countries come in handy: because the Fed does not pay any attention to conditions in these countries when designing its monetary policy, there is no need for an inertial assumption here. Consequently, we can just feed the US monetary policy shock (fully located within the US block of the system) through the estimated system for the dollarized economy, without imposing inertial or sign restrictions in the latter.

However, this is still no guarantee that the US monetary policy shock is identified correctly. But, as argued before, the fact that the dollarized countries considered are only imperfectly integrated with the US economy reduces the role played by any included non-monetary disturbances. Consequently, the route taken by this paper is less prone to misidentification of the monetary shock in the US block of the system.

4.4 What are the effects of monetary policy shocks?

By now, we are in the position to analyze the effects of US monetary shocks on output and prices in dollarized economies. Quarterly output and price data are available for three of the largest dollarized countries: Ecuador (dollarized since 2000q1), El Salvador (dollarized since 2001q1)[11] and Panama (dollarized since 1904, data available since 1996q1). For these countries, the left panels of all figures that are to follow display the IRFs of output and prices to a one standard deviation, contractionary US monetary shock. Note that these IRFs are obtained without imposing any restrictions on these variables. For comparison purposes, the right panels of all figures contain the IRFs of US prices and output to the same shock - a procedure that does need to impose a zero response on impact under the current identification scheme.

Following Bernanke and Mihov (1998), I use data on the implicit GDP deflator and real GDP as proxies for US prices and output, respectively. The federal funds rate is taken to be the monetary policy instrument. All US data are from the St. Louis Fed website. For the dollarized economies the GDP deflator is not available and the CPI (taken from the IMF's IFS database) is used instead.[12] Data on real GDP is obtained from the central banks of Ecuador and El Salvador and from the Instituto Nacional de Estadística y Censo for Panama. All series (except the federal funds rate) are logged before they enter the VAR.

[11] Prior to official dollarization in 2000, Ecuador was already effectively dollarized as its residents had started to use the US dollar for daily transactions in the mid-1990s and made increasing use of US dollar denominated loans and deposits since then (Beckerman, 2001). The former El Salvadorian currency (the colón) had already been pegged to the US dollar in 1993. So in practice both Ecuador and El Salvador had already been importing US monetary policy for some years before they dollarized officially in the early 2000s.

[12] This only strengthens this paper's finding that the price puzzle disappears once one analyzes the effects of monetary shocks through dollarized countries, as Hanson (2004, p. 1390) reports that the price puzzle is most severe when the CPI is used to measure the price level.

Results are based upon a VAR(2), where the lag-length was selected by Schwarz's Information Criterion. The reported 95 percent confidence bands are obtained via a Monte Carlo procedure (with 5,000 replications), in which artificial data was generated by bootstrapping the estimated residuals. As shown in the Appendix, results are robust to dropping the time trend and to adding M2 or a commodity price index to the VAR.

Ecuador Figure 1 shows the result of this exercise for Ecuador, where the VAR was estimated on data running from 2000q1 to 2010q3. Its right panel confirms the findings of many earlier studies in this literature: following a monetary tightening, the US price level increases significantly in a very persistent way, which is hard to reconcile with existing theories.[13] In addition, US output goes up as well, so one could also speak of an "output puzzle" here.

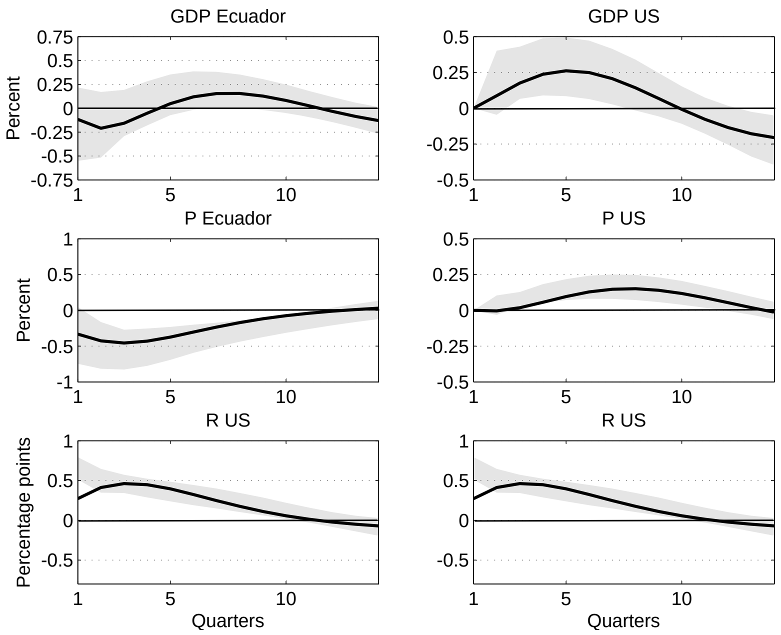

Figure 4.1: IRFs to a contractionary monetary policy shock for Ecuador and the US

But as shown in Canova and Pina (2005), these puzzling results may just be

[13] As noted before, the price puzzle can be rationalized through the working capital channel, but this channel only predicts a *short-lived* increase in the price level after a contractionary shock, which is inconsistent with the picture shown here.

due to shock misidentification - caused by the fact that the imposed zero impact restrictions, necessary to obtain these IRFs, are not met in practice.

As set out before, including data from a dollarized country allows us to analyze the effects of this shock *without* imposing the zero response on impact, while it also helps to filter out the effects of any non-monetary elements of the identified shock. The results of this exercise are shown in the left panel of Figure 1.

Three things are to be noted about this. First, the puzzling price response of the standard approach is now reversed: the Ecuadorian price level falls quickly and significantly after a monetary contraction. Second, although output does not move significantly, the point estimate indicates that it is depressed for about a year following the contraction. Finally, observe that the negative response of prices is quite large: after three quarters, prices have for example already fallen by 0.45 percent. This suggests that prices were rather flexible in Ecuador over the sample period, which might explain why output does not show a clear and significant response.

El Salvador Figure 2 contains the results of the same exercise, now applied to El Salvador (in which case the dataset runs from 2001q1 to 2010q3).

The right panel again shows the puzzling picture that emerges for the US variables, where both prices and output increase after a monetary tightening. However, if one looks at the IRFs of the dollarized country, one concludes that prices fall after a contractionary monetary shock. Although GDP is depressed for the first two quarters, it goes up afterwards and even shows an output puzzle at longer horizons.[14]

The latter finding may be reminiscent of the results in Uhlig (2005): he finds that there are quite a few "contractionary monetary shocks" (identified with sign restrictions on US prices and monetary variables) that do not lead to a subsequent fall in output, which leads him to conclude that "contractionary monetary policy shocks do not necessarily seem to have contractionary effects on real GDP" (p. 385).

[14] One should however keep in mind that this paper's procedure is less suited for analyzing the responses at longer horizons, as part of the possibly included non-monetary US shocks might have spilled over to the client countries by then.

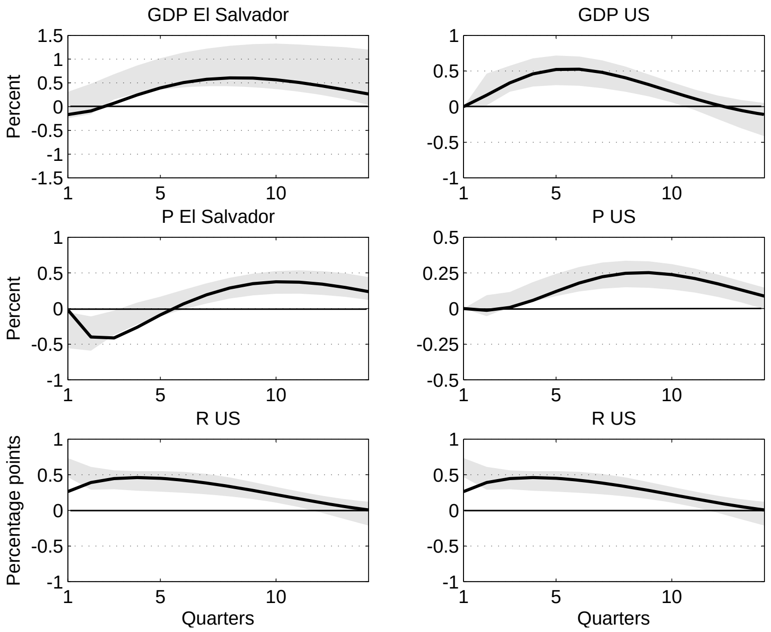

Figure 4.2: IRFs to a contractionary monetary policy shock for El Salvador and the US

Panama The results of applying the procedure to Panama (estimated on data running from 1996q1 to 2010q3) are depicted in Figure 3.[15]

The findings are largely in line with those for Ecuador and El Salvador: prices fall after a monetary tightening (although the response is never statistically different from zero), while output again does not show a significant response (the point estimate is insignificantly negative on impact, after which it becomes insignificantly positive in the third quarter after the shock).

Summary The results for the dollarized countries thus strongly suggest that the price level falls after a monetary contraction. This result is robust in a sense that it shows up across all countries as well as across different specifications (see the Appendix). Output, on the other hand, does not show such a clear response: the results for Ecuador suggest that output is depressed (insignificantly) for about a year after a monetary contraction, El Salvador shows an output puzzle, while the (insignificant) result for Panama lies somewhere in between. Therefore, one cannot

[15] Restricting the analysis to the post-1999 sample (so as to exclude the international debt crisis of 1997-1998) yields very similar IRFs.

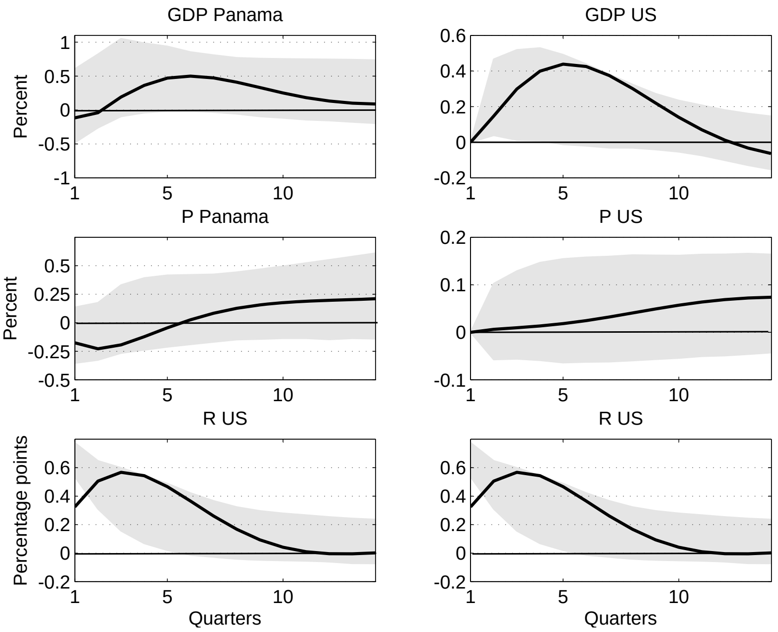

Figure 4.3: IRFs to a contractionary monetary policy shock for Panama and the US

reject monetary neutrality based on these findings. In this light, the findings are quite similar to those reported by Faust, Swanson and Wright (2004) and Uhlig (2005), as they also find that contractionary monetary shocks do not seem to have clear contractionary effects on real GDP. Corresponding results by Boivin and Giannoni (2006) indicate that this might be a characteristic of the sample period used, as they fail to find clear effects of monetary shocks on GDP once they restrict their analysis to the post-1980 period;[16] before 1980, they do find a clear contractionary effect, which suggests that the output effects of monetary shocks have gone down over time.

Lessons for dollarized countries Next to the fact that Figures 1-3 tell us something about the effects of monetary policy shocks in general, they are also informative for countries that are (considering to become) dollarized. First, the results show no evidence for an important role of the working capital channel in the analyzed economies. This suggests that these countries do not have to be greatly concerned with possible stagflationary effects of monetary contractions, as

[16] In some specifications they also find an output puzzle (see their Figure A1).

for example warned for in Cavallo (1977) and Van Wijnbergen (1982).

Second, the analysis indicates that dollarized economies should be prepared for large spillovers from US monetary shocks on their price level. There is no evidence for a clear spillover effect on output, however. This might be due to the fact that prices in the client countries seem to have been quite flexible over the sample period, as a result of which these countries were close to a situation of monetary neutrality.

4.5 Why are the results different?

A key question the reader is probably left with at this stage, is why the IRFs to the same monetary policy shock look so different for the US and the dollarized countries. A first and easy explanation is that the economies of the US on the one hand and those of Ecuador, El Salvador and Panama on the other, are so different, that they respond in completely opposite ways to a monetary shock. This would be the case if the working capital channel would be more important for the US, than it is for these dollarized countries. This is however hard to imagine. First, if anything, the working capital channel is probably more important *for emerging economies* than it is for the US, as short-term bank financing tends to be more important in the former (Van Wijnbergen, 1982: p. 134).[17] Second, the fact that the responses of US variables are difficult to reconcile with any existing theory, makes them hard to believe (*cf.* footnote 13).

A second possible reason for the differences is shock misidentification. As shown by Carlstrom, Fuerst and Paustian (2009, henceforth CFP), the "monetary policy shock" identified via the CEE-scheme may very well include non-monetary components. In particular, they algebraically show that in a New Keynesian model, the CEE-procedure actually identifies a combination of the true innovation in monetary policy and a negative technology shock (the latter is CFP's explanation for the price puzzle). However, for all dollarized countries for which data are available, the results do not show any evidence for this type of shock

[17] Also see Rabanal (2007): he estimates a DSGE-model on US data using Bayesian methods (allowing for a role for the working capital channel), but finds that the posterior probability of observing an increase in inflation after a monetary tightening is zero - thereby suggesting that the working capital channel is not that important for the US. Results by Gobbi and Willems (2011) (briefly discussed in 6 of this paper) confirm this.

confusion.[18] After all, in all client economies, the identified shock (i) increases the federal funds rate, (ii) decreases the price level, and (iii) has no clear effect on output.

Apart from a contractionary monetary shock, it is hard to think of a shock that can have these three properties. In particular, CFP's negative technology shock would *increase* the price level, which is inconsistent with (ii). Additionally, a negative technology shock is inconsistent with (iii), as one would then expect a clear negative effect on output. On the other hand, the lack of a clear response in output to a monetary shock is in line with a standard model in which prices are rather flexible (as suggested by (ii)).

What may play a role here are the findings of the earlier cited study by Canova (2005), who reports that non-monetary US shocks do not seem to produce significant output or price fluctuations in the client economies considered. Consequently, even if there are other disturbances present in the identified "monetary policy shock", the fact that the non-monetary components of this shock do not seem to survive the transmission process undamaged, acts like a convenient filter that leaves us more or less with what we are interested in.

If one has a strong faith in the filtering capacity of the employed setting, any attempt to identify the US monetary shock (currently done via the Choleski approach as in CEE (1999), to allow for contemporaneous values of output and prices in the Fed's information set) is not essential. After all, if non-monetary US shocks are indeed not transmitted to the dollarized countries, then the reduced form innovations to the Fed's policy rule should produce very similar responses in these countries.

And as can be verified by looking at Figure 4, this is indeed the case: if one gives a one standard deviation, reduced form "monetary policy innovation" (which certainly is a combination of all sorts of structural shocks) to the dollarized countries, the IRFs of especially Ecuador and El Salvador are very similar to the original ones. For Panama, the differences between the various IRFs are a bit larger, but this is consistent with the fact that Panama's economy is more open than those of Ecuador and El Salvador and therefore less capable of filtering out non-monetary

[18] If anything, the IRFs of output and prices in especially El Salvador look more like the response to a *positive* technology shock. This is, however, not only inconsistent with what is to be expected from theory (*cf.* CFP (2009)), but also with the response of the US price level as that should fall after a positive technology shock, which it does not.

US shocks.

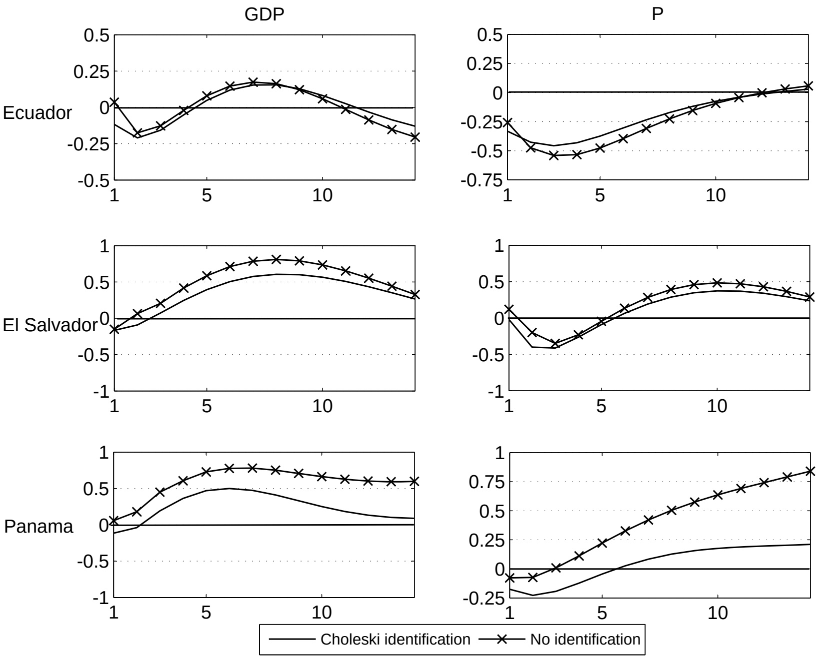

Figure 4.4: IRFs in dollarized countries to a "Choleski identified" US monetary policy shock and to an innovation to the Feds reaction function

4.6 Are the results informative for the US?

As set out in the Introduction, this paper makes no attempt to identify the US monetary policy shock in the US itself; instead, it exploits the filtering capacity of dollarized countries to analyze the effects of monetary shocks in the latter. As I will argue below, I believe that this exercise is informative on especially the sign of the effects of monetary shocks in general. As usual, however, there is no free lunch: the obvious cost of this approach is that one may be left wondering to what extent this paper's findings carry over to the US economy. To answer this question, one may want to distinguish between the qualitative and quantitative messages of this paper.

Qualitatively, results indicate that prices in dollarized countries fall after a contractionary monetary shock. This is a strong result, as many previous studies (starting with Cavallo (1977)) have emphasized the potential importance of the working capital channel for exactly these economies (in which case one would expect a price increase after a monetary contraction). Given that the price puzzle does not even emerge for these dollarized countries, it is, as said before, hard to imagine that this result would not carry over to the US (where short-term bank financing, and hence the cost channel, are less important).

Potential concerns that monetary policy affects, say, the agricultural sector of the economy in the complete opposite way as it affects the service sector (whatever the reason for that may be), are unlikely to be a major issue here: as Table 1 shows, the sectoral structure of the dollarized economies is not that different from that of the US. In all countries, the lion's share of production occurs in the service sector (with the industrial sector following at a considerable distance).[19]

	US	Ecuador	El Salvador	Panama
Agriculture	1.2%	6.8%	11.1%	6.3%
Industry	21.9%	35.7%	28.2%	18.2%
Services	76.9%	57.6%	60.7%	75.5%

Table 4.1: Composition of GDP by sector. Source: CIA World Factbook, 2009

Regarding the size of the effects of monetary shocks, a key issue is how degrees of price stickiness compare between the considered client, and US economies. Based on evidence from Brazil, Chile, Colombia and Mexico, Morandé and Tejada (2008) conclude that emerging economies typically exhibit more price flexibility than the US.[20] If this finding carries over to the countries considered in this paper, the effects of monetary shocks on output (prices) might be a bit larger (smaller) in the US. Differences in other rigidities (such as those in the labor market), may also play a role in this respect.

Related work by Gobbi and Willems (2011) however suggests that the present paper's conclusions do tend to carry over to the US economy itself - both qualitatively and quantitatively: when they identify US monetary shocks by putting

[19] Data on a more disaggregated industry level (where the various countries undoubtedly do differ substantially) are not available to the best of my knowledge. Recent evidence however contradicts the hypothesis that different industries respond in opposite ways to monetary policy shocks: Boivin, Giannoni and Mihov (2009) do a factor-augmented VAR-analysis using price indices for over a hundred US industries and report that there is relatively little heterogeneity in the disaggregated responses (p. 367).

[20] Morandé and Tejada (2008) find an average price duration of approximately 1.5 months for Brazil and Mexico, while prices in Chile and Colombia tend to change once every 3 months. For the US, Bils and Klenow (2004) report a median price duration of 4.3 months.

sign restrictions on prices in the client countries only (thus leaving the responses of US output and prices unrestricted), they also find that US prices tend to fall after a monetary contraction. This suggests that the working capital channel does not play a significant role in the US either. In line with this paper's results for the dollarized countries, US real GDP also does not show a clear response in their study.

4.7 Conclusion

This paper has presented an alternative way of analyzing the effects of US monetary policy shocks. The approach is akin to the exploitation of a natural experiment - formed by the fact that there exist countries that have established an informal monetary union with the US (thereby importing US monetary shocks), while being only imperfectly integrated with the US economy (as a result of which non-monetary US shocks are not transmitted fully and instantaneously).[21] Consequently, basing conclusions upon the responses of variables in these dollarized economies, makes the procedure less vulnerable to misidentification of the monetary shock in the US block of the system. In this sense, the natural setting that this paper exploits thus works a bit like a convenient filter.

Results obtained in this way are univocal: all dollarized economies are free of the so-called price puzzle, as prices fall immediately after a monetary contraction. The working capital channel thus does not seem to have played a major role over the sample period in any of the analyzed client economies. This is a strong result as many previous studies have emphasized the potential importance of this channel for exactly these economies. Hereby, this paper gives support to the sign restriction procedure, as it provides empirical evidence that prices indeed fall immediately after a contractionary monetary shock (which tends to be a key identifying assumption in this literature). More generally, obtaining a better insight into the sign of the price response to monetary shocks is important since this determines whether monetary policy is able to stabilize the economy or not. After all: if prices would really go up after a monetary contraction, the conventional policy of increasing the interest rate to fight inflation would be like throwing oil

[21] The question why these countries chose to dollarize despite the fact that they do not seem to form an optimum currency area with the US (*cf.* Lindenberg and Westermann (2010)) goes beyond the scope of this paper.

on fire.

Quantitatively, results indicate that the price effects of monetary shocks are large and show up quickly. This suggests that prices were relatively flexible in the dollarized economies over the sample period. Consistent with this, monetary policy shocks do not seem to have had a clear effect on output in the considered countries. Investigating to what extent the magnitudes of these findings carry over to the US economy itself, could be a fruitful topic for further research.