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The Effects of Real Exchange Rate Depreciation in an Economy with Extreme Liability Dollarization*

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Abstract

This paper studies the effects of real exchange rate depreciation in an economy with extreme liability dollarization using vector autoregression (VAR) methods. Bolivia's extreme liability dollarization makes it an interesting case for empirical testing of the contractionary-depreciations hypothesis. In contrast to the previous contractionary-depreciations literature, the paper uses identification assumptions which are inspired by modern macroeconomic theory and common in the empirical VAR literature on the effects of monetary policy. I find that a real exchange rate depreciation has negligible effects on output, since a contractionary balance-sheet effect on investment is counteracted by the standard expansionary effect on net exports. Furthermore, I find that a real depreciation has inflationary effects. A key finding is that the identification assumptions used in this paper gives more reasonable results than alternative assumptions used in the previous literature.

Keywords: Real exchange rate, VAR, liability dollarization, balance sheet effects, contractionary depreciation.

JEL codes: E44, F41, G15.

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1 Introduction

In standard small-open economy models, such as, for example, the model by Svensson (2000), a real exchange rate depreciation has an expansionary effect on aggregate demand and output. Depreciation increases the demand for domestically produced goods by reducing their relative price. Such expenditure-switching effects are familiar from the traditional Mundell-Fleming-Dornbusch models and generally remain valid in more modern New Open Economy Macro (NOEM) models.¹

However, the impact of depreciation on output could be reversed in an economy with substantial liability dollarization. When liabilities are denominated in foreign currency, but revenues in domestic currency, the possibility of contractionary depreciations arises. Currency depreciation increases the domestic-currency value of foreign-currency liabilities and the debt service burden, while firm revenues are denominated in domestic currency. Thus, there is an adverse effect on firms' balance sheet position. In the presence of financial frictions of the Bernanke-Gertler type, a balance sheet deterioration causes the external finance premium to increase and, consequently, investment to decrease. If this negative effect of depreciation on investment outweighs the positive effect on net exports, a real depreciation has contractionary effects rather than the standard expansionary effects.

This possibility has long been recognized in the literature, but the Asian crisis in the late 1990's created a renewed interest in the possible negative balance sheet effects of depreciation.² An indication that the topic is perceived as relevant by both researchers and policymakers is the title of an IMF Mundell-Fleming lecture by Jeffrey Frankel (2005): "Contractionary Currency Crashes

¹See Dornbusch (1976) for the original model and Lane (2001) for a survey of the modern NOEM literature.

²See Cooper (1971) for an early discussion. Krugman (1999) and Aghion, Bacchetta, and Banjeree (2000) are examples of papers inspired by the Asian crisis.

in Developing Countries”. Possible adverse balance-sheet effects of depreciation in countries with debts denominated in foreign currency is also a key topic in the current international financial crisis. For example, the case of Latvia, whose IMF program does not require an abandonment of the currency peg, has been much discussed. According to the IMF report, the risk of large adverse balance sheet effects was one of the main arguments for keeping the peg (see International Monetary Fund (2009)).

There is an extensive empirical literature which investigates whether real depreciations are expansionary or contractionary (see Bahmani-Oskooee and Miteza (2003) for a survey). However, no paper has studied the Bolivian economy, which is a particularly interesting case given its extreme liability dollarization. During almost the entire the sample period used in this paper (1990-2006), over 95 percent of the outstanding bank loans to households and firms in Bolivia have been denominated in dollars. This extreme figure can be compared to an average liability dollarization of 40 percent for a number of Latin American countries (see Table 1 for details) or around 25 percent in Korea during the 1997-98 crisis (as reported by Gertler, Gilchrist, and Natalucci (2007)). Thus, Bolivia’s financial dollarization stands out as extreme in an international comparison. However, most goods and services are priced in the local currency, the boliviano, so real dollarization is limited (see Morales (2003)). This is an important difference compared to fully dollarized countries such as Ecuador.

The purpose of this paper is to empirically test the contractionary depreciations hypothesis using Bolivian data and vector autoregression (VAR) methods. As succinctly stated by Bagliano and Favero (1998), VAR models are estimated to “provide empirical evidence on the response of macroeconomic variables to monetary policy impulses in order to discriminate between alternative theoretical models of the economy.” Accordingly, I estimate VAR models and investi-

gate the impulse response functions to real exchange rate depreciation shocks to test the contractionary-depreciations hypothesis, which states that a real depreciation causes an increase in net exports, but an even larger decrease in investment, and, hence, a fall in output. The main finding is that the two opposite effects on output tend to cancel out, which constitutes evidence against the contractionary-depreciations hypothesis. I also find that a real depreciation has significant inflationary effects, regardless of the definition of inflation. A key finding is that the identification assumptions used in this paper gives more reasonable results than alternative assumptions used in the previous literature.

This paper makes the following three contributions to the literature on contractionary depreciations. First, my identification assumptions differ from those first suggested by Kamin and Rogers (2000) and used in the subsequent empirical VAR literature on contractionary depreciations. I use the recursive Cholesky ordering output-inflation-real exchange rate, while Kamin and Rogers assume the reverse ordering real exchange rate-inflation-output. The assumptions used in this paper are more closely related to modern macroeconomic theory and the empirical VAR literature on the effects of monetary policy. The second contribution is that I study the Bolivian economy, which is a particularly interesting case given the country's extreme liability dollarization. If liability dollarization makes depreciations contractionary in developing countries in general, this effect should be especially strong in Bolivia. Third, while most other papers on contractionary depreciations only study the response of aggregate output, I also investigate the response of various sub-components of output. This helps to distinguish between the benchmark theoretical model with no financial frictions or liability dollarization, on the one hand, and the alternative model where real depreciations have contractionary effects, on the other hand.

The rest of this paper is organized as follows. Section 2 provides a theo-

retical background and Section 3 discusses the previous empirical evidence. In Section 4, I present some cross-country data showing that the Bolivian case is particularly interesting for empirical testing of the contractionary-depreciations hypothesis. Section 5 discusses the identification assumptions and Section 6 presents the empirical analysis, including robustness checks. Section 7 concludes the paper.

2 Contractionary depreciations: theoretical background

Before describing the theory behind contractionary depreciations, I first present a modern New-Keynesian macroeconomic model where a real exchange rate depreciation has the standard expansionary effect. Then I discuss possible deviations from the standard case due to the balance sheet effects arising from liability dollarization. There are other, alternative models of contractionary depreciations but the balance sheet channel has clearly received most attention in the academic literature and policy debate. For example, Frankel (2005) argues that the balance sheet channel is the most important one. Partly for this reason, and partly since liability dollarization is the motivation for studying the Bolivian case, I do not discuss other possible reasons for contractionary depreciations (see the survey by Bahmani-Oskooee and Miteza (2003)).

2.1 Benchmark model where a real exchange rate depreciation has expansionary effects

This section presents a model by Svensson (2000) where a real exchange rate depreciation has expansionary effects. The framework is a standard small-open economy model with microfoundations and forward-looking expectations. I

present the main equations and focus on the economic intuition (see the paper and especially the working paper version for further details). For simplicity, I only discuss the case where monetary policy follows a Taylor rule. The real exchange rate q_t is defined such that an increase denotes a real depreciation.

There are four main equations in the model. First, there is an aggregate supply equation (Phillips curve) for inflation (equation (1) in Svensson (2000)):

$$\begin{aligned} \pi_{t+2} = & \alpha_\pi \pi_{t+1} + (1 - \alpha_\pi) E_t \pi_{t+3} + \alpha_y [E_t y_{t+2} + \beta_y (y_{t+1} - E_t y_{t+1})] \\ & + \alpha_q E_t q_{t+2} + \varepsilon_{t+2}^{CP} \end{aligned} \quad (1)$$

where π_t denotes domestic inflation in period t , y_t is the output gap, q_t is the real exchange rate, ε_t^{CP} is a cost-push shock and, for any variable x , $E_t x_{t+\tau}$ is the rational expectation of $x_{t+\tau}$, given the information available in period t . Thus, domestic inflation depends on lagged inflation and previous expectations of output and inflation. Inflation is predetermined two periods in advance—that is, the desired prices for period $t + 2$ are determined at time t , but the actual inflation for the period is also affected by output at time $t + 1$ and the cost-push shock which is realized at time $t + 2$.

Second, there is an aggregate demand equation (IS curve) for output (equation (7) in the paper):

$$y_{t+1} = \beta_y y_t - \beta_\rho E_t \rho_{t+1} + \beta_y^* E_t y_{t+1}^* + \beta_q E_t q_{t+1} - (\gamma_y^n - \beta_y) y_t^n + \varepsilon_{t+1}^{AD} \quad (2)$$

where $\rho_t \equiv \sum_{\tau=0}^{\infty} E_t r_{t+\tau}$ summarizes current and future real interest rates, y_t^* is the foreign output gap and ε_t^{AD} is a combination of aggregate demand and productivity shocks. Thus, output depends on previous expectations of the real interest rate path, foreign output and the real exchange rate. Output is predetermined one period in advance—that is, the desired output quantity for

period $t + 1$ is determined at time t , before the shocks are realized at time $t + 1$.

The third equation is the Taylor rule for the instrument of monetary policy, i.e. the nominal interest rate i_t :

$$i_t = \gamma_\pi \pi_t + \gamma_y y_t + \varepsilon_t^{MP} \quad (3)$$

where ε_t^{MP} is a monetary policy shock which arises since the instrument rule is not followed perfectly. Interest rates can react contemporaneously to the observed values of output and inflation.

Fourth and finally, there is also an uncovered interest parity condition:

$$i_t - i_t^* = E_t s_{t+1} - s_t + \varphi_t \quad (4)$$

where i_t^* is the foreign nominal interest rate, s_t is the nominal exchange rate and φ_t is the foreign-exchange risk premium.

The model can be used as a basis for the necessary identification assumptions regarding the timing of relationships between variables. Monetary policy has a contemporaneous effect on real interest rates which affect output with a one-period lag (as shown in equation (2)). In turn, output affects inflation with another one-period lag, as can be seen in equation (1). The real exchange rate affects output with a one period-lag (see equation (2)). By making domestic goods relatively cheaper, a real depreciation stimulates net exports and output. Naturally, this has an indirect effect on inflation with a further one-period lag. In addition to this indirect, delayed effect of the real depreciation on domestic inflation, there is also a direct, contemporaneous effect on CPI inflation. A real depreciation increases the domestic-currency price of imports, which affects CPI inflation contemporaneously (but not domestic inflation).³

³CPI inflation is given by $\pi_t^c = \pi_t + \omega(q_t - q_{t-1})$ where ω is the share of imports in the CPI.

In sum, the model suggests that the effect of output shocks on inflation occurs with a shorter lag than the effect of inflation shocks on output. Moreover, monetary policy can react to contemporaneous values of output and inflation. Finally, the real exchange rate is an asset price and should be allowed to respond to the other variables within the period.

2.2 Liability dollarization, balance sheet effects and contractionary depreciations

Balance sheet effects have been extensively studied in a closed-economy context. An overview of the literature, as well as a modern general-equilibrium macroeconomic model with financial frictions, is presented by Bernanke, Gertler, and Gilchrist (1999). The key assumption is imperfect information between borrowers and lenders, which gives rise to an external finance risk premium for borrowing firms. External financing is more expensive than internal financing and the premium is particularly high when firms' balance sheets are in poor condition. The status of balance sheets affects the required rate of return for investment, and, hence, the quantity of investment.

In many emerging and developing countries, liabilities are to a large extent denominated in foreign currency. As is well known in the literature, financial frictions may have larger effects in open economies with extensive liability dollarization than in closed economies. Early papers on adverse balance sheet effects of currency depreciation in countries with foreign-currency liabilities are those by Cooper (1971), Gylfason and Risager (1984), van Wijnbergen (1986) and Lizondo and Montiel (1989). The Asian crisis caused a renewed interest in the role of balance sheet effects in currency crises. Some examples are the papers by Krugman (1999) and Aghion, Bacchetta, and Banjeree (2000). However, these papers only presented simple one- or two period models which were

not empirically evaluated.

Céspedes, Chang, and Velasco (2004) develop a dynamic general-equilibrium model with liability dollarization where the country risk premium depends on the value of investment relative to net worth. Holding income constant, a real depreciation increases the debt burden, which has a negative effect on net worth and thereby increases the risk premium. However, a real depreciation also causes an expansion of net exports and output through the standard expenditure-switching mechanism. This has the opposite effects on net worth and the risk premium. Whether the risk premium goes up or down depends on the steady-state ratio of foreign debt to net worth. Real depreciations only have contractionary effects in a “theoretically possible but empirically implausible” case (when an adverse foreign interest rate shock causes a domestic appreciation and an expansion of domestic output).

Similarly, Chang and Velasco (2001) study contractionary depreciations in a simplified version of the model in Céspedes, Chang, and Velasco (2004). They also find that contractionary balance sheet effects are not sufficiently large to offset the standard expansionary effects of a real depreciation. In these general-equilibrium models, liability dollarization does not reverse the standard expansionary effect of real exchange rate changes.

In contrast, Cook (2004) finds that a real depreciation causes a persistent contraction in output, and conjectures that the difference in results is due to differences in the modeling of nominal rigidities. Thus, it is not unambiguously clear from economic theory whether depreciations are expansionary or contractionary in the presence of financial frictions and liability dollarization.

3 Previous empirical evidence on the effects of the real exchange rate on output and inflation

This section summarizes previous empirical evidence with a special focus on VAR studies using the methodology first suggested by Kamin and Rogers (2000).

3.1 Previous international evidence

An important paper in the literature on contractionary depreciations is by Kamin and Rogers (2000). They estimate a number of different VAR models using Mexican quarterly data for the period 1980-1996. The real exchange rate, inflation and real GDP are included in all models, and other control variables are the nominal US interest rate, government spending, money, the capital account and oil prices. Even when control variables are included, real depreciations cause output to decrease and inflation to increase. Thus, real depreciations are found to be contractionary and inflationary.

A number of recent papers have applied the Kamin-Rogers (henceforth KR) methodology to other developing countries. Some examples are the papers by Ahmed, Ara, and Hyder (2006) for Pakistan, Berument and Pasaogullari (2003) for Turkey, Shi (2006) for China, and Vinh and Fujita (2007) for Vietnam. The estimated effects on output are mixed. Real depreciations are expansionary in China and Vietnam, but contractionary in Pakistan and Turkey. As for the effects on inflation, real depreciations are inflationary in Vietnam, Pakistan and Turkey (no evidence is reported for China).

Ahmed (2003) extends the KR methodology to a panel setting. He estimates a panel VAR model using annual data from Argentina, Brazil, Chile, Colombia and Mexico for the period 1983-1999, and finds that real depreciations are contractionary. The effect on prices is negative, but not statistically significant.

There also exist some panel studies of both developed and developing countries. Kamin and Klau (2003) use pooled annual data from 27 countries for the period 1970-1996. They find that real depreciations have contractionary effects in the short run, but insignificantly expansionary effects in the long run. A puzzling result is that real depreciations are (weakly) contractionary for *developed* countries, both in the short and long run. Another paper by Ahmed, Gust, Kamin, and Huntley (2002) finds more intuitively plausible results. The authors estimate panel VAR's for different groups of developed and developing countries using similar methods as those in Ahmed (2003). They find depreciations to be contractionary in developing countries, but expansionary in developed countries (as would be expected). In both cases, depreciations cause inflation. A paper by Kamin (1998) specifically focuses on the short-run effect of real depreciations on inflation. He uses a panel with annual data from 38 countries. Real depreciations are found to be inflationary in all cases, but the effect is stronger in Asia and especially Latin America than in developed countries.

To sum up, real depreciations are often found to have contractionary effects on output in developing countries, but there are some cross-country differences. In almost all cases, real depreciations are found to cause higher inflation.

3.2 Previous evidence from Bolivia

Some progress in understanding the effects of real exchange rate changes in Bolivia has already been made by central bank economists. Mendieta and Escóbar (2006) estimate a Vector Error Correction model using quarterly data for the period 1990-2005. They find that a real depreciation has an expansionary effect on output in the short run, but a contractionary effect in the long run. However, they do not investigate the effects on inflation. Other studies focus on the effects of nominal, rather than real, depreciations. Orellana, Lora, Mendoza, and

Boyán (2000) estimate VAR models using monthly data for the period 1990-1999 and study the effects of nominal depreciations. They find that a nominal depreciation does not affect output, but makes inflation increase. A similar IMF study by Jaramillo (2007) reaches the same conclusions.

Another IMF paper by Leiderman, Maino, and Parrado (2006) finds evidence of real depreciations having negative effects on company balance sheets in financially dollarized countries. Specifically, the authors show that the real exchange rate Granger causes nonperforming loans in Peru (where dollarization is high) but not in Chile (where dollarization is low), which is consistent with adverse balance sheet effects due to real depreciation. The authors also estimate monetary policy reaction functions for a number of countries. When discussing the results for Bolivia, they claim that “In view of its expansionary impact, an [real] exchange rate depreciation leads to . . . a slowing down of the rate of crawl [depreciation] in Bolivia” (p. 17). However, the paper does not present any evidence that real depreciations are, in fact, expansionary in Bolivia.

4 Why is the Bolivian case especially interesting?

This section discusses in more detail why we should be especially interested in the Bolivian case. When comparing Bolivia to other countries in Latin America, there are three key results: Bolivia has (1) an extreme degree of liability dollarization, (2) an above-average level of financial development and (3) a below-average level of openness.

Table 1 presents data from a paper by Barajas and Morales (2003) who study the empirical determinants of liability dollarization in a sample of Latin American countries. The first column in the table shows dollar-denominated bank

loans as a percentage of total bank loans. As previously discussed, the Bolivian economy exhibits extreme liability dollarization; 97 percent of the bank loans are denominated in dollars, as compared to an average across countries of 40 percent. The second column presents a standard measure of financial development: the outstanding credit to the private sector relative to GDP. If financial development had been very low for Bolivia, there would only have been minor balance sheet effects of depreciation, regardless of the currency composition of private sector liabilities. In an economy with few loans, their currency denomination is of little aggregate importance. In fact, Bolivia has an above-average credit-to-GDP ratio: 57 percent as compared to an average of 35 percent. For example, the ratio is higher than Argentina's (22 percent) and Mexico's (18 percent). Finally, the third column in Table 3 shows economic openness, defined as the sum of exports and imports relative to GDP. Bolivia is somewhat less open than the average economy (34 percent as compared to 55 percent). However, it is not an extreme outlier, which makes it reasonable to assume that the standard, expansionary effect of a real depreciation on the economy works in similar ways as in other economies.

If anything, Table 1 probably underestimates the extreme nature of liability dollarization in Bolivia. A recent study by Kamil and Sutton (2008) uses firm-level data from more advanced Latin American economies and finds that firms' foreign-currency exposure has been reduced over the past 10 years. One of the reasons behind the reduction has been a rapid development of currency-derivative markets. In contrast, liability dollarization in Bolivia only started to decrease in 2006, which does not affect the results in this paper (see Jaramillo (2007)). Furthermore, there is no currency-derivative market in Bolivia, so it is not possible to hedge currency-risk exposure.

It should be noted that there is also significant asset dollarization in Bolivia.

Table 1
Liability dollarization, financial development and openness
in 14 Latin American countries

Country	Liability dollarization	Financial development	Openness
	Dollar loans (percent of total)	Credit to private sector (percent of GDP)	Exports+imports (percent of GDP)
Argentina	59	22	17
Bolivia	97	57	34
Chile	19	64	47
Costa Rica	16	19	73
Dominican Republic	12	31	76
El Salvador	7	38	52
Haiti	26	15	24
Honduras	26	35	81
Jamaica	20	29	65
Mexico	24	18	56
Nicaragua	70	42	90
Paraguay	31	26	82
Peru	62	24	25
Uruguay	83	38	27
Average	40	35	55

Note: the data were taken from Tables 1 and 6 in a paper by Barajas and Morales (2003). The sample periods vary somewhat across countries and variables. The data for Bolivia are from 1989-2001 (column 1) and 1995-2001 (columns 2 and 3),

During the sample period 1990-2006, around 90 percent of bank deposits were denominated in dollars (see Escóbar (2003) and Jaramillo (2007)). To some extent asset dollarization tends to offset the adverse impact of depreciation on the balance sheets of firms and households. But in a world of heterogeneous agents and credit-market frictions, the adverse impact of depreciation on borrowers/entrepreneurs is more important for investment than the beneficial impact on savers/non-entrepreneurs.

5 Identification

It is well known that different identification assumptions may produce different results (see, for example, the discussion in Christiano, Eichenbaum, and Evans (1999)). Kamin and Rogers (2000) identify shocks using a standard Cholesky decomposition. They assume the following recursive ordering for the main variables: real exchange rate, inflation and output. This implies that the real exchange rate may affect both inflation and output contemporaneously, but not vice versa, and that inflation may affect output within the period, but not vice versa.⁴ The assumed recursive ordering is inspired by a simple model where a real exchange rate adjustment alters the nominal price level which, in turn, causes changes in output. However, it is not clear that the model is appropriate for imposing contemporaneous restrictions, since all variables are simultaneously determined in a static environment.

A more serious cause for concern is that the assumed Cholesky ordering (real exchange rate, inflation, output) departs from the standard theoretical small-open economy model, as well as the standard recursive ordering in the empirical VAR literature on the effects of monetary policy shocks (output, inflation, real

⁴When studying the effects of real exchange rate shocks, it is only the ordering of the real exchange rate relative to the other variables which may affect the impulse responses of output and inflation.

exchange rate). The theoretical model by Svensson (2000), which is outlined in subsection 2.1, suggests the latter ordering. Intuitively, the exchange rate is an asset price and should therefore be allowed to respond contemporaneously to other variables. Examples of empirical VAR studies using the standard recursive ordering are those by Eichenbaum and Evans (1995) and Peersman and Smets (2003). Based on modern open-economy macro models and following standard practice in the empirical VAR literature on the effects of monetary policy, this paper uses the standard recursive ordering (output, inflation, real exchange rate) rather than the reverse KR ordering (real exchange rate, inflation, output).

Bolivia has a fixed nominal exchange rate against the U.S. dollar which is gradually adjusted by the central bank in response to economic conditions (crawling peg). In fact, Banco Central de Bolivia uses the nominal boliviano-dollar exchange rate as the main instrument of monetary policy. McCallum (2006) argues that “use of [the nominal exchange rate] as the policy-rule instrument rather than the more standard [interest rate], is perfectly sensible and coherent. Which of the two instrument/indicator variables would be more desirable will be determined by quantitative aspects of the economy under consideration” (pp. 7-8). Parrado (2004) and Leiderman, Maino, and Parrado (2006) estimate monetary policy reaction functions with the nominal exchange rate as the policy instrument. Moreover, Jaramillo (2007) finds that the interest rate controlled by Banco Central de Bolivia has insignificant effects on output and inflation.

In the Bolivian case, the economic meaning of the real exchange rate being ordered last is that the central bank may change the nominal exchange rate contemporaneously in response to observed output and inflation. In a sticky-price environment, changes in the nominal exchange rate have short-run effects on the real exchange rate. However, the real exchange rate should not be interpreted

as a policy instrument. It is also assumed that the real exchange rate does not have any contemporaneous effects on output or inflation.

An alternative empirical specification would include the nominal boliviano-dollar exchange rate instead of the real multilateral exchange rate, which would allow a clearer interpretation of the residuals in the exchange rate equation as deviations from the central bank's instrument rule. A problem with such an approach is that the trade-weighted real exchange rate may change even when the bilateral boliviano-dollar exchange rate is constant. This paper uses the trade-weighted real exchange rate, which also facilitates a comparison with the rest of the literature, in particular the contractionary-depreciations literature.

As discussed above, the recursive-ordering identification method imposes zero-restrictions on the contemporaneous relationships between variables. In fact, several alternative methods have been suggested in the literature. For example, a paper by Bjornland (2008) allows contemporaneous two-way effects between the interest rate and the exchange rate, but adds the restriction that interest rate shocks have no effect on the long-run level of the real exchange rate. While alternatives to the recursive-ordering method are useful, the recursive method remains widely used, not least because of its simplicity. Among all possible recursive orderings, the standard ordering is preferable to alternative recursive orderings, such as that used by Kamin and Rogers (2000) and subsequent papers in the contractionary-depreciations literature.

6 Empirical VAR analysis of the effects of real exchange rate depreciation

The two main empirical relationships of interest are those between the real exchange rate and output, and between the real exchange rate and inflation.

Figure 1 illustrates the relationships in Bolivia for the sample period 1990:Q1-2006:Q3. As can be seen in the upper part of the figure, there is no clear relationship between the real exchange rate and output (for illustrative purposes, the graph shows the output gap rather than the level of output). In the lower part of the figure, we can see that real depreciations tend to be associated with increases in inflation. The remainder of this section empirically analyzes the macroeconomic effects of real exchange rate depreciations in Bolivia.

In addition to the modifications of the Kamin-Rogers approach discussed in Section 5, this paper also differs in two other respects. First, while KR estimate a VAR in first differences, I estimate a VAR in levels. As pointed out by Sims, Stock, and Watson (1990) and Hamilton (1994), if the true process is not a VAR in first differences, then estimates from a VAR in first differences will be inconsistent. My procedure avoids inconsistent estimates, but at the cost of reduced efficiency. Second, KR estimate a single VAR over four different exchange rate regimes. This may be problematic since their Granger causality tests show that the relationship between the real exchange rate and real GDP is different in different parts of the sample. In contrast, I use a sample with only one exchange rate regime. As demonstrated by Bagliano and Favero (1998) using U.S. data, the estimates may suffer from parameter instability unless the VAR is estimated over a sample with a single monetary regime.

Another issue is which measure of output to include in the VAR. Most empirical papers use the level of output but as argued by Giordani (2004), it is more consistent with the theoretical models to use the output gap. However, the output gap is difficult to measure since the level of potential output is unobservable. Following Lindé (2003), Mojon and Peersman (2003) and Bjornland (2009), I use the level of output but include an exogenous linear trend. As a robustness check, I also estimate a model with a measure of the output gap.

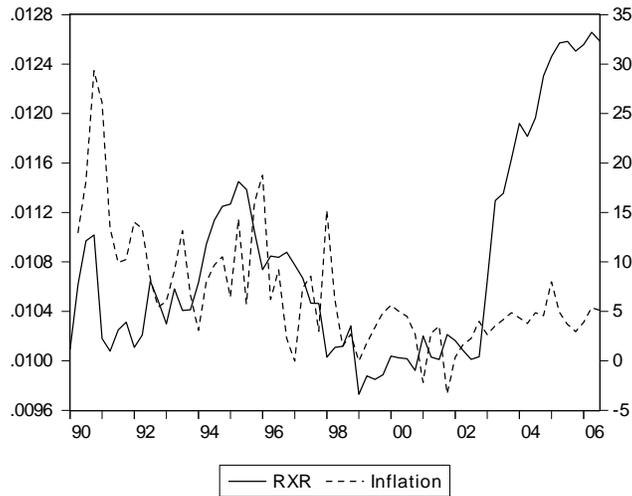
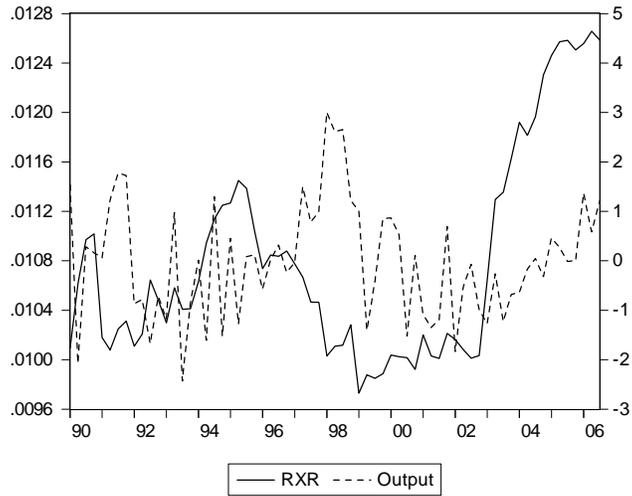


Figure 1: Upper graph: real exchange rate (denoted RXR, left scale, inverse index, increase=depreciation) and output (right scale, percent output gap using HP-trend). Lower graph: real exchange rate (denoted RXR, left scale, inverse index, increase=depreciation) and inflation (right scale, percent).

Given the limited number of observations, it is necessary to limit the number of variables included in each VAR model. Following Kamin and Rogers, I first estimate a baseline model with the main variables and then estimate a number of alternative models with one additional control variable for each model. As a small open economy, Bolivia is affected by financial and macroeconomic conditions abroad (but not vice versa). The exogenous external variables which are included in all specifications are a U.S. interest rate and the trade-weighted external GDP. The endogenous variables included in the baseline model are output, inflation and the real exchange rate. It is also important to control for other factors which may be correlated with the exchange rate and have an effect on the endogenous variables. Otherwise the estimated impact of real exchange rate shocks on output and inflation could be due to such confounding factors rather than reflect a true causal relationship. The control variables are the terms of trade, the capital account balance, government spending and dummy variables for periods affected by social unrest and the weather phenomenon El Niño. All control variables are assumed to be exogenous, except for the capital account and government spending (for example, foreign remittances and government spending could react endogenously to changes in Bolivian output). While KR only investigate the effects of the exchange rate on aggregate GDP, I also study the effects on exports, imports, investment and consumption (inspired by Mojon and Peersman (2003)). Detailed variable definitions and data sources are given in the appendix. All models are estimated with two lags, as suggested by standard lag length criteria, and using the sample period 1990:Q1-2006:Q3. Specifically, the following VAR models are estimated (with variables listed according to the assumed Cholesky ordering):

Model 1 (baseline): U.S. interest rate, external GDP, output, inflation, real exchange rate

Model 2: U.S. interest rate, external GDP, terms of trade, output, inflation, real exchange rate

Model 3: U.S. interest rate, external GDP, capital account, output, inflation, real exchange rate

Model 4: U.S. interest rate, external GDP, output, inflation, real exchange rate, government spending

Model 5: U.S. interest rate, external GDP, dummies for social unrest and weather, output, inflation, real exchange rate

Model 6: U.S. interest rate, external GDP, output, inflation, real exchange rate, exports

Model 7: U.S. interest rate, external GDP, output, inflation, real exchange rate, imports

Model 8: U.S. interest rate, external GDP, output, inflation, real exchange rate, investment

Model 9: U.S. interest rate, external GDP, output, inflation, real exchange rate, consumption

Figure 2 presents the impulse responses of output and inflation to a real exchange rate depreciation shock in the baseline case (Model 1). There is a minor and gradual increase in output, but it is small and not statistically significant. In contrast, there is a significant and persistent increase in inflation. The peak effect on inflation is reached two quarters after the shock, and the increase in inflation remains significant during six quarters.⁵

Figure 3 presents the impulse responses of output and CPI inflation to a real exchange rate depreciation shock when including a number of additional control

⁵The results do not depend on the specific variable definitions used. Similar impulse responses are obtained when using GDP deflator inflation rather than CPI inflation or when excluding the mining and hydrocarbons sectors from GDP. Likewise, excluding one or both of the external exogenous variables does not change the results. These robustness checks are available from the author on request.

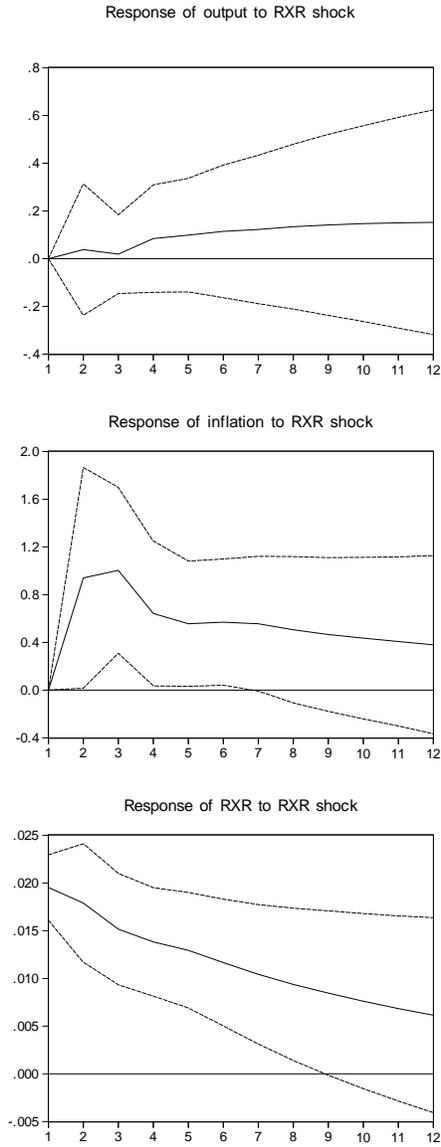


Figure 2: Impulse responses of output (percent) and inflation (percentage points) to real exchange rate (denoted RXR) depreciation shock. Confidence intervals: plus/minus two Monte Carlo standard errors (500 repetitions).

variables (one for each row in the figure). These impulse responses correspond to Models 2-5, respectively. The main results are very robust to inclusion of control variables. There is no significant change in output for any specification, and the response of inflation is always positive, significant and persistent.

Figure 4 shows the impulse responses of GDP components: exports (Model 6), imports (Model 7), investment (Model 8) and consumption (Model 9). There is a significant increase in exports and imports remain relatively unchanged. This creates a significant increase in net exports (not shown). Thus, there is evidence of a standard expansionary effect of real depreciations. Furthermore, there is a significant decrease in investment, as predicted by the balance sheet channel. Consumption remains relatively unchanged. There is no significant change in government spending either (not shown). Combined with the evidence for exports and imports, the decrease in investment indicates that the standard positive effect and the negative balance-sheet effect tend to outweigh each other, which helps explain the lack of a significant response of aggregate GDP.

Figure 5 investigates how the results change when using the output gap, as suggested by Giordani (2004), rather than the level of output. The first row shows impulse responses from the same specification as in Model 1, but using the output gap instead of output. The remaining graphs in the figure present responses of GDP components from gap versions of Models 6-9. In general, the effects of real exchange rate shocks are similar but less significant.

Finally, Figure 6 presents impulse responses for models including the same variables as in Models 1 and 6-9, but now using the reverse, Kamin-Rogers recursive ordering (real exchange rate-inflation-output) for the key variables. As compared to the results presented above, the responses of output and its components are similar. However, there are notable differences in the response of inflation. In all impulse response functions presented above, inflation increases

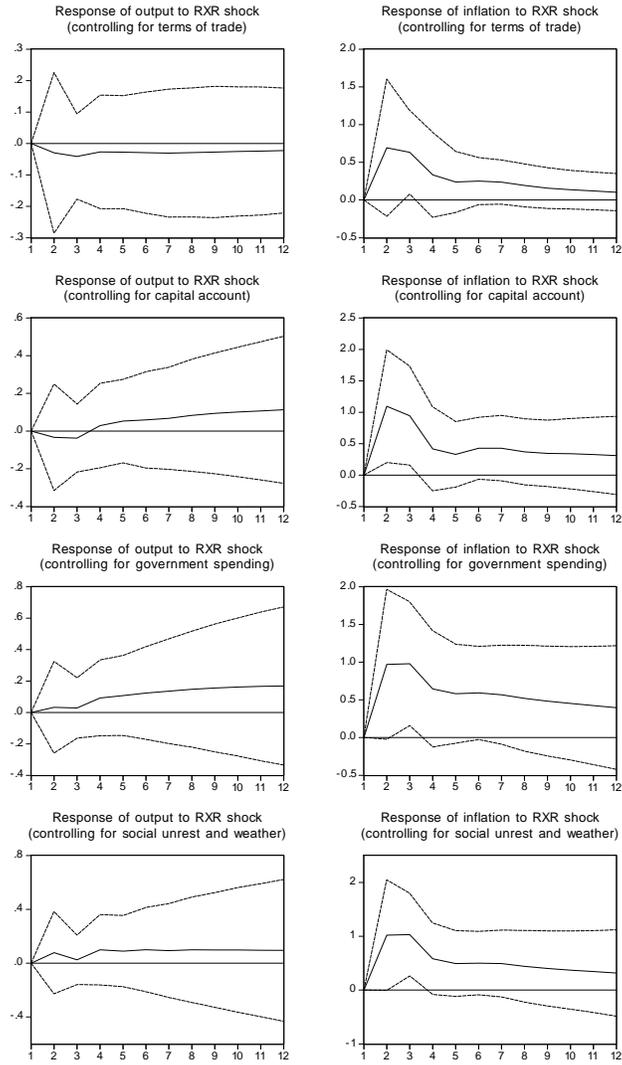


Figure 3: Impulse responses of output (percent) and inflation (percentage points) to real exchange rate (denoted RXR) depreciation shock with control variables. Confidence intervals: plus/minus two Monte Carlo standard errors (500 repetitions).

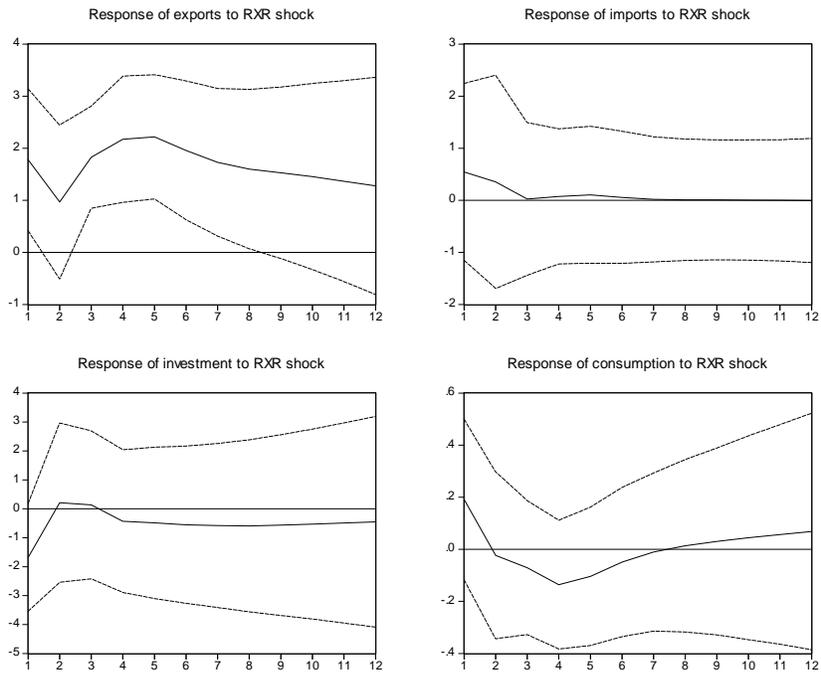


Figure 4: Impulse responses of exports, imports, investment and consumption (percent) to real exchange rate (denoted RXR) depreciation shock. Confidence intervals: plus/minus two Monte Carlo standard errors (500 repetitions).

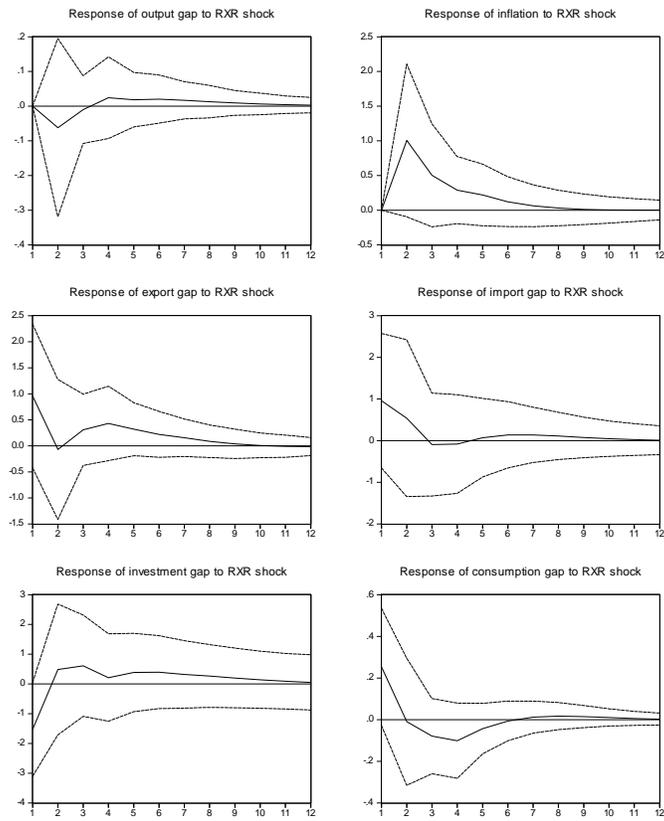


Figure 5: Impulse responses when using output gaps rather than output levels to real exchange rate (denoted RXR) depreciation shock. Confidence intervals: plus/minus two Monte Carlo standard errors (500 repetitions).

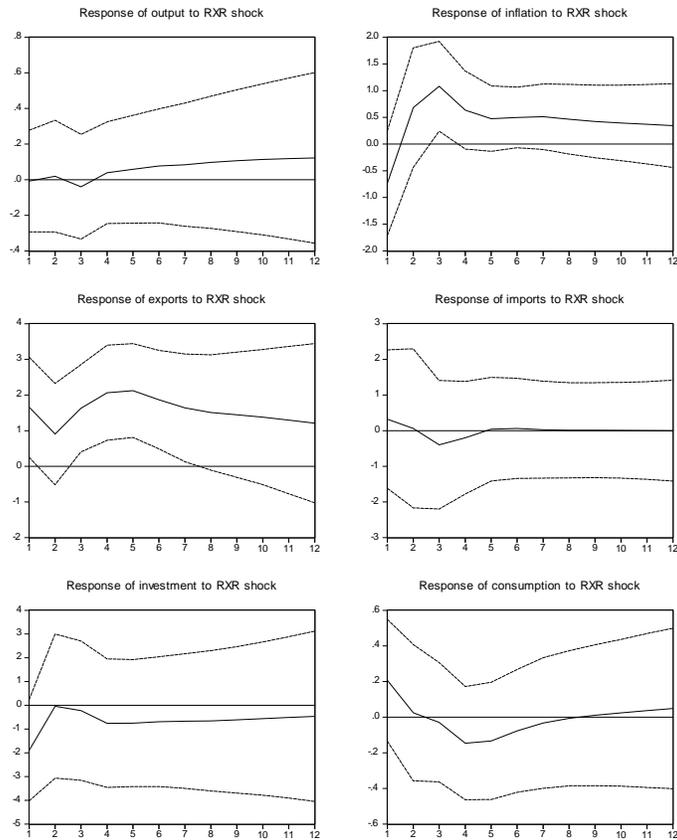


Figure 6: Impulse responses to real exchange rate (denoted RXR) depreciation shock when using the Kamin-Rogers recursive ordering (RXR, inflation, output). Confidence intervals: plus/minus two Monte Carlo standard errors (500 repetitions).

significantly in the short term. In contrast, with the Kamin-Rogers ordering of variables, there is an immediate *decrease* in inflation which is counter-intuitive. A possible justification for ordering the real exchange rate before inflation would be to allow for an immediate inflationary impact of depreciation. The observed deflationary impact of depreciation is puzzling and suggests model misspecification. Thus, the empirical results clearly depend on the assumed Cholesky ordering, which underlines the importance of using appropriate identification assumptions based on modern economic theory and following standard empirical practice. However, the general arguments in favor of the ordering used in this paper would remain valid irrespective of how the empirical results depend on identification assumptions in the specific case of Bolivia.

7 Conclusions

As in most of the empirical literature, real exchange rate depreciations are found to be inflationary in Bolivia. However, depreciations are not contractionary, since the negative balance-sheet effects are not sufficiently large to outweigh the standard positive effects on international competitiveness. Thus, the adverse balance-sheet effects of currency depreciation are of limited size, even in an economy with extreme liability dollarization. Another result is that the identification assumptions affect the results, and that the recursive ordering used in this paper produces more reasonable results than the alternative ordering used in the previous contractionary-depreciations literature.

A caveat is that the macroeconomic evidence presented in this paper does not formally distinguish between different potential explanations for the adverse effects of real depreciation on investment. In order to better distinguish between different channels, it is necessary to use micro-level data. Nevertheless, previous research emphasizes balance-sheet effects over other possible channels. The

predominance of the balance-sheet channel is likely to hold a fortiori in the case of Bolivia, given the country's extreme liability dollarization. More generally, if any adverse effects of depreciation on investment (whether primarily due to balance-sheet effects or not) are too small to outweigh the standard expenditure-switching effect in Bolivia, they are even less likely to do so in countries with less extreme liability dollarization.

An interesting extension of the analysis in this paper would be to study a larger number of countries to investigate if the strength of adverse balance-sheet effects varies with liability dollarization. It would also be interesting to study the importance of recursive-ordering assumptions for the results in a broader set of countries.

Appendix

The following variables were seasonally adjusted using the X-12 method (multiplicatively): GDP, consumption, investment, government spending, exports, imports, CPI and GDP deflator.

The variables used in the paper are defined as follows.

Output: log real gross domestic product (GDP). Source: Banco Central de Bolivia (BCB).

Output gap: percent output gap calculated using an HP filter to remove the trend from log real GDP (smoothing parameter 1600).

Consumption: log real private consumption. Source: BCB.

Investment: log real gross fixed capital formation. Source: BCB.

Government spending: log real government spending. Source: BCB.

Exports: log real exports. Source: BCB.

Imports: log real imports. Source: BCB.

The consumer price index (CPI) and the GDP deflator are also from BCB.

Inflation: annualized log difference in quarterly CPI.

U.S. interest rate: nominal interest rate on 3-month Treasury Bills. A quarterly series was constructed by averaging monthly data. Source: Federal Reserve Bank of St. Louis.

Terms of trade: log unit value of exports divided by the unit value of imports. Source: Instituto Nacional de Estadísticas.

Real exchange rate: log multilateral trade-weighted real exchange rate based on relative CPI. The original series is defined such that an increase in the series signifies a real appreciation. For pedagogical purposes, I inverted the series so that an increase means a real depreciation. Source: IMF International Financial Statistics.

Foreign output: log export-weighted average of real GDP in the ten most important Bolivian export markets (Argentina, Belgium, Brazil, Chile, Colombia, Peru, Switzerland, Venezuela, the United Kingdom and the United States). The Bolivian export weights are from 2000. In the few cases where only annual real GDP was available, I used the same annual index value for all quarters of the year. Source: IMF International Financial Statistics (foreign GDP) and BCB (Bolivian export weights).

Capital account: net capital and financial account. Source: IMF Balance of Payments Statistics.

Dummy variable for social unrest: during quarters with substantial economic effects of social unrest, the variable takes the value 1, otherwise it takes the value 0. Source: Mendieta and Escóbar (2006).

Dummy variable for the weather phenomenon El Niño: during quarters with substantial economic effects of El Niño, the variable takes the value 1, otherwise it takes the value 0. Source: Mendieta and Escóbar (2006).

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