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Non-linear effects of monetary policy and real exchange rate shocks in partially dollarized economies: an empirical study for Peru

I. INTRODUCTION

Starting from the first Neo-Keynesian theories related to nominal rigidities which emphasized the fact that changes in nominal wages are rigid downwards, the presence of menu costs and the existence of output capacity constraints (surveyed by Gordon, 1990), monetary policy literature has focused some attention to the asymmetries that arise when this policy operates. Altogether, these issues have suggested the existence of a convex aggregate supply curve. Additionally, another group of theories have indicated the possibility that the reaction of the demand curve could be asymmetric in the presence of borrowing constraints and also as a consequence, along with other supply effects, of non-homothetic preferences (surveyed by Castillo and Montoro, 2005).

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By using modern econometric techniques, several studies for developed economies[1] have shown that the response of inflation and output can differ depending on the state of the economy as well as on the size and sign of monetary shocks. These asymmetries have been found to arise depending on the position of a given variable (e.g., in terms of the position of the business cycle) –we will refer to this one as the "transition" or "state" variable in the rest of the paper. Particularly appealing is the evidence reported by Weise (1999), who suggests the existence of a convex supply curve in the US as the main element in determining asymmetries, by using a Smooth Transition Vector Autoregression (STVAR).

To our knowledge, though of great importance for monetary policy analysis in partially dollarized economies, not many studies regarding asymmetries have been carried out with data from these countries. In this paper, we try to fill this gap. Also, we depart from the traditional exclusive study of monetary shocks as we also analyze the asymmetric dynamics derived from real exchange rate shocks, since we believe that monetary policy in highly dollarized economies is tightly linked to exchange rate disturbances. In particular, we show how monetary policy and exchange rate shocks operate depending on the position of the business cycle in Peru, an economy with a high degree of dollarization. For each of these situations, we draw different impulse response functions that vary in sign and magnitude using the same methodology employed by Weise (1999).

The value of this study, we believe, is not only in terms of testing the existence of asymmetries (and in posing consequent observations for monetary policy management), but since partially dollarized economies may present different dynamics than "single-currency" ones, we can also establish comparisons on how do these two type of economies respond to shocks of similar nature. *A priori*, in dollarized economies, a relevant difference is probably the presence of a negative balance sheet effect associated to real exchange rate depreciations. This issue is very relevant for our study since it could be a key element generating additional asymmetries to those observed in developed economies. The balance sheet effect occurs whenever a country characterized by agents who are highly indebted in foreign currency –and where assets are mostly denominated in domestic currency– experiences

[1] De Long and Summers (1988), Cover (1992), Morgan (1993), Thoma (1994), Karras (1996), Weise (1999), Karamé and Olmedo (2002), among others.

a large real exchange rate shock that weakens the economy's balance sheet, usually in the non-tradable sector. Moreover, in the presence of frictions in the financial system, the "financial accelerator" mechanism (Bernanke and Gertler, 1989) predicts a strong negative effect in terms of aggregate demand (Céspedes et al., 2004). An additional implication for liability-dollarized economies is that a change in the central bank's reference rate may trigger a movement in the real exchange rate that, by activating the balance sheet effect, could bring about a variation on output of the opposite sign to the expected by monetary authorities. As it is widely known, as well, in these economies, central bank's intervention in the exchange rate market is very likely. In fact, shocks in this variable can also operate asymmetrically as a consequence of policy intervention and not just because of a latent balance sheet effect directly.

To round up the idea, in the case of an economy such as Peru, asymmetries may surge as a result not only of the traditional supply and demand arguments, but also of the presence of the balance sheet effect. This effect might have direct implications on output and prices or indirect ones *via* monetary policy intervention.[2] By studying the role of asymmetries, we try to elucidate the importance of this mechanism and consequently, to more clearly identify distinctions among monetary policy in both types of economies (i.e., non-dollarized and highly dollarized). Besides, it is worth to take into account the difficulty to conclude that the balance sheet effect is only activated after devaluations or rather, in general, after shifts in the real exchange rate regardless of their direction; on the other hand, it could be also important to contrast whether the size of the shock is relevant to activate such effect. These are additional reasons, which justify the use of a non-linear econometric technique.

In sum, the main objective of our research is to answer two relevant questions for monetary policy: first, what are the asymmetries in terms of monetary and real exchange rate shocks present in dollarized economies, and second, how different are these from those that have been found in "single-currency" economies? The Peruvian economy is of particular interest as a case study since dollarization has reached about 70% of deposits while mac-

[2] This intervention could eventually be an evidence of "fear of floating" from the central bank (Calvo and Reinhart, 2002), this is, fear of large currency swings due to their pervasive consequences in terms of output and, among other possible reasons, a higher pass-through effect than in non-dollarized economies.

roeconomic conditions have remained stable and inflation has remained at developed economy standards for several years.[3] We believe that the shape of asymmetries found in this country may shed light on the questions posed in this paper.

We arrange the document as follows: in section II we discuss related literature; in section III we explain the formal framework of the methodology, while in section IV the impulse response functions of the baseline linear model are shown. We test the presence of asymmetries in section V and report and explain the results of the STVAR estimation in section VI. We conclude in section VII.

II. RELATED LITERATURE

Among the literature related to the convexity of the supply curve, Ball and Mankiw (1994) build a theoretical model to explain the asymmetric dynamics of inflation. In short, they use menu costs for firms so when inflation is positive, negative shocks can bring relative prices back to their optimal level. As a result, firms will tend to adjust prices only when negative shocks are big enough to compensate menu costs. In contrast, when shocks are positive, relative prices depart further from their optimal level; thus, changes in nominal prices are more probable. Hence, under the presence of menu costs one could expect positive shocks to be more likely to induce shifts in inflation than negative ones.

Along with nominal price rigidities, if firms are confronted to capacity constraints their marginal cost should be more elastic to aggregate demand shocks when the economy is closer to its short-run output capacity, meaning that price adjustments would be more likely. In opposition, nominal wage rigidities would render inelastic marginal costs that make demand shocks more responsive in terms of output than prices.

More recently, Castillo and Montoro (2005) build a Neo-Keynesian model in which a concave aggregate supply curve co-exists with non-homothetic preferences –which proxy borrowing constraints. Their analytical study can be used to explain asymmetries in any direction since asymmetric shocks in the supply side are counteracted by asymmetric demand responses. In any

[3] This performance is in line with the analysis of Reinhart et al. (2003), who find evidence that a high degree of dollarization does not seem to be an obstacle to monetary control or to disinflation.

case, the prevalence of one of these effects (depending on the state of the economy) will rely upon the chosen parameterization. They conclude that for their set of parameters, monetary policy is more effective in terms of output in booms. Asymmetries are higher when deviations from the steady state come from supply shocks rather than demand shocks.

These authors also survey evidence on the asymmetric effects of monetary policy for developing countries. They divide the empirical literature into two categories. Within those that report evidence for differentiated responses in terms of size and sign, De Long and Summers (1988), Cover (1992) and Morgan (1993) argue that in the US, expansionary monetary shocks have no effect on output, whereas negative ones show some impact in economic activity (the first two use money aggregates while the latter uses the Federal Funds rate). Karras (1996) finds similar evidence for several other industrial countries. In contrast, Ravn and Sola (1996) disagree with those results since they state that it is not a different sign which causes asymmetries but rather their size. They conclude that small unanticipated changes in money supply are non-neutral whereas big unanticipated shocks have no effects.

In the second category of studies surveyed by Castillo and Montoro (2005), the asymmetries follow the state of the economy at a given point in time. For instance, they discuss the work of Thoma (1994).[4] Using rolling causality, this study suggests that the relationship between income and money becomes stronger when activity declines and weaker when it increases, implying the existence of a non-linear response of income to monetary policy shocks. Additionally, when testing differences between negative and positive shocks, the author finds that negative shocks have stronger output effects during high-growth periods than in the opposite case. On the other hand, positive shocks do not seem to cause distinct effects.

Highly dollarized economies may present a third source of asymmetries if a balance sheet effect is latent.[5] Thus, additional asymmetries may appear as a consequence of the interaction between policy rate and the exchange rate when the balance sheet becomes a threat. Specifically, as explained in the previous section, reductions in the policy rate could have no expansionary ef-

[4] Caballero and Engel (1992), Agénor (2001) and Holmes and Wang (2002) are other studies cited by Castillo and Montoro (2005).

[5] For instance, Castro and Morón (2004) explore both analytically and empirically the asymmetric responses of output and prices to exchange rate shocks.

fects in the presence of this channel if it caused real exchange rate depreciations.

Regarding this last point, several studies have exposed that in spite of the so-called Fear of Floating,[6] a high level of dollarization has not completely inhibited the role of monetary policy (Reinhart et al., 2003). Peru has been no exception: despite maintaining an average of over 70% of credits and liquidity in dollars during the past 10 years, monetary policy has proven effective. For instance, Winkelried (2004) concludes by using an error correction model, that in the event of a restrictive monetary shock of 1%, the GDP (output gap) reacts by falling between 0.5% and 0.6% within a year. In Bigio and Salas (2004), it is stated that an increase of 1% in the rate of the Deposit Certificates of the Central Reserve Bank of Peru triggers a fall in the product. Such fall lasts between the 6th and 8th month after the shock, with a considerable average impact of -0.4%. When it comes to inflation response, the evidence has also shown monetary policy effectiveness (Quispe, 2000; Rossini, 2001). Winkelried (2004) finds that a 1% shock in the reference rate lowers inflation in a magnitude around 0.3% within a year.

Concerning the effects of exchange rate shocks in partially dollarized economies, the international evidence on the question of whether competitiveness effect –this is, the classical effect in which export-related sectors is boosted by currency depreciations– offsets the balance sheet effects is not conclusive, as surveyed by Carranza et al. (2003). However, these authors' own firm-level analysis focuses in the Peruvian case and they find evidence contrary to a significant competitiveness effect and in favor of a negative balance sheet effect.[7] By using aggregate Peruvian data, Winkelried (2004) arrives to the same conclusion regarding the balance sheet effect, but this paper does suggest a significant competitiveness effect in the long term.[8]

Castro and Morón (2004) have analyzed the non-linear effect

[6] See Calvo and Reinhart (2002).

[7] Loveday et al. (2004) have also found empirical support for a latent balance sheet effect in Peru in the level of non financial firms.

[8] Céspedes (2005) uses a large sample of devaluation episodes for a group of emerging and developed countries and he finds that balance sheet effects have a significant and negative impact on output, but in the medium term, the expansionary effect of the real devaluation tends to prevail. Interestingly, he also suggests that countries with deeper financial markets experience lower output losses after devaluations.

of real exchange rate shocks on output. This work suggests that the higher the shock, the more negative the response becomes –a symptom of the presence of a balance sheet effect. In terms of prices, the results reported in this study are intriguing since the greater the real exchange rate shock, the smaller (and even negative!) the rate of pass-through would be.[9] A kind of similar pattern has been found in Carranza et al. (2004), although they focus on the effect of nominal rather than real exchange rate shocks over inflation. By employing univariate threshold models this document shows evidence that in dollarized emerging economies a negative pass-through coefficient would prevail during economic downturns. Nonetheless, a more exhaustive analysis concerning pass-through in Peru has been carried out in Winkelried (2003), where the presence of asymmetries is proven but according to this paper, the asymmetries do not behave in the manner proposed by Carranza et al. (2004), in the sense that the pass-through coefficient would always be positive. By using a STVAR approach, the study states that once the nominal exchange rate has already depreciated, an additional increase in the exchange rate has a pass-through rate about 10% higher, and that in expansionary periods depreciations have around 30% more pass-through rate than in recessions.[10] Finally, an interesting result of this paper is that a reduction in the rate of dollarization reduces the pass-through rate.

Of course, not only the latent balance sheet effect but also the uncertainty of its consequences has been enough incentive for central banks' interventions in the exchange rate market. As well, as a consequence of the high dollarization, since a greater pass-through level of exchange rate over domestic inflation should be expected, these economies have relied upon dirty floating (Parrado and Velasco, 2001).[11] It is feasible to expect exchange rate

[9] It is worth to mention that these authors carry out a similar methodological approach than ours, but they employ a monetary aggregate as the instrument of monetary policy, while we use an interest rate, given that this is the tool controlled by the Peruvian Central Bank since some months previous to the Inflation Targeting Regime adoption (in January 2002) –see more discussion about the monetary policy interest rate in the Appendix–. This fact may imply a misspecification of their VAR. Additionally, they do not include any exogenous variable nor do they report any confidence bands.

[10] Another study by Miller (2003) employs a linear VAR analysis and states that for 100% devaluation, inflation would increase by 16%.

[11] As pointed in the Fear of Floating literature, not only a higher pass-through coefficient would be the exclusive reason behind this type of central

shocks to be followed by monetary policy responses that quickly neutralize them.[12]

Policy reactions after real exchange rate shocks has been vastly analyzed; as a matter of fact, an open debate has been recently present in the economic literature on what should be the optimal monetary policy followed by small open economies (see, for instance, Galí and Monacelli, 2004). Despite a relative consensus among recent studies favoring an absolute free floating, it is worth to note that many of them compare extreme situations, i.e., flexible exchange rate against fixed exchange rate. On the contrary, Parrado and Velasco (2001) build a stochastic model concluding that the optimal monetary policy is that by which external shocks to interest rates are accompanied by raises in domestic interest rates less than proportional to their size. Lahiri and Végh (2001), and more recently Morón and Winkelried (2005), have suggested that the optimal policy to be followed by monetary authorities should be asymmetric, where large fluctuations in the exchange rate should be counterbalanced in greater proportion than smaller ones since only large shocks trigger balance sheet effects, while intervention as a response to small sized shocks would incentive a raise in dollarization.

III. METHODOLOGY: SMOOTH TRANSITION VAR

The origin of the STVAR methodology goes back to the Time-Varying Smooth Transition Autoregressive models presented originally by Terasvirta and Anderson (1992). These autoregressive models rely on the specification of a function related to a transition or state variable (or set of variables in more elaborate versions) that will determine the dynamics of the difference equation that conform the models. Extending them into their VAR formulation is straightforward. Different functional forms can be

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banks' behavior in dollarized economies, but also the possible loss of access to international capital markets and the restrictive balance sheet effects after large devaluations, and the negative consequences for import activities and the "Dutch Disease" threat in the case of currency revaluations.

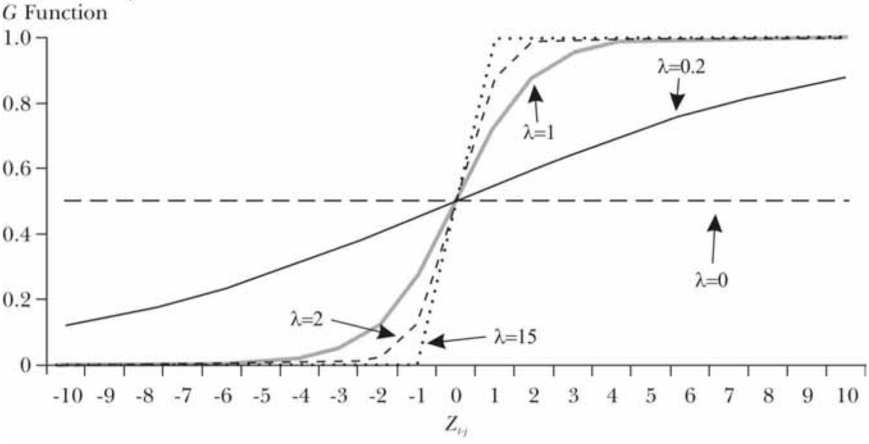
[12] The question of whether Peru, where a managed floating exchange rate regime officially exists, could be catalogued as a "phony floater" has been discussed at least in two papers (and remains as a non conclusive debate): Castro and Morón (2000) and Rossini (2001). The former presents evidence in favor of that hypothesis while the latter rejects it.

tested for a given state variable. We will use the logistic formulation for the transition function (or *G*-function) as expressed by equation (1).

$$G(z_{t-j};\gamma,\theta)=\left[1+e^{-\gamma\frac{(z_{t-j}-\theta)}{\sigma_z}}\right]^{-1} \quad \text{where } \gamma>0. \tag{1}$$

This function takes values from 0 to 1 depending on a given threshold represented by θ, a smoothing parameter γ and the value of a transition variable z in a given point of time (t-j), where σ_Z is the standard deviation of z_t. As z_{t-j} approaches to infinity, the *G*-function tends towards 1 whereas when the former approaches to minus infinity, the function tends to 0. This can be viewed in figure 1: for greater values of γ the *G*-function behaves more closely as a dummy variable that activates whenever $z_{t-j} > \theta$ (such as the curve for γ=15, where the transition describes an almost vertical line for z_{t-j} = 0).

FIGURE 1. THE SHAPE OF *G*-FUNCTION FOR THRESHOLD θ = 0 AND DIFFERENT VALUES OF γ



To understand how a non-linear VAR is built, we start by presenting its moving average representation as:

$$Y_t=[I-\Phi(L)]^{-1}C\varepsilon_t\,, \tag{2}$$

Where Y_t represents a k-vector of variables at point t in time and $[I-\Phi(L)]^{-1}$ is an array of parameters and lag operators. C is a k-by-k matrix that defines interrelations among the system's vector of disturbances ε_t (typically, C is defined as to be an identity matrix).

The Smooth Transition version for this VAR may incorporate the G-Function, to yield the following form:

$$Y_t = [1 - \Phi_1(L) - G(z_{t-j})\Phi_2(L)]^{-1} C\varepsilon_t \tag{3}$$

The simplest way to interpret equation (3) is to think of the extreme case of $\gamma = \infty$. One can observe that in such instances, Y_t will be represented by two different linear VARs, operating once G transits to one of its respective two possible values (i.e., 0 and 1, since G-function behaves more like a dummy). When γ takes smaller values, the states are no longer two but rather, work as a continuum that transit smoothly from the extreme situations in which $z_{t-j} = -\infty$ and $z_{t-j} = \infty$. It is also possible to extend (3) in order to include possible exogenous regressors.

IV. THE CORE LINEAR MODEL

We use a core linear model to identify the transmission of structural shocks through the economy. Later on, we add a non-linear structure to this model [i.e., we build a setup for (2) and then extend it to (3)]. The baseline Structural VAR (SVAR) model is built following Christiano et al. (1999), as the monetary policy's reaction function is identified by dividing the variables that can be contemporaneously affected by the policy tools. Thus, the SVAR is specified in the form of three recursive blocks: variables that are not contemporaneously affected by monetary policy, policy variables and variables that may be contemporaneously affected by the former block.

Regarding the policy block, it is assumed that, as has been recently surveyed by Woodford (2003), money aggregates can be treated as endogenous to the policy rate when this one is the instrument employed by monetary authorities to reach their objectives, as in the Peruvian case.

We further assume that the policy block is unable to affect contemporaneously both output and inflation. Moreover, we understand that output is the most exogenous variable of the VAR, as relevant information for production decisions may take several lags to be processed. As well, a second assumption regarding the non-policy block is that inflation has a certain inertial component but can contemporaneously react to output shocks. Finally, we presume that the real exchange rate could respond to all the previously mentioned variables, even the policy tools,[13] so it is the most endogenous variable of the system.

Consequently, the structural form of our procedure is as follows:

$$
\begin{aligned}
R_t &= \phi_1 M_t + \phi_2 i_t + \phi_3 y_t + \phi_4 P_t + f_1(Y_{t-1}, X_t^*) + \varepsilon_t^R \\
M_t &= \phi_5 i_t + \phi_6 y_t + \phi_7 P_t + f_2(Y_{t-1}, X_t^*) + \varepsilon_t^M \\
i_t &= \phi_8 P_t + \phi_9 y_t + f_3(Y_{t-1}, X_t^*) + \varepsilon_t^i \\
P_t &= \phi_{10} y_t + f_4(Y_{t-1}, X_t^*) + \varepsilon_t^P \\
y_t &= f_5(Y_{t-1}, X_t^*) + \varepsilon_t^y
\end{aligned} \tag{4}
$$

In this formulation, R_t, M_t, i_t, P_t and y_t represent the real (bilateral) exchange rate, a money aggregate, the monetary policy reference rate, the CPI and the output gap, respectively. All variables are expressed as twelve-month log differences, except for the policy rate, which is expressed in a simple annual difference. As well, f_i represents a linear function composed by two sets of information (variables), Y_{t-1} and X_t^*. These sets represent information regarding to the endogenous and exogenous variables, respectively, from a given point in time up to periods *t*-1 and *t,* respectively again. Finally, ϕ_i symbolizes a given parameter and ε_t is a stochastic disturbance. The system of equations in (4) takes the form of (2) once it is expressed in its moving average formulation.

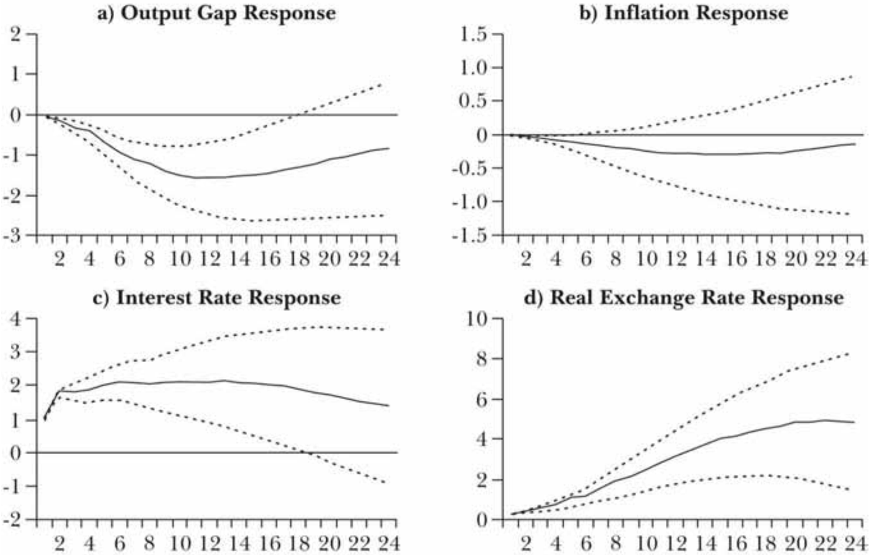
In the Smooth Transition version of this system, we let ϕ_i to take different values depending on a transition variable. We discuss this in the following section.

We estimated this specification using the usual ordinary least squares procedure. We tried over several tentative models using alternative variables.[14] The exogenous variables corresponding to X_t^* are reviewed in the Appendix. Lag structure and autocorrelation tests indicated the use of 4 lags in the estimation; in the case of the exogenous variables, only one lag is added to the contemporaneous value.

[13] As mentioned by Bravo and García (2002), who implement the same SVAR for the Chilean economy, the central bank may affect the real exchange rate through the existing connection between the nominal exchange rate, the policy rate and exchange market interventions.

[14] We discuss details on the employed data and the transformations that were necessary to be performed in the Appendix.

PANEL FIGURE 1. ACCUMULATED RESPONSES TO A MONETARY IMPULSE (1% INTEREST RATE INCREASE) IN THE LINEAR MODEL



NOTE: Dotted lines represent 95% Monte Carlo-confidence bands (based on 1,000 replications).

1. Linear impulse response functions

The accumulated impulse response functions for the linear system expressed by (4) can be observed in Panel Figures 1 and 2.[15]

Panel Figure 1 shows the responses to an increase of 1% in the policy rate. One can notice that the monetary policy operates in a traditional fashion causing a reduction in the output gap (Panel Figure 1.a) and inflation (Panel Figure 1.b). Instead, Panel Figure 1.c suggests the existence of an exchange rate puzzle since an increase in the interest rates causes a real depreciation in opposition to the appreciatory effect that would prevail in the short run (if prices were less elastic than the nominal exchange rate, as expected). We failed to solve this problem by introducing exogenous variables (in alternative estimations), which are typically suggested as a way to circumvent this type of puzzle (see Christiano et al., 1998). A similar puzzle was found in Winkelried (2004) and the author attributed this result to the high volatility

[15] We show accumulated responses in order to make comparisons more feasible along the paper.

and monthly frequency of the data,[16, 17] and in Parrado (2001) for the case of Chile, who argued that the managed exchange rate regime and the taxation of capital inflows could explain this phenomenon. An alternative explanation to this puzzle is that the extension of the data covers a period of a severe sudden stop, which was characterized by high interest rates along with depreciating real exchange rates. Therefore, we estimated an additional (non-reported) specification of the VAR controlling for the short-term external liabilities of Peruvian banks –a very proper variable to capture the capital flows' sudden stop experienced in Peru after the Russian crisis of 1998. However, we found no significant changes in the dynamics compared to those observed in the reported results.

The responses to real exchange rate shocks reported in Panel Figure 2 show some different dynamics than those expected in "single-currency" economies. In particular, real exchange rate depreciation, in contrast to the typical *J*-curve effect, only produces a short run significant fall in output.[18] This result is in line with the evidence presented by Carranza et al. (2003) and Bigio and Salas (2004). However, it is difficult to assure whether the real depreciation is triggering a balance sheet effect that lowers output in the short run or, rather, this is a consequence of the central bank's reaction –the raise in the policy rate shown in Panel Figure 2.c– or to a combination of both factors. Nonetheless, it is hard to believe that only monetary policy is working here since we have previous empirical evidence of a latent balance sheet effect in Peru (see section II) and, moreover, we find a positive pass-through rate in Panel 2.b. Again, the rapid significant responses are quite intriguing.

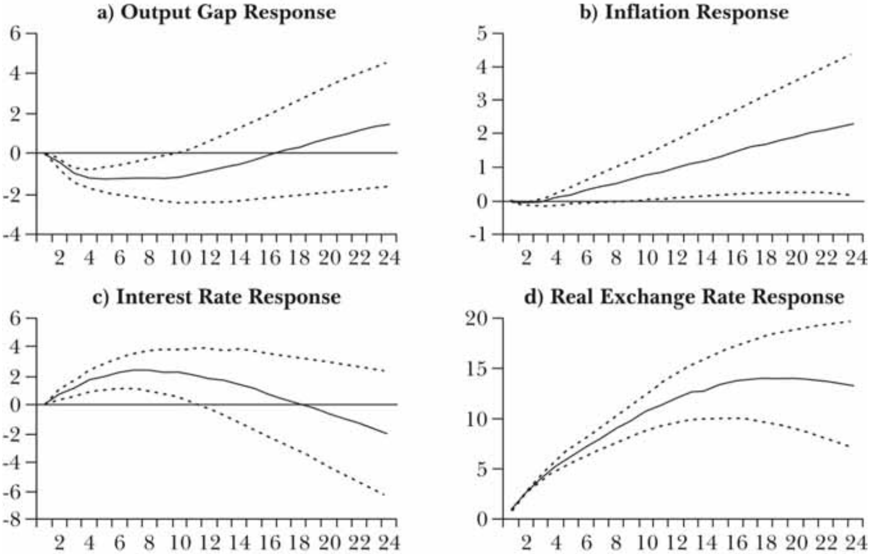
In the next section we present the asymmetric version of this model.

[16] This might also explain the fast significant responses observed in the impulse response functions. A similar pattern is found in previous exercises which used monthly Peruvian data (see, for example, Quispe, 2000; Bigio and Salas, 2004; and the same Winkelried, 2004).

[17] Accordingly, this problem may be solved in future extensions by employing data of higher frequency (e.g., quarterly data) –a solution not considered in our case due to the subsequent loss of degrees of freedom.

[18] An argument to explain the absence of a medium term competitiveness gain as a response to the shock is that the Peruvian economy does not substitute imports substantially with local production. On the contrary, many of its imports are industrial inputs so depreciations basically have a greater price than substitution effect.

PANEL FIGURE 2. ACCUMULATED RESPONSES TO A REAL EXCHANGE RATE IMPULSE (1% INCREASE) IN THE LINEAR MODEL



NOTE: Dotted lines represent 95% Monte Carlo-confidence bands (based on 1,000 replications).

V. THE STVAR

1. Testing the Presence of Asymmetries

One can expand the core linear model in (4) into a form such as (3) and thus we have the non-linear version of the model. Before presenting estimates for this model, we prove the presence of non-linearities by testing the null hypothesis Ho: $\gamma = 0$, where non-rejection would imply that that the system (3) is linear as in (2). In standard estimations, one could test any restriction in any of the VAR equations by building an F-test. The problem with this procedure is that since γ and θ are not previously known, direct χ^2 or F distributed tests are no longer valid. A solution proposed by Lukkonen et al. (1988) is to use a Taylor expansion that distributes χ^2 and has the additional advantage that it no longer requires an estimate for γ or θ.

The first order Taylor expansion of equation (3) takes the following form:

(5) $$Y_t = [1 - \Gamma_1(L) - z_{t-j}\Gamma_2(L)]^{-1} C\varepsilon_t \, ,$$

So that the null hypothesis $\gamma = 0$ becomes $\Gamma_2(L) = 0$. In order to contrast it, we use the well-known Likelihood-Ratio (*LR*) test.

We define $\Omega_\varepsilon^{linear}$ and $\Omega_\varepsilon^{non-linear}$ as the variance-covariance matrixes of the fitted errors extracted from the OLS estimation of (2) and (5) respectively. The subsequent *LR* test can be calculated under the following specification –which includes the modification proposed by Sims (1980) to take into account small-sample bias:

$$(6) \qquad LR = [T - (\rho k + n_X)](Ln\left|\Omega_\varepsilon^{linear}\right| - Ln\left|\Omega_\varepsilon^{non-linear}\right|) \sim \chi^2(\rho k^2) .$$

Here, *T* represents the sample size, ρ stands for the number of lags in the VAR, *k* is the number of endogenous variables, and n_X is the number of parameters of the exogenous variables estimated per equation. Notice that what is being tested is the significance of ρk^2 coefficients. We present the corresponding *p*-values for all the variables in our model in Table 1.[19]

TABLE 1. LIKELIHOOD-RATIO TEST FOR NON-LINEARITIES: *P*-VALUES

	Transition variable				
	y_t	P_t	i_t	M_t	R_t
Lag 1	0.36	0.05	0.00	0.49	0.00
Lag 2	0.00	0.02	0.00	0.00	0.00
Lag 3	0.07	0.02	0.00	0.11	0.00
Lag 4	0.00	0.00	0.00	0.13	0.00
Lag 5	0.18	0.00	0.00	0.24	0.00
Lag 6	0.01	0.00	0.00	0.51	0.00

As observed, the *LR* test reveals overall non-linearities when taking (at least one of the lags of) all the series in the system as transition variable. However, as mentioned before, in this study we are focusing on the role of the output gap as the state variable, since the economic theory provides strong arguments to consider its relevance for the type of asymmetries that we are interested in explore empirically here. The evidence in Table 1 is also helpful to pick a certain lag for the chosen transition variable: four of the six lags considered in the test proved to be statistically appropriate in the case of the output gap.[20]

[19] Equation by equation *F*-tests were also performed to contrast non-linearities. The results are available upon request.

[20] The final STVAR estimations were performed using the third lag of this se-

In the following section we present the procedure adopted in order to parameterize our estimation of the extension of (4) into (3).

2. Parameterization of the STVAR

In order to choose the correct parameters in (1), namely the threshold θ and the smoothing parameter γ, one could use a maximum likelihood technique with complete information or a non-linear least squares approach. These procedures have one possible problem that renders this estimation unfeasible: the presence of plenty of local maxima. This is because the model is highly sensitive to γ. As a matter of fact, the greater γ becomes, the larger the difference among states because they are conditioned to be more markedly distinct; in contrast, differences among distinct sign or size shocks will tend to dilute.

We take the same direction as in Weise (1999) who follows Leybournes et al. (1998) by performing a grid search for γ and θ. We do so by estimating *LR* tests that compare each non-linear model for a given pair of parameters γ and θ against the linear version. The 3-d plot that results from this search for the case where the output gap's third lag is treated as state variable is depicted in Figure 2. The range of search for θ is limited to the middle quintile of this series' distribution.[21]

In figure 2, we observe that significant non-linearities are particularly accentuated for values of θ equal or higher than zero, and for high values of γ. Hence, we parameterize θ very close to zero, since it is intuitively appealing,[22] and $\gamma=100$, a very high point that will emphasize the contrasts between one state (i.e., when $y_t>0$) and the other ($y_t<0$). This parameterization turns out to be very similar to the one used by Weise (1999) for US data.

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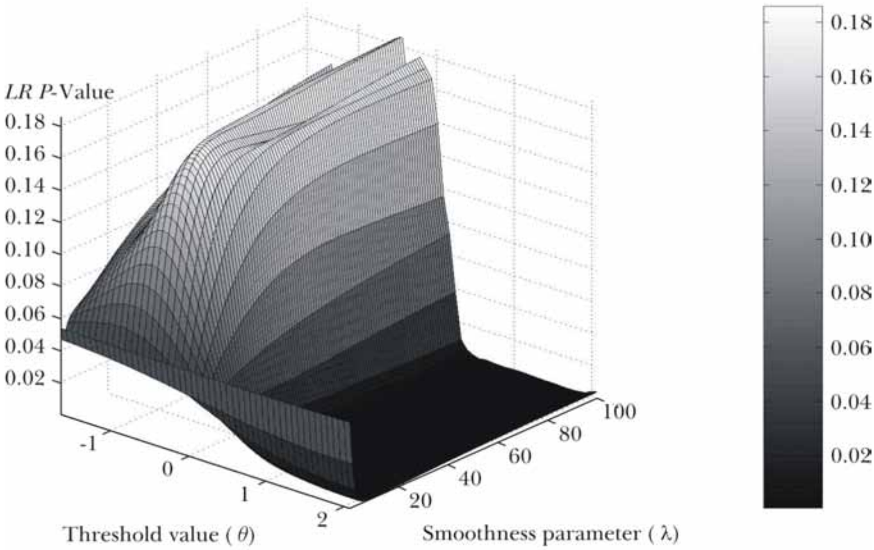
ries as the transition variable, since the asymmetric effects proved to be more clear in the impulse-responses analysis with such election.

[21] Because the data is highly concentrated in the middle of the distribution, when a grid search is performed over broader n-tiles, for high values of θ, the number of periods that lie within one of the states are too few to perform properly the test. This particular difficulty is stressed for a high smoothness parameter and provokes distortions in the *LR* tests.

[22] Given our specification of the output gap in the VAR –i.e., transformed as a twelve-month log difference– the intuition behind $\theta \cong 0$ is straightforward: the threshold is given by the point where the GDP annual growth rate equals the Potential GDP annual growth rate.

FIGURE 2. GRID SEARCH: *LR P*-VALUES FOR DIFFERENT THRESHOLDS AND SMOOTHNESS PARAMETERS GIVEN OUTPUT GAP (THIRD LAG) AS THE TRANSITION VARIABLE



The lag order of the non-linear VAR is 4. We choose this specification using as a guide the linear model. Weise (1999) also suggests the election of the same lag order used in the linear model for several other econometric reasons.

We now continue by commenting the results for the non-linear model estimation in the next section.

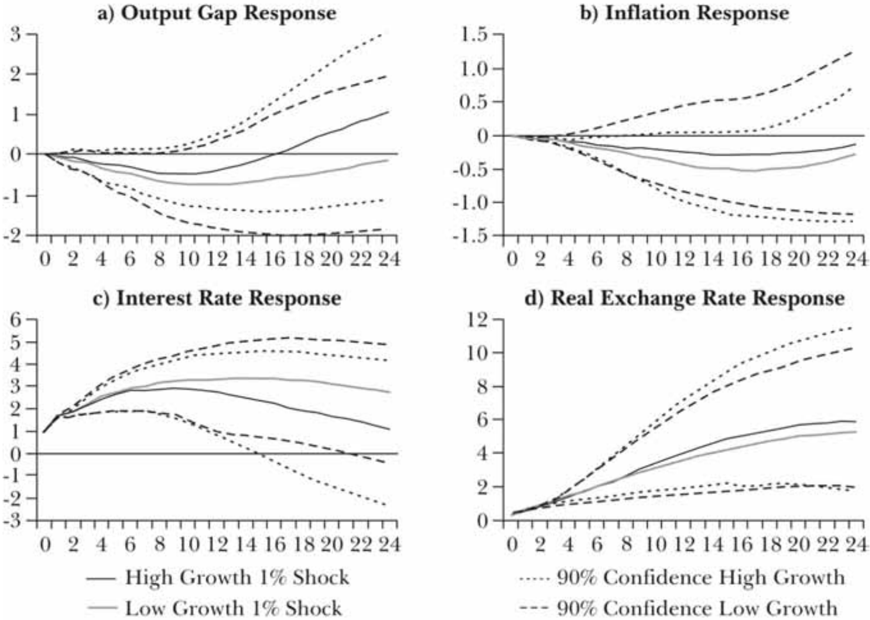
VI. RESULTS

1. Output dependant asymmetries of monetary shocks

The first main result of our study is found in Panel Figure 3 where we show the distinct non-linear impulse-response functions.[23] In panel (a) we find the accumulated response of the output

[23] These impulse-response functions are not constructed in the same fashion as in linear models. In the case of non-linear models, impulse response functions are highly dependant on their past history and on the position of the state variable at a given point in time. Taking expectations over the difference of a path characterized by a given shock and other where the shock is absent would not be the appropriate procedure since the dynamics of the function are not necessarily linear combination of shocks, but rather more complex construc-

PANEL FIGURE 3. ACCUMULATED RESPONSES TO A MONETARY IMPULSE (1% INTEREST RATE INCREASE) BY OUTPUT GAP STATE



(gap) to a 1% increase in the interbank rate depending on the position of the output gap's second lag. Dotted lines represent 90% confidence Generalized Impulse Response Functions (GIRF) bands both when the (annual growth rate of) output gap was greater than zero ("high growth") and for the opposite case ("low growth"). In particular, though not reported in the paper, non-accumulated responses show statistical significance between the third and eighth month after the shock. We can see that about a year ahead from the shock, the magnitude of the output gap response during high economic growth is, on average, two thirds of the response observed in downturn periods.[24] In contrast, the response of inflation is near the double in the former case [see panel (b)]. Moreover, the confidence bands depicted in the same graph suggest a more lasting effect during high growth periods. This feature may also explain why the policy shock proves to be

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tions. So, in contrast, we use the Generalized Impulse Response Function technique detailed in Koop et al. (1999).

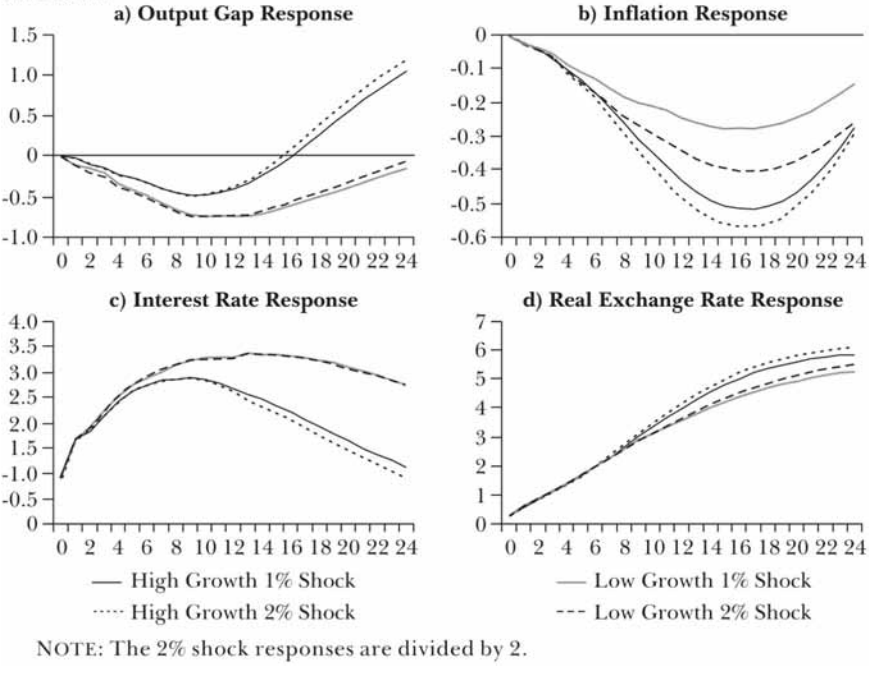
[24] Notice also that, in general, the magnitudes of responses are more realistic here than in the linear model. Compare, for instance, the responses for the output gap [i.e., panel figure 1 (a) *vs.* panel figure 3 (a)].

significantly more inertial during low growth episodes, as shown in panel (c). In general, these graphs prove the presence of asymmetries in terms of the response of some key variables of the economy to monetary policy shocks.

The evidence also suggests that monetary policy shocks over the aggregate demand probably dominate those related to an increase in marginal costs (see Castillo and Montoro, 2005). These findings suggest a convex supply curve as the one attributed by Weise (1999) to the US economy, in line with the Neo-Keynesian literature. The likely presence of a latent balance sheet effect seems not to affect the shape of asymmetries dependent on the output cycle. In the following subsections we show the effects once shocks of different size and sign are introduced.

The solid lines in Panel Figure 4 correspond to the expected impulse response functions, just as in Panel Figure 3, while the dashed lines represent the responses to 2% shocks in the policy rate during high and low output starting points. We divide the response of the 2% shock by two in order to observe if the impact is more than proportional. As one can observe in panel (a), we find

PANEL FIGURE 4. ACCUMULATED RESPONSES TO A MONETARY IMPULSE (1% INTEREST RATE INCREASE) BY OUTPUT GAP STATE FOR SHOCKS OF DIFFERENT SIZE

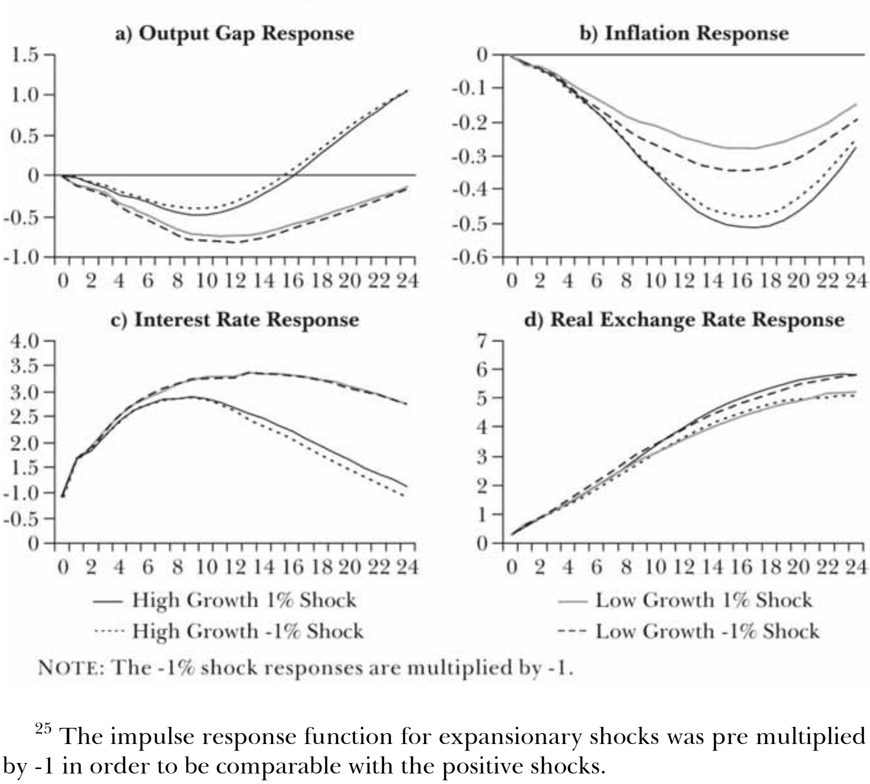


NOTE: The 2% shock responses are divided by 2.

that a double size shock seems to have no particular asymmetric effect in terms of the output gap. The opposite is found in terms of prices: more restrictive shocks generate an even greater restrictive response as one observes in panel (b), and this result is accentuated during low growth periods. Both graphs suggest that supply effects are more relevant in marginal terms the stronger the shocks become. This issue can be interpreted as support for Neo-Keynesian arguments that suggest that capital costs translate to the supply curve once shocks are strong enough as to compensate nominal rigidities such as menu costs; once adjustment costs overpass menu costs, relative prices are corrected and hence, the lesser is the marginal impact in terms of output. Since the share of capital costs is greater than labor costs in determining the firms' marginal costs, our findings are hardly surprising.

Panel Figure 5 compares negative and positive shocks.[25] Again, we find no marked asymmetries in output responses but they do

PANEL FIGURE 5. ACCUMULATED RESPONSES TO A MONETARY IMPULSE (1% INTEREST RATE INCREASE) BY OUTPUT GAP FOR SHOCKS OF DIFFERENT SIGN



NOTE: The -1% shock responses are multiplied by -1.

[25] The impulse response function for expansionary shocks was pre multiplied by -1 in order to be comparable with the positive shocks.

appear more clearly in the case of inflation. For low growth periods, an expansionary shock (i.e. a reduction of 1% in the policy rate) shows to have greater than proportional effects in terms of prices and output when compared to restrictive shocks. Conversely, for high growth periods, expansionary shocks have less effect in both output and prices. Hence, this panel figure suggests something quite appealing: the fact that monetary policy has more power to contract when the economy is in expansion and has more power to expand in low growth periods. One reason for the former case is the existence of capacity constraints that will restrict the expansionary power of monetary impulses. We also may conclude that wage rigidities are not of principal relevance as one might think since restrictive shocks have less impact on output precisely when wage rigidities are more damaging, during low growth periods,[26] compared to positive impulses during the same phase.

For the US, Weise (1999) found no sign asymmetries for 1.5% monetary shocks (in any direction), though when shocks are raised to a double, the evidence indicates that output and prices are more responsive to negative shocks, while only prices are responsive to expansionary shocks in low growth periods.

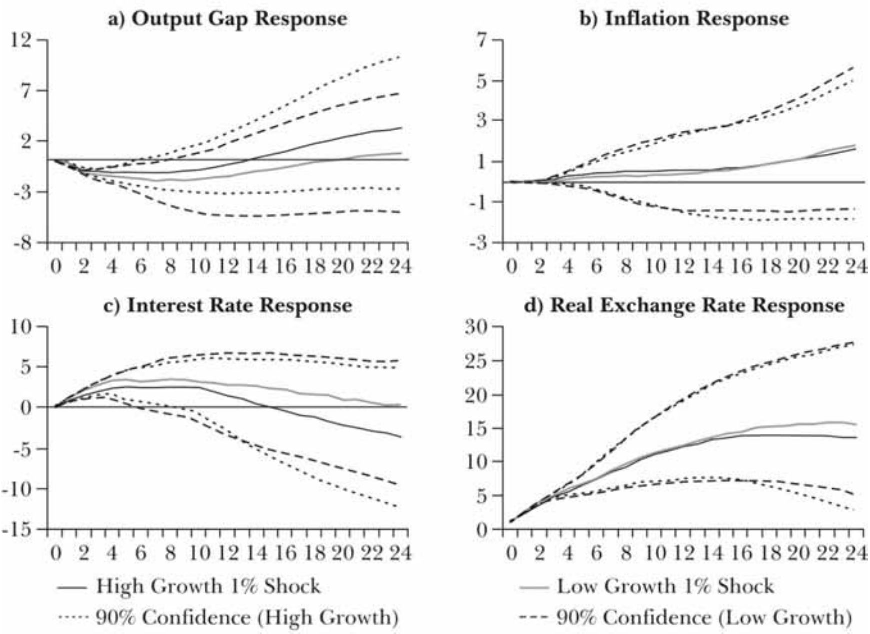
2. Output dependant asymmetries of real exchange rate shocks

As mentioned in section II, for economies that do not suffer from dollarization one should expect a real exchange rate depreciation to have positive effects on output, some periods after a slight contraction –the so called "*J*-curve" shaped effect. For a dollarized economy such as Peru, this may not always be the case as one observes in Panel Figure 6.a. As in the linear model, it is not clear that the quick negative responses of the output gap surge as a consequence of a balance sheet effect that hits the economy or by the response of the policy interest rates to this shock. We believe both effects to be present; moreover, considering previous empirical research based on firm-level analysis where the balance sheet effect was found to exist in the Peruvian economy (see section II). Under such circumstances, monetary authorities would have incentives to raise interest rates for two reasons: to counteract the pass-through of the exchange rate to prices and to avoid the balance sheet effect. Furthermore, given that monetary policy is said to work with several lags, if output is

[26] See for example Jackman and Sutton (1982).

affected almost immediately after the real exchange rate shock, as our results reveal, it is likely that only the balance sheet effect is working in the very short run.

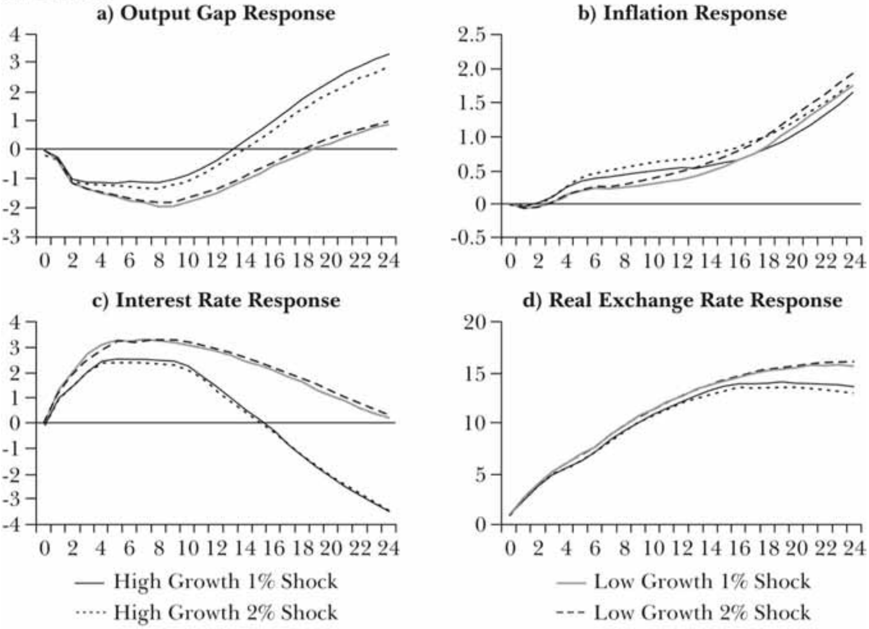
PANEL FIGURE 6. ACCUMULATED RESPONSES TO A REAL EXCHANGE RATE IMPULSE (1% INCREASE) BY OUTPUT GAP STATE



Panel (a) presents additional evidence, in particular, that the negative effect in terms of the output gap is greater and lasts significantly more when the economy is a low growth context. As a matter of fact, Panel (c) shows a more aggressive response by monetary authorities when in low growth thus suggesting greater fear for abrupt depreciations during these periods. This last point makes sense taking into account that firms are stand in a more fragile position when the economy in not growing enough. Turning back to the effects on output, it is hence not clear whether the greater impact of the real exchange depreciation on low growth periods is a consequence of the asymmetric response of the monetary authorities worried for a greater balance sheet effect, or by a more damaging balance sheet effect itself. Panel (a) also shows the apparent absence of a significant long-run positive output response.

Panel (b) shows a superior pass-through rate when the economy is in a high growth period [this is more clear when observing Panel (b) in Panel Figure 7]. It is again not obvious if this is because of some overheating in the economy or because the response of monetary authorities during these periods is less emphatic. In any case, the results are consistent with Winkelried (2003), who reports an always positive pass-through rate both in periods of economic growth and downturns. The strong dynamics regarding the evolution of the real exchange rate respond to a highly persistent autoregressive process.

PANEL FIGURE 7. ACCUMULATED RESPONSES TO A REAL EXCHANGE RATE IMPULSE (1% INCREASE) BY OUTPUT GAP STATE FOR SHOCKS OF DIFFERENT SIZE

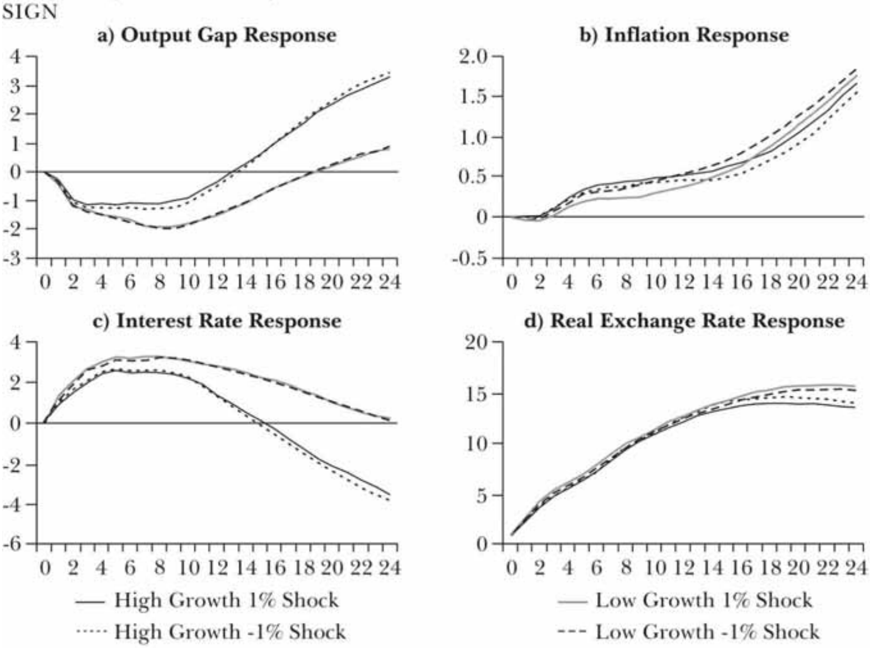


NOTE: The 2% shocks responses are divided by 2.

When comparing 2% shocks against 1% shocks (Panel Figure 7), we find that double sized shocks have almost the same effect in terms of output during low growth periods but their effect is more than proportional when we have high economic growth. Another relevant idea suggested by panel (a) is that the balance sheet effect appears regardless of the size of the exchange rate shock. On the other hand, as expected, the effect in terms of the pass-through rate is more than proportional in both cases as was also found by Winkelried (2003).

Panel Figure 8 shows that negative against positive shocks have relatively symmetric effects in all variables of the system except for prices where we find that negative shocks have a lesser than proportional effect when in high growth. The opposite differences occur in low growth periods. An interesting general conclusion derived from this evidence is that the balance sheet effect not only would operate in a single direction, this is, contracting the output gap after devaluation episodes, as the "classic" approach to the balance sheet effect sustains, but also having a expansionary impact after a positive shock in the real exchange rate.

PANEL FIGURE 8. ACCUMULATED RESPONSES TO A REAL EXCHANGE RATE IMPULSE (1% INCREASE) BY OUTPUT GAP STATE FOR SHOCKS OF DIFFERENT SIGN



NOTE: The -1% shocks responses are multiplied by -1.

VII. CONCLUDING REMARKS

Several conclusions underlie this study, providing answers to the main questions that were posed in the initial section of the paper. We summarize them below.

• Asymmetries regarding the position of the output gap are found to be present in the Peruvian economy. In particular, increases in the monetary policy reference rate have a greater relative impact on output than inflation during low growth periods and the opposite is found for high growth periods. Thus, asymmetries relative to interest rate shocks work in a similar manner as they do in the US; the presence of a latent balance sheet effect appears not to have originated substantial differences in terms of the way in which monetary policy works in a highly dollarized economy. For both types of economies the general picture suggests a convex aggregate supply curve.

• Larger interest rate shocks show that they are marginally more powerful to affect prices rather than output. We interpret this result as evidence of menu costs that become less relevant once shocks are of greater magnitude and/or of output capacity constraints.

• When comparing negative against positive interest rate shocks we find that interest reductions render a more powerful effect that tends to increase in low growth episodes, but the exact opposite asymmetries are found during high growth periods. Hence, monetary policy in Peru is more powerful to force output towards its long-term trend than to take it apart from it.

• In terms of real exchange rate shocks, we find evidence that suggests that depreciations have only negative significant effects in terms of output. Increases in the policy interest rate tend to follow sudden depreciations. Conditional on an initial low growth, the impact on output of this shock is proportional but the monetary policy is asymmetrically more restrictive as compared to high growth periods. We find a rationale for this response in the fact that the balance sheet effect is more harmful during low growth periods. Consequently, we infer that the Central Bank is more fearful of the balance sheet effect during economic downturns. On the other hand, we suggest that the shape of the output response to real exchange rate shocks could also be related to the fact that depreciations generate greater price than substitution effects and to a high correlation with credit-crunch episodes. Finally, inflation response proves to be always positive but larger during the positive side of the business cycle.

• In terms of shocks of different sign and magnitude, the real exchange rate generates no important asymmetries except for the pass-through rate, which is larger the greater the shock. Thus, the balance sheet effect would generate output expansions in the events of real exchange rate appreciations. On the other hand, monetary authority's reaction has behaved asymmetrically in terms of the business cycle, but not in response to different sign and magnitude of real exchange rate shocks. This result enters in contradiction with recent optimal monetary policy literature's suggestions (see section II).

Finally, we expect to motivate further research on non-linearities. Contributions such as this paper seem to suggest that this sort of response patterns in key variables for macroeconomic policy analysis are a fact that deserve to be studied more in detail.

To conclude, it is important to point out several limitations of this paper. As usual with VAR models, there are many alternative ways of identification that may imply different impulse-response results. In spite of having adopted a largely used identification scheme –which is based on a simplified structural representation of a small open economy–, our choice is certainly subject to potential criticisms. In particular, even though the finding of a puzzling response of the real exchange rate after the interest rate shock can have some economic explanations, as mentioned in the text, a different identification procedure might support or discard this outcome. Within a different model framework, the potential balance sheet effect could also be tested by changing the source of the shock –e.g., simulating a more underlying shock, such as to the international interest rate, instead of using the real exchange rate shock–. We leave these topics for future research.

Appendix

The data

The data used in the estimations has monthly frequency. It starts in January 1994 and ends in July 2004. The endogenous series (detailed below) were transformed to annual differences[27, 28] to

[27] Alternative estimations based on first differences transformations were also performed, but as some series seemed not be stationary, we preferred the annual differences specification of the variables.

[28] To be more precise, all variables are expressed in annual percentage

achieve stationarity, which was tested with Augmented Dickey-Fuller, Phillips-Perron and KPSS unit root tests. In the case of the series that, according to the Zivot and Andrews test, presented structural breaks, we followed Weise (1999) –who mentions the existing risk of rejecting linearity in the benchmark VAR because of time-dependent structural breaks in the data– and proceeded to model these breaks in a simple regression equation and then captured the residual series.

The Output Gap (y_t): Log level of seasonally adjusted GDP real index (Source: Central Reserve Bank of Peru) and its permanent component, which was estimated by employing the Hodrick-Prescott filter with the traditional 14400 smoothing parameter for monthly data.

Prices (P_t): Log level consumer price index (Source: Central Reserve Bank of Peru), "corrected" for a trend break in February 2002.

Monetary Policy Interest Rate (i_t): Approximately until 2002, when the Inflation Targeting regime was introduced in Peru, the Interbank Rate (Source: Central Reserve Bank of Peru) –which is now the dominant instrument of monetary policy– was determined by market forces, so we had to reconstruct a "smoothed" policy rate in a similar fashion as in Winkelried (2004): we regressed the interbank rate against operative indicators of monetary policy, such as the official discount rate and the banks' current account balance in the Central Bank (we also tried an alternative specification which included the average reserve surplus or deficit as a percentage of liabilities subject to reserve requirement, with no significant improvements in the estimation). For the period 1994-2002, the fitted series from this regression was used as the policy interest rate; from then on, we just used the observed interbank rate. Of course, this procedure also allows us to overcome the problem that the interest rate was not the monetary policy tool in the period 1994-2001.

Monetary Aggregate (M_t): Log level of seasonally adjusted M_0 (Source: Central Reserve Bank of Peru), "corrected" for a mean break in March 1996.

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changes, since after taking twelve-month differences to the log levels we multiplied the resulting series by 100. Of course, we did not follow the same procedure for the interest rate, since this series is originally expressed in percentage terms; in particular, we took no logarithms nor did we perform the multiplication by 100 for the case of this variable.

Real Exchange Rate (R_t): Log level of the real bilateral exchange rate between Peru and the US (based on nominal *nuevo sol* per dollar exchange rate). (Source: Central Reserve Bank of Peru.)

Exogenous variables (X_t^*): At first, we specified alternative VARs with several series that were candidates to be included as exogenous variables, according to previous similar empirical work for other economies (e.g., oil price, US real GDP and inflation rate, commodity price index, among others). However, in the final model we just included the Fed Funds rate (in first difference) for simplicity, because the inclusion of other variables seemed not to offer any important qualitative differences to the results. (The sources of the alternative series employed in the exogenous variables block were the IFS database and Economagic.com.)

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