

Estimating the Equilibrium Real Exchange Rate: The case of Venezuela ¹

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Abstract: To determine whether the real exchange rate is misaligned with respect to its long-run equilibrium level is an important issue for policy makers. This note clarifies and calculates the concept of the equilibrium real exchange rate using a structural vector autoregression (VAR) model. By imposing long run restrictions on a VAR model for Venezuela, four structural shocks are identified: Nominal demand, real demand, supply and oil price shocks. The identified shocks and their impulse responses are consistent with an open economy model of economic fluctuations, and highlight the exchange rate as a transmission mechanism in a large oil producing country.

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1. Introduction

Ever since Meese and Rogoff (1983) reported that a comprehensive range of exchange rate models were unable to outperform a random walk, the role of economic fundamentals in explaining exchange rate behaviour has been scrutinized. Economic theory typically predicts that the behaviour of the real exchange rate (RER) should be closely related to the behaviour of deviations from purchasing power parity (PPP). According to the PPP theory, nominal exchange rates adjust to offset changes in relative prices. If this is correct, then the real exchange rate will be stationary and fluctuate around the mean in the long run. Non-stationary series, on the other hand, wander wildly and rarely return to an earlier value. However there is widespread agreement that substantial deviations from PPP have occurred since the abandonment of the Bretton Woods fixed exchange rate system (see e.g. Froot and Rogoff 1995). In particular, real exchange rates can deviate from the PPP in the short run, and can in fact be very volatile. Recently, empirical studies have also shown that real exchange rates are not only very volatile in the short run, the speed of convergence to PPP in the long run is extremely slow (see Rogoff 1996).

How is it possible to reconcile the enormous short term volatility of real exchange rates with the very slow rates at which these shocks seem to disappear? The persistent deviation from PPP casts doubt on the Dornbusch (1976) open macroeconomic (overshooting) model, which explains short run real exchange rate volatility with sticky prices and monetary disturbances. Instead, long run deviation from PPP suggests the influence of real shocks with large permanent effects. The fact that many empirical studies do not reject the hypothesis of a unit root in the real exchange rate (see e.g. Serletis and Zimonopoulos 1997), also supports the argument that the variations in real exchange rates are attributed to permanent shocks.

This paper clarifies and calculates the concept of the equilibrium real exchange rate in Venezuela, using a structural vector autoregression (VAR) model, and compares the results with those of a simple time series model, like the unobserved components model. Without imposing strong economic beliefs, I identify different demand and supply shocks through assumptions about the long run impacts of these shocks on the variables in the VAR model. As the direct measure of these shocks is difficult, it motivates the use of a VAR model, where, rather than specifying the impulses that correspond to the different policies, a set of equations are instead specified that characterise the different policies. The VAR approach is also particularly useful for the purpose of this paper, as it allows us to decompose the variation in a set of variables to the relative contribution of the different underlying shocks.

The paper is organised as follows. In section two I test the hypothesis of PPP, and then calculate the long-run real exchange rate identified by an unobserved components model. Section three identifies the structural VAR model and traces out the impulse response and the variance decomposition of the RER to the identified shocks. In section four I display the response in the real exchange rate to the shocks in each historical period. Section five summarizes and concludes.

2. Long run exchange rates and economic fundamentals.

A natural starting point for discussing the relationship between exchange rates and fundamentals, is the concept of PPP, which is attributed to Cassel (1921, 1922). Assuming there are no costs in international trade, then domestic prices would equal foreign prices multiplied by the exchange rate. The expression for absolute PPP can then be written (in log-form) as:

$$e_t = p_t - p_t^* \tag{1}$$

where p_t is the log of the domestic price, p_t^* is the log of the foreign price, and e_t is the log of the nominal exchange rate. However, since trade is costly, PPP will not hold continuously. It is therefore informative to define the real exchange rate as:

$$s_t = e_t - p_t + p_t^* \quad (2)$$

where s_t is the real exchange rate. If PPP shall hold, this would imply that the real exchange rate would be stationary and fluctuate around a fixed value in the short run.

Figure 1. The real exchange rate



Figure 1 graphs the real exchange rate in Venezuela, during the sample 1980-1998. The RER refers to the real effective exchange rate, (IMF's International Financial Statistics). An increase means an appreciation whereas a decrease means a depreciation.

Testing for non-stationary using the Augmented Dickey Fuller (ADF) unit-root test confirm our suspicion that the RER in Venezuela is most likely non-stationary. Hence, the hypothesis of PPP does not hold in the long run. In particular, table 1 shows that one cannot reject the hypothesis that the (logarithm of) RER is non-stationary against the (trend) stationary hypothesis. This result holds whether I use a sample starting in 1980 or 1990, and using monthly or quarterly data (see table 1).

Table 1. Augmented Dickey Fuller unit-root tests^a

Sample period	ADF(lags) ^b	Monthly data	ADF(lags) ^b	Quarterly data
		t_{ADF}		t_{ADF}
1990-1998	ADF(2)	-1.97	ADF(1)	-3.23
1980-1998	ADF(2)	-0.65	ADF(1)	-0.81

^a A time trend and a constant are included in the regressions. 5% critical values = -3.46, (i.e. Fuller, 1976).

^b The number of lags is determined by selecting the highest lag with a significant t value on the last lag, as suggested by Doornik and Hendry (1997).

As the RER in Venezuela is non-stationary, one cannot use the PPP measure to find a base period in which the RER is believed to be in equilibrium.

One way to take explicitly into account the fact that equilibrium RER may change over time as economic fundamentals change, is to measure the long-run real exchange rate in a time series model, like the unobserved components model. An unobserved components model divides the real exchange rate into permanent and transitory components. The underlying assumption of this model is based on an economic theory in which the permanent (long-run) component represents real influences, while the transitory component represents short-term movements due to nominal exchange rate fluctuations. Below I describe the model used in some more detail.

2.1. Structural time series model

A structural time series model is specified in terms of components that have a direct interpretation. These components are not directly observable, but are assumed to have ARIMA representations, (see Harvey, 1989). Structural time series models for monthly or quarterly data will typically consist of a trend, cycle, seasonal and irregular component. All four components are stochastic, and the disturbances driving them are mutually uncorrelated. In this framework, assuming that the logarithm of a variable, y_t , (i.e. the RER), can be decomposed as:

$$y_t = g_t + c_t + s_t + \varepsilon_t \quad (3)$$

where g_t is the trend, c_t is the cycle, s_t refers to the seasonal component, and ε_t is the noise component, the stochastic trend evolves as:

$$g_t = g_{t-1} + \beta_{t-1} + \eta_t \quad (4)$$

$$\beta_t = \beta_{t-1} + \zeta_t \quad (5)$$

where β is the slope of the trend, and η and ζ are normal, independent, white noise disturbances, with variances σ_η^2 and σ_ζ^2 respectively. The cyclical component is defined as:

$$\begin{aligned} c_t &= \rho \cos \lambda_c c_{t-1} + \rho \sin \lambda_c c_{t-1}^* + v_t \\ c_t^* &= -\rho \sin \lambda_c c_{t-1} + \rho \cos \lambda_c c_{t-1}^* + v_{t-1}^* \end{aligned} \quad (6)$$

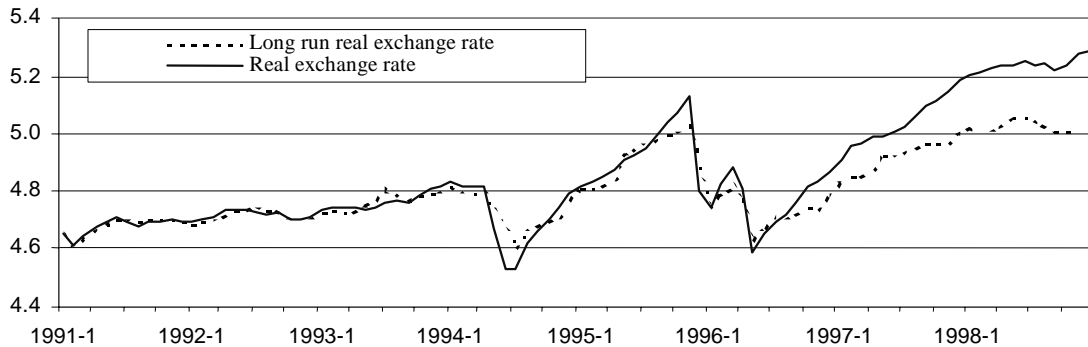
where ρ is the damping factor such that $0 \leq \rho \leq 1$, λ_c is the frequency of the cycle in radians, and v_t and v_t^* are independent white noise disturbances, with variances σ_v^2 . Finally, the irregular component is assumed to be white noise, and the seasonal component will be estimated as a trigonometric function.

This model has also been called the unobserved components (UC) model. It has the advantage that nonstationarity can be handled directly, without having to difference the data explicitly. It has the clear advantage over a more restricted detrending method like the Hodrick-Prescott filter, in that the smoothness of the trend will be intrinsic in the estimation, rather than having to be determined apriori.

Estimation of the whole model will be carried out by maximum likelihood and the Kalman filter in the STAMP package. Using monthly data from 1990M1-1999M3, figure 2 below graphs the log of the RER and the long-run exchange rate, measured by the UC method. The misalignment can be calculated as the deviation of the long-run RER from actual RER, adjusted for seasonality and noise. The model has the nice property of being stable over time (e.g., starting the estimation at an earlier or

later point essentially provides the same results). The results indicates that from late 1996, the real exchange rate has been overvalued, on average 22 percent in 1998.

Figure 1. Long-Run Real Exchange Rate Identified in an Unobserved Components Model



Although based on economic theory, the UC model is essentially a statistical model, which does not directly link the long-run component to other fundamental economic variables. Clearly it would be of interest to try to find economic variables that could explain the long run behaviour of the RER. However, testing for long-run (cointegration) relationships between the RER and potential fundamental economic variables such as the external current account, productivity and the fiscal deficit, turned out to be unsuccessful. Rather than imposing nonexisting long-run relationships between economic variables, I therefore decided to proceed by using a methodology that decomposes the variation in the real exchange rate into components attributable to different economic shocks (impulses).

3. A structural vector autoregression (VAR) model

Here we use a structural VAR model to estimate the relative importance of different types of macroeconomic shocks for fluctuations in the real exchange rate. However, the unrestricted VAR is on reduced form, and the innovations generated by the model are therefore uninterpretable. To go from the reduced form to the structural model, a set of identifying restrictions must be imposed on the variables in the model. Here, the different structural disturbances will be identified through plausible long-run restrictions, that are based on economic theory, as first introduced in Blanchard and Quah (1989).

The VAR model estimated here comprises the real exchange rate, real oil prices, real manufacturing production (relative to its trading partners) and consumer prices (relative to its trading partners). It can be shown that these four variables will be sufficient to identify four different structural shocks. Two demand shocks (real demand and monetary shocks) and two supply shocks (aggregate supply and real oil price shocks). In the framework of the traditional IS-LM macroeconomic model, these shocks can be thought of, respectively, as shocks to the goods market (shift in the IS curve), shocks to the money market (shift in the LM curve), shocks that affect the long run level of capacity output and shocks in the oil price. Although the focus here will be to study the sources behind the real exchange rate fluctuations, the model imply that the shocks can have interactive effects on all four variables.

The restrictions on the long-run multipliers of the system that are used here to identify the structural shocks, are based on an open economy model presented in appendix B. The key (long run) identifying assumption that distinguishes between the demand and supply shocks, asserts that in the long run, the level of output will be determined by supply side factors (aggregate supply and real oil price shocks) only. Hence, there is a full employment (natural) level of output that can only change with the supply factors in the economy. However, in the short run, due to nominal and real rigidities, all four disturbances can influence output.

For a resource rich country like Venezuela, a dominant energy sector can also have effects on the domestic economy via the exchange rate. Especially, a resource discovery may give rise to wealth effects that appreciate the exchange rate. This may squeeze the tradable sector, a phenomenon that has been termed the “Dutch Disease” in the economic literature. To allow both the demand and supply shocks to also influence the domestic economy through an exchange rate channel, I therefore include the real exchange rate into the model.

The choice of the real exchange rate in the VAR model is also important in the sense that it allows me to separate a monetary shock from the real demand shock, by assuming that the monetary shock can have no long run effect on the real exchange rate (cf. Clarida and Gali 1994). This is consistent with most models of short run exchange rate variability but long run purchasing power parity. No restrictions are placed on the response of the real exchange rate to the three other shocks. Hence, here I assume that the real exchange rate encompasses *both* short term volatility and long run deviations from purchasing power parity. In particular, PPP is preserved in the long run with respect to monetary changes, so that a monetary shock will increase the price and depreciate the exchange rate proportionally. This leaves the real exchange rate unchanged in the long run, as predicted by the Dornbusch overshooting model and the Mundell-Fleming model with flexible prices. The same models also predict that a real demand expansion appreciates the real exchange rate (via an increase in the interest rate, a capital inflow and a balance of payment surplus). The effect of an aggregate supply shock on the real exchange rate is more difficult to establish. A flexible price exchange rate model would typically predict that following an aggregate supply shock, the price level falls monotonically and the real exchange rate depreciates. I put no restriction on the effect of the oil price on the real exchange rate, as it allows me to investigate the possibility that the exchange rate may be a “petrocurrency”, that appreciates when the oil price is high and depreciates with a low oil price.

Finally, the oil price shock itself is identified as the only shock that can have a long run effect on the real oil price. However, in the short run, all shocks are allowed to influence real oil prices. The long run restrictions on oil prices are plausible given that Venezuela have only limited influence on the price of oil. In addition, oil prices have been dominated by a few exogenous developments, like the OPEC embargo in 1973 and the collapse of OPEC in 1986.

To sum up, neither monetary nor real demand shocks can have long run effects on the level of manufacturing output. In addition, monetary shocks have no long run effects on the real exchange rate and only oil price shocks can have a long run effect on the real oil price. Below I discuss how one can identify a structural VAR model that is consistent with the economic model briefly put forward here.

3.1 Identifying a structural VAR model

The analysis above suggested that by estimating a VAR model containing the four variables; real oil prices (op_t), real manufacturing production (relative to its trading partners) (y_t), real exchange rate (s_t) and consumer prices (relative to its trading partners) (p_t), the four structural shocks; oil price (ϵ_t^{OP}),

aggregate supply (ϵ_t^{AS}), real demand (ϵ_t^{RD}) and money shocks (ϵ_t^{MON}) can be identified. Assume for now that all variables are nonstationary integrated, I(1), variables, (where stationarity is obtained by taking first differences).² Ordering the vector of stationary variables as $z_t = (\Delta op_t, \Delta y_t, \Delta s_t, \Delta p_t)'$, the reduced form of z_t can be modelled as:

$$\begin{aligned} z_t &= \alpha + A_1 z_{t-1} + \dots + A_p z_{t-p} + e_t \\ A(L)z_t &= \alpha + e_t \end{aligned} \tag{7}$$

where e_t is a vector of reduced form serially uncorrelated residuals with covariance matrix Ω . As all the variables defined in z_t are stationary, z_t is a covariance stationary vector process. The Wold Representation Theorem implies that under weak regularity conditions, a stationary process can be represented as an invertible distributed lag of serially uncorrelated disturbances. The implied moving average representation from (7) can be found and written as (ignoring the constant term for now):

$$z_t = C(L)e_t \tag{8}$$

where $C(L)=A(L)^{-1}$ and C_0 is the identity matrix. As the elements in e_t are contemporaneously correlated, they can not be interpreted as structural shocks. To go from the reduced form to the structural model, the elements in e_t must be orthogonalized by imposing a set of identifying restrictions. Assume that the orthogonal structural disturbances (ϵ_t) can be written as linear combinations of the Wold innovations (e_t), i.e. $e_t = D_0 \epsilon_t$. A (restricted) form of the moving average containing the vector of original disturbances can then be found as:

$$z_t = D(L)\epsilon_t \tag{9}$$

where $C_j D_0 = D_j$, or:

$$C(L)D_0 = D(L) \tag{10}$$

The ϵ_t 's are normalized so they all have unit variance, i.e. $cov(\epsilon_t) = I$. If D_0 is identified, I can derive the MA representation in (9) since $C(L)$ is identifiable through inversions of a finite order $A(L)$ polynomial. However, the D_0 matrix contains sixteen elements, and to orthogonalize the different innovations sixteen restrictions are needed. First, from the normalization of $var(\epsilon_t)$ it follows that:

$$\Omega = D_0 D_0' \tag{11}$$

There are $n(n+1)/2$ distinct covariances (due to symmetry) in Ω . With a four variable system, this imposes ten restrictions on the elements in D_0 . Six more restrictions are then needed to identify D_0 . These will come from restrictions on the long run multipliers of the $D(L)$ matrix.

² The assumptions of stationarity are discussed and verified empirically below.

I first order the four serially uncorrelated orthogonal structural shocks:

$\varepsilon_t = (\varepsilon_t^{OP}, \varepsilon_t^{AS}, \varepsilon_t^{RD}, \varepsilon_t^{MON})'$. The long run expression of (9) can then simply be written as:

$$\begin{bmatrix} \Delta op \\ \Delta y \\ \Delta s \\ \Delta p \end{bmatrix}_t = \begin{bmatrix} D_{11}(1)D_{12}(1)D_{13}(1)D_{14}(1) \\ D_{21}(1)D_{22}(1)D_{23}(1)D_{24}(1) \\ D_{31}(1)D_{32}(1)D_{33}(1)D_{34}(1) \\ D_{41}(1)D_{42}(1)D_{43}(1)D_{44}(1) \end{bmatrix} \begin{bmatrix} \varepsilon^{OP} \\ \varepsilon^{AS} \\ \varepsilon^{RD} \\ \varepsilon^{MON} \end{bmatrix}_t \quad (12)$$

where $D(1) = \sum_{j=0}^{\infty} D_j$ indicate the long run matrix of $D(L)$. Above I found that only oil price shocks can affect real oil prices in the long run, hence:

$$D_{12}(1) = D_{13}(1) = D_{14}(1) = 0 \quad (13)$$

Only real oil price and aggregate supply shocks can affect manufacturing production in the long run:

$$D_{23}(1) = D_{24}(1) = 0 \quad (14)$$

and all shocks except the monetary shock can affect the real exchange rate in the long run:

$$D_{34}(1) = 0 \quad (15)$$

No restrictions are placed on prices, although there are some overidentifying restrictions on prices that can be tested informally by examining the impulse response analysis. For instance, the standard aggregate demand/supply diagram suggests that whereas positive real demand and monetary shocks shall increase prices permanently, following a positive aggregate supply shock, prices shall fall permanently.

With the six long run restrictions, it is now easy to see that the matrix $D(1)$ will be lower triangular, and I can use this to recover D_0 . The long run representation of expression (10) and (11) implies:

$$C(1)\Omega C(1)' = D(1)D(1)' \quad (16)$$

(16) can be computed from the estimate of Ω and $C(1)$. As $D(1)$ is lower triangular, expression (16) implies that $D(1)$ will be the unique lower triangular Choleski factor of $C(1)\Omega C(1)'$. Let E denote the lower triangular Choleski decomposition of (16), then D_0 can easily be obtained from:

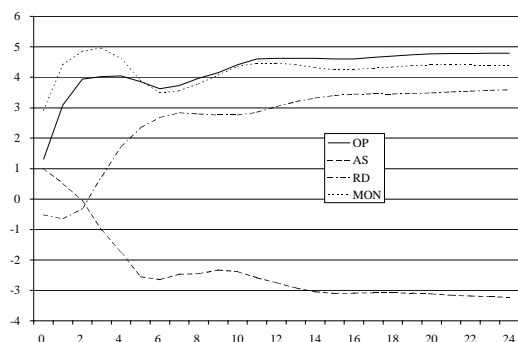
$$D_0 = C(1)^{-1} E \quad (17)$$

3.2 Empirical results

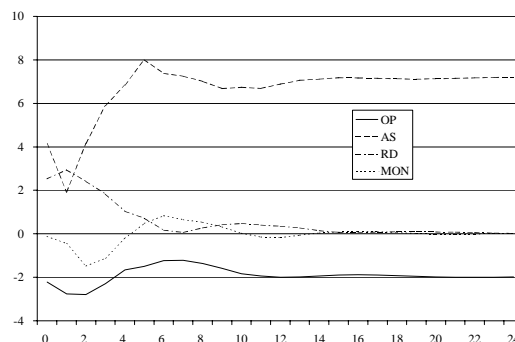
The variables used in the VAR analysis are; the real manufacturing production in Venezuela relative to the US, consumer prices in Venezuela relative to the US, petroleum spot West Texas Intermediate, and the real effective exchange rate (RER).³ All variables are taken from the IMF's IFS, (the real exchange rate from the line *rec*) except the real manufacturing production in Venezuela that has source Central Bank of Venezuela. The sample uses quarterly data, from 1985Q1-1999Q1. The start date reflects availability of data.

Figure 2. Impulse responses to oil price (OP), aggregate supply (AS), real demand (RD) and monetary (MON) shocks (cumulative percent change):

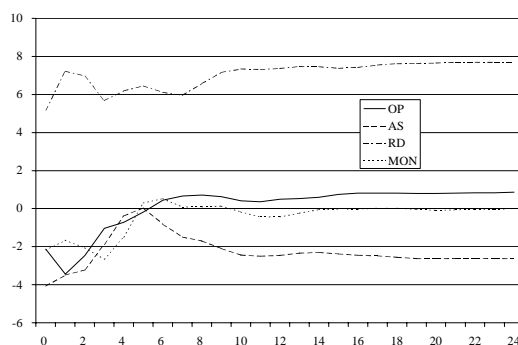
A) Price



B) Manufacturing Production



C) Real Exchange Rate



To test whether the underlying processes contain a unit root, I use the augmented Dickey Fuller (ADF) test of unit root against a (trend) stationary alternative (cf. table A1 in appendix A). For neither of the variables, can I reject the hypothesis of I(1) in favour of the (trend) stationary alternative. However, I can reject the hypothesis that all variables are integrated of second order, I(2). Lag reduction test suggest a lag order of four. Estimating a VAR-model with four lags and seasonal dummies, I can reject the

³ Although the RER measures the real exchange rate relative to all Venezuela's trading partners, the US is by far the dominant trading partner, so that in the model I use the US as a proxy for Venezuela's trading partners.

hypothesis of serial correlation, heteroscedasticity and non-normality in each equation at the 1 pct. level, except for the RER where I can reject non-normality at the 5 pct. level (see table A2 in appendix A). Finally, testing for cointegration between relative real manufacturing production, relative prices, the real exchange rate and the real oil price, I can conclude that none of the variables in the VAR models are cointegrated (see table A.3 in appendix A). Hence, the nonstationary variables in the VAR model can be specified in accordance with equation (5) above.

Estimating a well-specified VAR model, I can now assess the effects of all the shocks on the relevant variables. Figure 2A-C plot the (impulse) responses of the four shocks on relative prices, relative real manufacturing production and the real exchange rate respectively.⁴ All the different shocks have the effects as expected by an open economy model like that presented in appendix B. Consistent with Dornbusch's overshooting model, a monetary shock that increases prices, depreciates the real exchange rate, before it appreciates (overshoots) back to long run equilibrium. Due to the quick adjustment in prices, the effect on real output is essentially zero.

A positive real demand shock increases prices gradually and appreciates the real exchange rate (via an increase in the interest rate, a capital inflow and a balance of payment surplus). Real output also increases temporarily but after a one and a half year, the effect is no longer significant. A supply shock (that increases capacity and real output permanently) depreciates the real exchange rate, which is consistent with a flexible price exchange rate model, where the price level falls monotonically.

Finally, for a large oil producing country like Venezuela, a positive oil price shock changes relative prices and appreciates the real exchange rate in the long run. However, the effect is small and in the short run the RER actually depreciates, suggesting an overshooting of the real exchange rate to an oil price shock. As expected, manufacturing production falls in response to the oil price shock, an indication that Venezuela is experiencing Dutch disease effects of the oil price shocks.

Table 2. Variance decompositions of real exchange rate¹

Quarters	OP	AS	RD	MON
1	8.6	31.5	50.8	9.1
4	9.6	17.5	65.3	7.7
8	6.1	11.3	77.3	5.3
12	4.1	10.4	82.0	3.5
32	2.0	10.2	86.7	1.1

1) OP; Oil price shock, AS; Aggregate supply shock, RD; Real demand shock, MON; Monetary shock.

Table 2 reports the variance decomposition for the real exchange rate⁵ For a resource rich country, stochastic shocks to the goods market (IS shocks) may induce excessive exchange rate volatility. This view is supported in table 2, as real demand shocks explain 65 pct. of the variation in the real exchange rate the first year, increasing to almost 80 pct. after two years. Interestingly, Clarida and Gali (1994), also found demand (as opposed to supply) shocks to dominate in all the four countries they examined, especially in UK and Canada, which are also resource rich countries. Aggregate supply shocks explain approximately 20 pct of real exchange rate variation the first year, stabilising at

⁴ Standard deviations of all the shocks can be obtained from the author on request.

⁵ Variance decompositions for other variables can be obtained from the author on request.

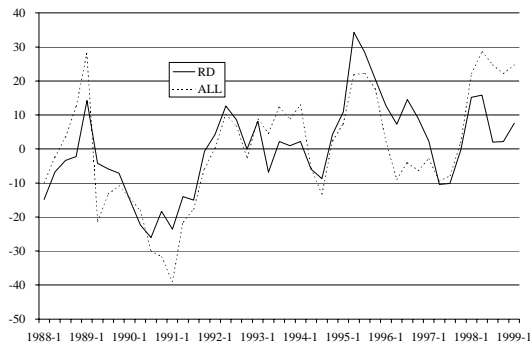
about 10 pct. after two years. Oil price shocks and monetary shocks each explain just less than 10 pct. of the variation in the real exchange rate the first year, and the effect dies out after approximately three years.

3. Sources of real exchange rate fluctuations

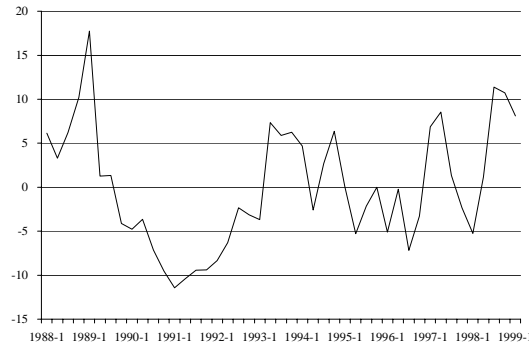
Until now, I have discussed the responses of the variables to the different shocks on average over the whole period. In the remaining part, I investigate more thoroughly the contributions of the most important shocks to the fluctuations in *each* historical period for the real exchange rate. Here I focus on the real exchange rate only, but similar analysis can be made for all variables in the VAR model. Figure 3A below plot the total forecast error in the RER (denoted ALL) together with the forecast error that is due to real demand shocks, whereas figure 3B-D give the forecast error of the real exchange rate due to the three remaining shocks; aggregate supply, real oil price and monetary shocks respectively. As the RER is in logarithm, these plots can be interpreted as pct. deviation from a trend. This decomposition allows me to interpret economic fluctuations in terms of the different shocks that have hit the RER.

Figure 3. Sources of real exchange rate variation (percent change)

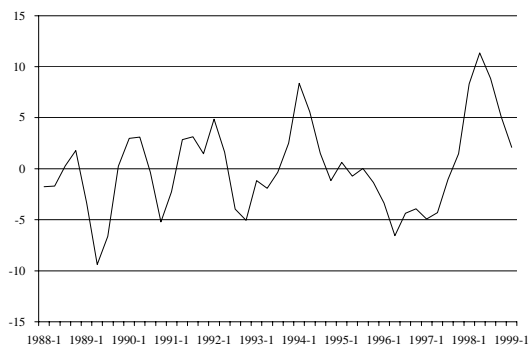
A) Real demand (RD) shocks



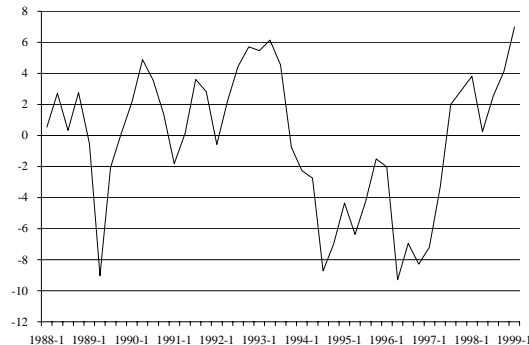
B) Aggregate supply shocks



C) Oil Price shocks



D) Monetary shocks

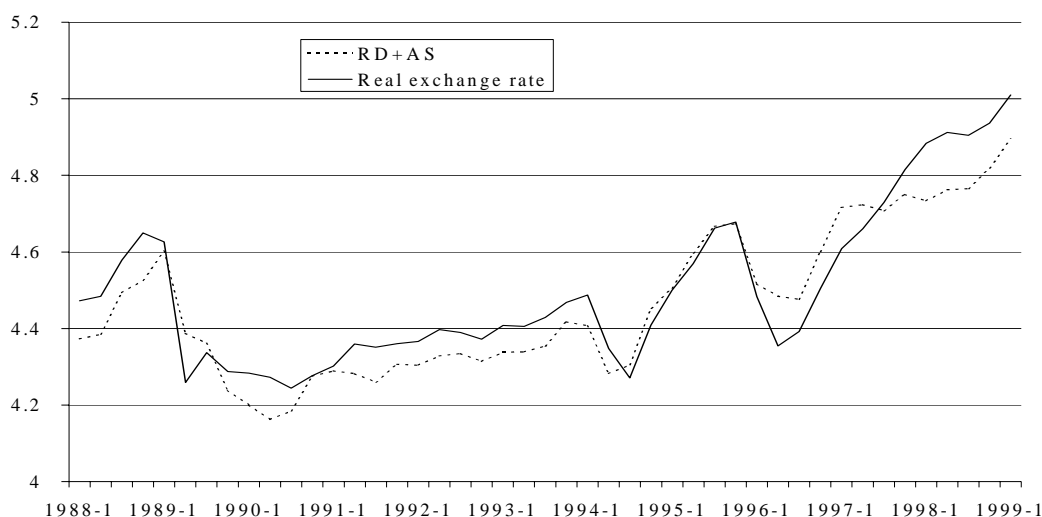


Overall, real demand shocks have the largest effect on the real exchange rate in most historical periods, as it seems to contribute a large fraction of the total contribution of all the shocks (ALL), (c.f. figure 3A). However, in some periods, real demand shocks fail to explain the full move in ALL. In particular, in the late 1980s, supply shocks explain most of the real appreciations of the exchange rate, whereas the depreciation in 1991 is explained jointly by real demand, supply and real oil price

shocks. Further, the depreciation from 1995 is mainly explained by monetary shocks and oil price shocks.

Focusing on the two most recent years in the sample, the real exchange rate in Venezuela has appreciated steadily, being almost 60 percent higher in March 1999 than in January 1997. This is clearly emphasized in figure 3A, where the total contribution of all the shocks has been to increase the RER from the middle of 1997. Positive demand shocks have worked to increase the real exchange rate during 1997 and the first half of 1998, but as real demand has declined from late 1998, the rate of appreciation has slowed down somewhat recently. Negative monetary shocks has also appreciated the real exchange rate steadily from the end of 1997 (cf. figure 3D). At the same time, negative supply shocks have worked to appreciate the real exchange rate from early 1998, (as real output and prices have fallen) (cf. figure 3B). On the other hand, the fall in oil prices from 1997 and onwards, on the other hand, has worked to depreciate the real exchange rate through 1998.

Figure 4. Real exchange rate and real demand and supply shocks (drift term added) (Logarithms)



Finally, in figure 4, the time path of the real exchange rate that is due to the joint permanent effect of the real demand shock and the supply shock, adding the drift term, is plotted together with the log of the actual real exchange rate.⁶ If one takes the contribution of the permanent shocks to the real exchange rate as a measure of the long run trend in the real exchange rate, then this is a measure of the long run equilibrium real exchange rate. Any deviation of the real exchange rate above the trend signifies an overvaluation, whereas a deviation below trend signifies an undervaluation.

Overall, then real exchange rate was overvalued throughout the first part of the 1990s, it followed the trend in the middle 1990s, was undervalued in 1996 and parts of 1997, before it again was overvalued by the end of the 1990s. The overvaluation of the real exchange rate in the late 1990s is the most severe, being on average 24 percent in 1998 and 25 percent in the first quarter in 1999.

⁶ Adding the long run effect of the real oil price shock does not really change the results, as the real oil price shock has a negligible effect in the long run.

4. Conclusions and summary

In this paper, I have focused on the relative ability of demand and supply shocks in explaining real exchange rate fluctuations in a large open, energy rich country like Venezuela. To do so I have specified a structural VAR model in manufacturing production, price, the real exchange rate and the real oil price that are identified through long run restrictions on the dynamic multipliers in the model. The way the model is specified, I identify four structural shocks; Nominal, real demand, aggregate supply and oil price shocks.

The results confirm the conventional view about the existence of significant shocks with impulse responses consistent with a standard open economy model of economic fluctuations. In particular, I have found a plausible sequence of shocks that help to explain the evolution of the variables in the model.

Following a nominal and a real demand shock, manufacturing production increases temporarily whereas prices increases permanently. However, whereas a nominal shock depreciates the real exchange rate before it overshoots back to equilibrium, the real demand shock has a long run appreciation effect on the real exchange rate. Supply shocks have a long run positive effect on manufacturing production, whereas oil price shocks reduces production and appreciates the real exchange rate in the long run, which indicate long run Dutch disease effects.

Comparing the VAR model to a simple unobserved components model, both models imply that the real exchange rate is overvalued by the late 1990s. The exchange rate overvaluation is 22 percent (UC) and 25 percent (VAR) in 1998.

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**APPENDIX A
MODEL SPECIFICATIONS**

Table A.1. Augmented Dickey-Fuller unit-root tests, 1986Q4-1999Q1^a

Series	ADF(lags) ^b	t _{ADF}	Series	ADF(lags) ^b	t _{ADF}
y	ADF(4)	-2.57	Δy	ADF(5)	-3.50*
p	ADF(2)	-2.17	Δp	ADF(2)	-3.49*
s	ADF(2)	-2.07	Δs	ADF(2)	-4.28**
op	ADF(3)	-2.88	Δop	ADF(2)	-4.98**

^a Critical values were taken from Fuller (1976). A constant and a time trend are included in the regression using levels, whereas only a constant is included in the regression using first differences.

^b The number of lags are determined by selecting the highest lag with a significant *t* value on the last lag, as suggested by Doornik and Hendry (1994).

* Rejection of the unit root hypothesis at the 5 percent level, ** Rejection of the unit root hypothesis at the 1 percent level

Table A.2. Misspecification tests, 1986Q2-1999Q1^a

Test	Statistic	Δy	Δp	Δs	Δop
AR 1-4 ^b	$F^2(4, 28)$	0.84 (0.51)	1.02 (0.41)	0.83 (0.52)	0.91 (0.47)
ARCH 4 ^c	$F^2(4, 24)$	0.62 (0.65)	0.50 (0.73)	0.10 (0.98)	0.93 (0.46)
Normality ^d	$X^2(2)$	3.30 (0.19)	2.40 (0.30)	7.52 (0.02)	1.86 (0.39)

^a The number in brackets are the p-values of the test statistics. All statistics have been calculated using PcFiml 9.0 (see Doornik and Hendry 1997).

^b LM test for residual autocorrelation of order 5

^c LM test for 4th order ARCH in the residuals

^d Test of normality, see Doornik and Hendry (1997) for references and descriptions.

Table A.3. Johansen cointegration tests; Cointegrating vector (y_t, p_t, s_t, op_t), 1986Q2-1999Q1^a

H ₀	H ₁	Critical value 5 %	Critical value 5 %	df-adj ^b		df-adj ^b	
		λ_{max}	λ_{trace}	λ_{max}	λ_{max}	λ_{trace}	λ_{trace}
r=0	r≥1	27.07	47.21	15.05	9.26	37.70	23.20
r≤1	r≥2	20.97	29.68	13.58	8.36	22.65	13.94
r≤2	r≥3	14.07	15.41	8.56	5.27	9.07	5.58
r≤3	r≥4	3.76	3.76	0.51	0.32	0.51	0.32

^a All test-statistics are calculated using PcFiml 9.0 (see Doornik and Hendry 1997). Critical values are taken from Table 1 in Osterwald-Lenum (1992), corresponding to the case where the constant is unrestricted.

^b df-adj refers to the eigenvalue adjusted for degrees of freedom (see Reimers 1992).

APPENDIX B
AN ECONOMIC MODEL OF OUTPUT FLUCTUATIONS

Below I propose a simple economic model where energy price shocks may affect the economy through several channels. The model is a variant of a simple (Keynesian) model of output fluctuations presented in Blanchard and Quah (1989) that builds on Fischer (1977). The model consists of an aggregate demand function, a production function, a price setting behaviour, a wage setting behaviour and a real exchange rate equation.

$$y_t = m_t - p_t + d_t + \alpha\theta_t + \beta(e + p^* - p)_t + \phi o_t \quad (\text{B.1})$$

$$y_t = n_t + \theta_t + \rho o_t \quad (\text{B.2})$$

$$p_t = w_t - \theta_t + \psi o_t \quad (\text{B.3})$$

$$w_t = w \left[E_{t-1} n_t = \bar{n} \right] \quad (\text{B.4})$$

$$(e + p^* - p)_t = \Delta m_t + \pi d_t + \delta \theta_t + \kappa o_t \quad (\text{B.5})$$

where y_t is the log of real output, θ_t is the log of productivity, p_t is the log of the nominal price level, w_t is the log of the nominal wage, m_t is the log of nominal money supply, e_t is the log of the nominal exchange rate, p_t^* is the log of the foreign price level, d_t reflects real demand in the goods market, o_t is the log of real oil price, n_t is the log of employment and \bar{n} implies the log of full employment. α , β , ϕ , ρ , ψ , π , δ and κ are coefficients. Δ is the difference operator, (1-L). The rate of unemployment is defined as $u_t = \bar{n} - n_t$.

Equation (B.1) states that aggregate demand is a function of real balances, demand in the goods market, productivity, the real exchange rate and the real oil price. Both productivity, the real exchange rate and real oil prices are allowed to affect aggregate demand directly. I expect $\alpha > 0$, as a higher level of productivity may imply higher investment demand. The sign on β reflects the joint effect of the real exchange rate on the total economy. Typically, one would expect $\beta > 0$, as a depreciation (increase) of the real exchange rate induces a balance of trade improvement, via an expenditure switching. $\phi > 0$ is plausible in an economy with a large energy producing sector, as higher real oil prices may increase demand from energy producers (like the government).

The production function (B.2) relates output to employment, technology and real oil prices through an increasing return Cobb-Douglas production function. The real oil price is used instead of an energy quantity, as a third factor of production, as competitive producers treat the real oil price as parametric (see also Bjørnland 2000). Hence, we would expect ($\rho < 0$).

The price setting behaviour (B.3) gives the nominal price as a mark up on wages adjusted for productivity and the real oil price, ($\psi > 0$). As in Blanchard and Quah (1989), wages are chosen one period in advance to achieve full employment in (B.4).

Equation (B.5) suggests a function for the real exchange rate that encompasses *both* the short term volatility and the long run deviations from purchasing power parity. In (B.5), the real exchange rate is a function of changes in money supply, real demand innovations and some fundamentals, represented here by productivity and the real oil price. As will be seen below, PPP is preserved in the long run with respect to monetary changes, so that, leaving all other shocks aside, a monetary shock will increase the price and depreciate the exchange rate proportionally. This would leave the real exchange rate unchanged in the long run, as predicted by the Dornbusch overshooting model and the Mundell-Fleming model with flexible prices. The same models also predict that a real demand expansion appreciates the real exchange rate (via an increase in the interest rate, a capital inflow and a balance of payment surplus), hence I expect $\pi > 0$.

Productivity and real oil prices are proxies for the fundamentals in the economy, as they will determine the path of real output in the long run. A supply shock (that increases capacity and real output permanently) will most likely depreciate the real exchange rate, which is consistent with a flexible price exchange rate model, where the price level falls monotonically ($\delta < 0$). For a large oil producing country like Venezuela, the discovery of natural resources may have the same effects on the exchange rate as the introduction of a new technology, that changes relative prices and appreciates the real exchange rate in the long run. This may squeeze the tradable sector, a phenomenon that has been termed the “Dutch Disease” in the economic literature, (see e.g. Corden and Neary 1982).¹ Hence, if Venezuela is a petrocurrency, the real exchange rate is expected to appreciate when the oil price is high and depreciates when the oil price is low ($\kappa > 0$).

To sum up then, I expect, $\alpha, \beta, \phi, \psi, \pi, \kappa > 0$, , whereas $\rho, \delta < 0$. The model is closed by assuming m, θ, o and d evolve as random walks, driven by four serially uncorrelated orthogonal nominal (i.e. monetary) shocks (ϵ^{MON}), aggregate supply (or productivity) shocks (ϵ^{AS}), real oil price shocks (ϵ^{OP}) and real demand shocks (ϵ^{RD}):

$$m_t = m_{t-1} + \epsilon_t^{MON} \quad (B.6)$$

$$\theta_t = \theta_{t-1} + \epsilon_t^{AS} \quad (B.7)$$

$$o_t = o_{t-1} + \epsilon_t^{OP} \quad (B.8)$$

$$d_t = d_{t-1} + \epsilon_t^{RD} \quad (B.9)$$

Solving for $\Delta y, \Delta p, \Delta(w-p)$ and $\Delta(e+p^*-p)$ yields:

$$\Delta y_t = (1 + \beta)\Delta\epsilon_t^{VEL} + (1 + \beta\pi)\Delta\epsilon_t^{FI} + \epsilon_t^{PR} + (\alpha + \beta\delta)\Delta\epsilon_t^{PR} + \rho\epsilon_{t-1}^{OP} + (\phi + \beta\kappa - \psi)\Delta\epsilon_t^{OP} \quad (B.10)$$

$$\Delta p_t = \epsilon_{t-1}^{VEL} + (1 + \beta\pi)\epsilon_{t-1}^{FI} - \epsilon_t^{PR} + (\alpha + \beta\delta)\epsilon_{t-1}^{PR} + (\phi + \beta\kappa - \rho)\epsilon_{t-1}^{OP} + \psi\Delta\epsilon_t^{OP} \quad (B.11)$$

$$\Delta(w - p)_t = \epsilon_t^{PR} - \psi\epsilon_t^{OP} \quad (B.12)$$

$$\Delta(e + p^* - p)_t = \Delta\epsilon_t^{VEL} + \pi\epsilon_t^{FI} + \delta\epsilon_t^{PR} + \kappa\epsilon_t^{OP} \quad (B.13)$$

Equation (B.10) states that only productivity and labour supply shocks will affect the level of output, y_t , in the long run, as y_t will be given as accumulations of these two shocks. However, in the short run, due to nominal and real rigidities, all four disturbances can influence output. Neither of the shocks will have a long run effect on unemployment (B.11). Only productivity shocks will affect the real wage in the long run (B.12), whereas all shocks but the nominal shock can have a long run effect on the real exchange rate (B.13).

The model can be specified and identified empirically. As the model above is rather static, I will allow for more dynamics by introducing lags. Further, I let equations (B.6-B.9) evolve as random walks with drift, i.e., I allow for a constant in all the equations in the VAR. Note also that I will allow for some more flexibility in equation (B.12), by letting the real wage potentially be determined by all four shocks in the short run. However, consistent with the model predictions above, in the long run, only productivity shocks can affect the real wage.

ⁱ A related explanation for why supply side factors like productivity may appreciate the real exchange rate in the long run, is due to Balassa (1964) and Samuelson (1964). The Balassa-Samuelson hypothesis states that the real exchange rate may appreciate if there are exceptionally large difference between productivity growth in the traded and the nontraded sector. A rise in productivity in the traded goods sector will lead to a wage effect only (as prices are tied down by the world price level). With no corresponding increase in productivity in the nontraded sector, prices in the nontraded sector must rise (to match the higher wage level), appreciating the real exchange rate.