Macroeconomic Risk Evaluation of International Reserves in Venezuela[1]

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Abstract. Based in an operational definition of risk, this paper presents a methodology that will allow decision makers to synthesize and analyze information about international reserves, in an environment with high uncertainty. In particular, we suggest the construction of three dynamic indicators to summarize available information more efficiently: the forecasted path of international reserves, the likelihood of a currency crisis, and an indicator of optimality of reserves. Probability distributions of these variables over which risk is measured, are obtained by simulations of stochastic shocks in a Venezuelan external sector model. The model describes the path of the nominal exchange rate using the definition of the exchange market pressure, and the behavior of the main components of the balance of payments, i.e. net exports and private capital movements. It also includes some features to capture the dynamics of the economy under exchange rate controls. The estimation of the model helps to evaluate and interpret the nature of the risks faced by policy makers.

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Introduction

In the World Bank Conference "Liquid Reserves and Debt" in 1999, Alan Greenspan pointed out that it would be desirable if policy makers incorporated in their analysis of international reserves the risks associated to the occurrence of stochastic shocks, as it is usually done in the evaluation of other financial assets. The rationale for this assessment is that when the occurrence of shocks is neglected, biases in the decision making process may arise, and wrong decisions can be costly for the economy.

Recently, the concepts of "value at risk" and "managing risk" have been popularized, but few applications have been developed to macroeconomic variables. Among them, Killian and Manganelli (2003) propose a tool for "risk management" that measures risk on inflation forecasts as the expected deviations of inflation respect to its target. This risk measure is then used to interpret historic Federal Reserve's decisions, considering the same set of information available to the authorities at each point in time.

Following a similar reasoning, this paper tries to generate a methodology to evaluate the performance of international reserves, based on the idea reserves are related to other macro variables trough a joint probability distribution, over which we can measure risks. For example, when external shocks hit the economy for consecutive periods of time, balance of payments flows are perturbed, generating stochastic paths for the stock of international reserves and changing probability distributions through time. If policy makers reveal to prefer a certain range of international reserves or of other related macro variables, risk can simply be measured as the probability of not achieving these preferred set of values. In this way, for any probability distribution defined, we can attach an operational risk measure, and evaluate its evolution through time.

To study risks on international reserves, we focus on the construction of three indicators: the forecasted path of international reserves, the likelihood of a currency crisis, and an indicator of optimality of reserves.

To obtain consistent probability distributions of these indicators, we construct a model of the economy that summarizes the time-dependence relationships among variables.

We model the external sector of the Venezuelan economy, which is basically described by the path of the nominal exchange rate and the main components of the balance of payment: oil exports, imports and private capital movements.

Since the Venezuelan economy has experienced several kinds of exchange rate regimes in the last twenty years, directly modeling the nominal exchange rate is not a simple task. We overcome this difficulty recurring to the definition of "exchange market pressure". This concept, although not new in the literature[4], it has been used recently to predict currency crises through logit or probit models. García and Soto (2004), Edwards (2004), Berg and Pattillo (1999) and Sachs, Tornell and Velasco (1996) are examples of empirical models on external crises. In this paper we model the determinants of the exchange market pressure with two purposes: to explain the behavior of the nominal exchange rate independently of the exchange rate regime and to compute the probability of an external crisis.

Among the empirical determinants of the exchange market pressure, one of importance is the level of international reserves, since it accounts as a broad measure of external vulnerability. Models like Sachs, Tornell and Velasco (1996) and Sims (2001) provide theoretical background to explain the negative relationship between international reserves and external crises. In Sachs, Tornell and Velasco (1996) agents observe the level of international reserves to determine whether capital outflows of the economy can occur without causing a balance of payment crisis. The morale from this model is that when a country faces weak fundamentals, the probability of occurrence of a crisis due to self fulfilling prophecies is higher if reserves are low. In the same line of reasoning, Sims (2001) in a stylized model of a small economy, shows that explosives paths of prices (i.e., the exchange rate) can be ruled out if the Central Bank commits to maintain enough reserves to back up the quantity of money in the economy.

In the estimated model for the Venezuelan economy, we do find that the exchange market pressure is partially explained by the level of international reserves. The fact that reserves relate inversely to the exchange market pressure, and this one proportionally to the probability of a crisis, implies that reductions in reserves increases the likelihood of

[4] Among the first references to the concept of exchange market pressure are Girton y Roper (1977), and Weymark (1995).

a crisis and might translate either in further losses of reserves or depreciations of the domestic currency. This makes reserves crucial, not only for its level, but also for its implications on economic stability.

The main components of the balance of payments, specially imports and private capital movements, are estimated using standards arguments proposed in the literature[5]. Given the expected behavior of balance of payment flows and a Central Bank policy rule, future levels of reserves are determined.

The complete model allows computing forecasts for international reserves and the probability of a crisis. Simulating stochastic shocks in the exogenous variables of the model, we can retrieve probability distributions on these variables. Establishing policy makers' preferences on them, defines risk as the chances of missing the desired accumulation of reserves and as the chances of facing extremely high possibilities for an external collapse.

To assess the degree of optimality of forecasted international reserves requires imposing a definition of "optimal reserves". Empirically, there are several grounds for which countries rationalize the accumulation of foreign reserves[6]. Theoretically, reserves are mostly treated as an inventory and optimal reserves must minimize the costs associated[7]. In this paper we follow a variation developed by García and Soto (2004) in which optimal reserves minimize the expected costs, and the probability of a crisis depends on the behavior of several macroeconomic variables, among them, the ratio of foreign debt to reserves. Additionally, we compare optimal reserves to forecasted reserves in order to asses to what extent optimality is achieved. Risk arises when, according to the preferences of policy makers, "suboptimality" exceeds established thresholds.

The suggested measure of risk computed on these indicators have the attribute of conveying all the relevant information from different sources of uncertainty and, of changing through time according to the state of the economy. These characteristics

[5] For a survey on capital flow determinants see Rigobón (2004).
[6] A detailed explanation of different rules used by countries to explain reserve accumulations is given in Beaufort y Kapteyn (2001).
[7] See for example, Frenkel y Jovanovic (1981).

endow policy makers with sufficient information, not only to have a proper assessment of the nature of risks faced, but also to compare different policy regimes on the basis of the risks implied. These comparisons can be done since risk arises from the context of a macroeconomic model that describes the response of the economy to diverse types and magnitudes of shocks.

This document is structured in the following way: first, we present a stylized version of the external sector of the Venezuelan economy and extract some lessons from the dynamics of the model. Then, we present the estimation of the main relationships of the model. Third, we present the operational definition of risk, and explain how to construct the indicators over which this measure is computed. Finally, we apply the methodology described to analyze the accumulation of reserves in year 2005, and then draw the main conclusions.

Stylized Model of the External Sector

In this section, we present a basic theoretical model that summarizes the main characteristics of the external sector, using the concept of exchange market pressure. This model is a system of differential equations with rational expectations from which we qualitatively derive the dynamic paths for the nominal exchange rate and international reserves. From this section we expect to build some intuition for the dynamic properties of the model and on how a balance of payment crisis might occur.

To model the nominal exchange rate, we use the concept of exchange market pressure, which is a measure that increases its value when an excess of demand of foreign currency (US dollar) occurs. Since this excess of demand of dollars is reflected either in a depreciation of the domestic currency or in an increase of the amount of dollars sold by the Central Bank to the market, then the exchange market pressure (*EMP*) can be measured as: $EMP \equiv g\left(\frac{\dot{E}}{E}, \frac{V}{R}\right)$, where E is defined as the nominal exchange rate (domestic currency per dollar) and *V/R* is the ratio of net Central Bank sales of dollars to international reserves. Measuring the exchange market activity in this way allows comparing moments with identical exchange market pressure independently of the existing exchange rate regime.

All those factors that potentially cause a higher demand of the foreign currency can be interpreted as determinants of the exchange market pressure. In particular, we are interested in stressing that the level of reserves has a negative relationship with the exchange market pressure. Intuitively this accounts for the fact that when the Central Bank has a big enough stock of reserves, it is more capable of facing speculative attacks to the domestic currency. This intuition translates in the first equation of the model:

$$EMP = f_0(R; G_0) \quad (1)$$

where G_0 represents all fundamental variables that are exogenous to the model and $f_{0R} < 0$ is the partial derivative of the function with respect to the level of reserves.

Using the definition of the exchange rate pressure, we can obtain the movement equation for the nominal exchange rate:

$$\dot{E} = f_1(EMP, E, V, R) \quad (2)$$

where $f_{1EMP} > 0, \quad f_{1E} > 0, \quad f_{1V} < 0, \quad f_{1R} > 0$. Note that in this case, for a given value of the exchange market pressure , a lower ratio of Central Bank net sales to reserves causes a higher depreciation of the domestic currency.

To complete the external sector model, it is necessary to describe the behavior of the main components of the balance of payments. The imports of goods and services (*M*) can be modeled as:

$$M = f_2(E; G_2) \quad (3)$$

Since imports depend on the real income and real exchange rate, G_2 contains the levels of domestic and foreign prices, and real income, which are determined outside the model. It is the case that $f_{2E} < 0$.

Private capital inflows (*K*) are assumed to be inversely related to the expected depreciation of the domestic currency, since the anticipation of a loss in domestic assets causes a reallocation of the agents' portfolios to foreign currency. This capital flows are as well explained by other exogenous variables such as the domestic foreign interest rate and the sovereign risk, all of which are considered in G_3.

$$K = f_3\left(\dot{E}^e; G_3\right) \quad (4)$$

In order to characterized the path of international reserves, we incorporate to the model a Central Bank policy rule that indicates how much of the demand of foreign currency will be supplied to the market[8]. This demand of foreign currency is basically given by the imports of goods and services and the demand of capital outflows, which can be simply expressed as:

$$V = \phi_1 M - \phi_2 K \quad (5)$$

where $\phi_1, \phi_2 \geq 0$ are the policy parameters chosen by the Central Bank according to the existing exchange rate regime. For example ϕ_1<1 implies that the Central Bank is partially financing imports, and ϕ_2<1 might reflect the fact that during exchange rate controls, the Central Bank mainly sells dollars for imports of goods and services and not for capital transactions.

Finally, the change in international reserves is described by:

$$\dot{R} = G_4 - V \quad (6)$$

where G_4 includes all net inflows of foreign currency to the economy not directly modeled. In the case of the Venezuelan economy this inflows are mainly represented by oil exports.

Solving the model starts by substituting equations (1), (3) and (4) in the movement equation of the nominal exchange rate (2), an substituting (3) and (4) in the policy rule:

$$\dot{E} = f_1\{f_0(R, E; G_0), E, V, R\} \quad (7)$$

$$V = \phi_1 f_2(E; G_2) - \phi_2 f_3(\dot{E}^e; G_3) \quad (8)$$

$$\dot{R} = G_4 - V \quad (6)$$

Assuming perfect foresight, that is $\dot{E}^e = \dot{E}$, and imposing linearity of f_3(.) with respect to $\dot{E}$ and f_1(.) with respect to V, we can re-write (7) and (8) as the following reduced form:

$$\dot{E} = f_5(E, R; G_0, G_2, G_3) \quad (9)$$

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[8] It is important to notice that according to the institutional arrangement in Venezuela, the state oil company has to sell all its foreign currency from the oil business to the Central Bank. As a consequence, the Central Bank participates in the exchange rate market in a daily basis, supplying at least half of the foreign currency traded between private agents.

where: $f_{5E} = \overset{+}{f_{1E}} + \overset{-}{f_{1V}}\ \phi_1\ \overset{-}{f_{2E}} > 0$; $\quad f_{5R} = \overset{+}{f_{1EMP}}\ \overset{-}{f_{0R}} + \overset{+}{f_{1R}} \neq 0$.

Substituting (8) in the movement equation of reserves, and using the reduced form of the exchange rate depreciation (9), we can re-write (6) as:

$$\dot{R} = f_6(E, R; G_0, G_2, G_3, G_4) \tag{10}$$

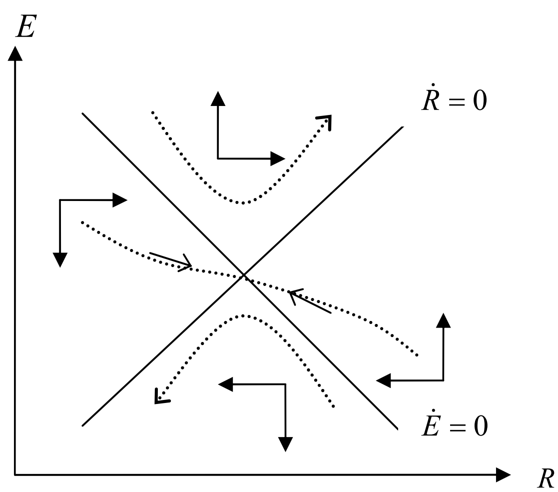
where: $f_{6E} = -\phi_1\ \overset{-}{f_{2E}} + \phi_2\ \overset{-}{f_{3\dot{E}}}\ \overset{+}{f_{5E}} \neq 0$; $\quad f_{6R} = \phi_2\ \overset{-}{f_{3\dot{E}}}\ f_{5R} \neq 0$.

Equations (9) and (10) form the reduced system of differential equations that characterizes paths of the nominal exchange rate and reserves.

The dynamic evaluation of the system is done by analyzing all possible combinations of the derivatives f_{5R} , f_{6E} , f_{6R} . Of all possible configurations that describe the steady state of the system, the saddle path is obtained when $f_{5E} > 0$, $f_{5R} > 0$, $f_{6E} > 0$, $f_{6R} < 0$. For all the other combinations of the derivatives, unstable equilibriums arise, which implies that the final state of the economy will depend on agents expectations.

The phase diagram of the system for the saddle path can be depicted in figure 1 as:

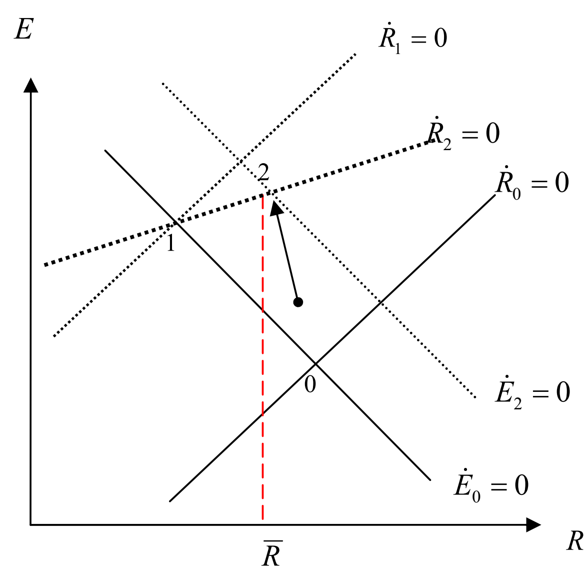
Figure 1. Phase Diagram



where: $\frac{\partial E}{\partial R}\Big|_{\dot{E}=0} = -\frac{f_{5R}}{f_{5E}}$; $\frac{\partial E}{\partial R}\Big|_{\dot{R}=0} = -\frac{f_{6R}}{f_{6E}}$.

To illustrate the dynamics of the system, let us suppose that a negative oil shock occurs. The shock shifts $\dot{R} = 0$ to the left, and the new steady state is represented by a higher exchange rate and lower reserves. If the oil shock is sufficiently big such that the new equilibrium of international reserves is under a critical level ($\overline{R}$) set by the Central Bank, then agents anticipate the abandon of the exchange rate regime, which is basically represented by a shift to the right of the curve $\dot{E}_0 = 0$, and a change in the parameters of the policy rule, i.e. the reduction of $\phi_2 = 0$. The final steady state is described by $(\overline{R}, E_2)$. These dynamics of the nominal exchange rate and reserves, described in terms of the exchange market pressure imply a sustained high pressure since the oil shock occurs until the exchange rate regime is abandoned [9].

Figure 2. A Balance of Payment Crisis



[9] The way balance of payment crises occur under this equilibrium reproduces the logic of Krugman (1979), and in general, that of first generation models.

Model Estimation

All equations are estimated using quarterly data for the period 1988:4 – 2004:2. Since this time period contains episodes of exchange rate control[10], the differentiation between the dual (or parallel) and the official exchange rate market is addressed whenever is relevant for estimation purposes. In general, the working strategy consisted in the estimation of linear equations using Generalized Instrumental Variables (GIV) or Generalized Method of Moments (GMM) since endogeneity of variables was taken into account. Prior to the estimation of the models, Augmented Dickey-Fuller tests were performed on the data (table 7 of appendix 1).

i) Exchange Market Pressure.

One of the most important parts of the external model is the description of the determinants of the nominal exchange rate. As mentioned earlier, this description is undertaken indirectly through the estimation of an equation for the exchange market pressure. The empirical definition of exchange market pressure is:

$$EMP_t = \frac{1}{\sigma_{dlep}} DL[EP_t] + \frac{1}{\sigma_{vr}} L[V_t - R_{t-1}] \qquad (11)$$

where σ_{dlep} is the standard deviation of the log-variation of the nominal exchange rate (*EP*) and σ_{vr} is the standard deviation of the logarithm of the ratio of Central Bank net sales to reserves, $L\left(\frac{V}{R}\right)$. During periods of exchange rate control, *EP* refers to nominal exchange rate in the parallel or dual market. For the sample: $\sigma_{dlep} = 0{,}12$ y $\sigma_{vr} = 1{,}42$.

The literature mostly uses the relative variations of international reserves as the indicator that captures quantities adjustments in the exchange rate market. This is generally correct when Central Banks modify their stock of reserves by buying or selling foreign currency to the market through a process of bargaining. For the Venezuelan case, this is not always true since the Central Bank can increase its stock of reserves by receiving dollars from the oil state company. These transactions are mandatory by law and do not involve any bargaining of the price of the currency.

[10] Periods of exchange rate control: 1994-1996 and 2003-2004.

Therefore, the variable used in our definition is the Central Bank net sales of dollars, which refer strictly to transactions where the price of the currency arises from a process of bargaining between private agents and the Central Bank.

The theoretical grounds for the estimation of the exchange market pressure are found in the literature of currency crises[11]. Reserves are introduced as an explanatory variable in relation to the stock of outstanding public foreign debt. Other variables that try to capture the state of fundamentals are also included, such as the misalignment of the real exchange rate and the amount of money supply generated by the government, the oil state company and the Central Bank (public sector). Additionally, the misalignment of terms of trade respect to its long term trend is used as a proxy for oil windfalls (or shortfalls)[12]. Estimations are summarized in table 1.

Table 1. Exchange Market Pressure Estimation

Dependent Variable: EMP
Method: GLS
II Q 1989 - II Q 2004

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1,850	0,164	-11,307	0,000
EMP(-1)	-0,419	0,028	-14,906	0,000
MLER(-1)	-1,417	0,415	-3,411	0,001
MPS_GDP(-1)	6,623	1,061	6,240	0,000
D[R_FD(-1)]	-12,172	1,518	-8,019	0,000
DUM_DEP*MLTT	0,931	0,411	2,269	0,027
DUM_C94	4,184	0,153	27,337	0,000
Weighted Statistics				
R-squared	0,994	Mean dependent var		0,972
Adjusted R-squared	0,993	S.D. dependent var		16,253
Unweighted Statistics				
R-squared	0,581	Mean dependent var		-0,640
Adjusted R-squared	0,534	S.D. dependent var		1,347

Weighting: EMP(-1)*MLER(-1)

Variables: EMP: exchange market pressure; MLER: misalignment of real exchange rate; MPS_GDP: ratio of public sector money supply to GDP; R_FD: ratio of international reserves to foreign debt; MLTT: misalignment of terms of trade; DUM_DEP: dummy that takes value 1 when MLER>0; DUM_C94: dummy that takes value 1 for the beginning of the 1994 exchange rate control; D[.]: refers to the first difference operator.

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[11] References to this topic are Sachs, Tornell y Velasco (1996), Sims (2001), García y Soto (2004) y Edwards (2004).

[12] Terms of trade are defined as the relative price of oil exports in terms of imports. The long term trend is estimated with a Hodrick-Prescott filter.

Coefficient signs are consistent with the predictions of the theory: an appreciation of the real exchange rate below its long term trend, a relative increase in money supply, and a reduction in the ratio of reserves to public foreign debt (net worth of the economy) will tend to increase the demand of foreign currency and therefore, the exchange market pressure. Additionally, when an oil windfall occurs with a depreciated real exchange rate, i.e. the relative price of oil exports is above its long term trend, the exchange market pressure rises reflecting that agents try to reallocate this transitory income in foreign currency.

Since the determinants of the exchange market pressure are relevant for the behavior of the nominal exchange rate, we can conclude that any factor that will drive the demand of foreign currency upwards without an increase in the Central Bank supply (sales), will cause a depreciation of the domestic currency.

ii) Imports.

In its simplest form, imports are expressed as a function of the real exchange rate and real income. A new explanatory variable is added to the analysis: the relative gap between the parallel and the official nominal exchange rate during exchange rate controls. This variable intends to capture the fact that during controls there is an incentive to import more due to the subsidy the government provides when assigning foreign currency at the official price, which is always lower than the one quoted in the parallel or dual market. Estimations results are summarized in table 2.

Estimated coefficients show that the demand for import is inelastic to its price but very elastic to income, indicating that the response of imports to the economic cycle is significant. Also, an increase of the nominal exchange rate gap during controls in 1% will increase imports in 0,2%, showing that imports do respond to the subsidy created by the exchange rate control.

Table 2. Imports Estimation

Dependent Variable:DL[M] Method:GMM II Q 1989 - II Q 2004				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-0,016	0,015	-1,049	0,299
DL[GDPR]	2,019	1,076	1,876	0,066
DL[ER(-1)]	-0,559	0,173	-3,225	0,002
GPE(-1)	0,208	0,119	1,747	0,086
DUM_POL	-0,147	0,061	-2,403	0,020
R-squared	0,520	Mean dependent var		0,004
Adjusted R-squared	0,486	S.D. dependent var		0,195

Intruments: C DL[GDPR(-1)] DL[ER(-1)] GPE(-1) DUM_POL

Variables: GDPR: real GDP; ER: real exchange rate; GPE: relative gap between the parallel and the official nominal exchange rate; DUM_POL: dummy that takes value 1 for II and III Q 2002, due to political events; DL[.]: refers to the log difference operator.

iii) Private Capital Inflows.

Since this variable is not directly defined in the external sector statistics, it is constructed as the sum of the balance of the capital account and "errors and omissions", minus the foreign debt flows from the public sector. As portfolio decision theory would indicate, capital inflows are a function of the expected return of foreign assets, i.e. expected depreciation of the nominal exchange rate, the return of domestic assets and a the risk imputed to those returns[13]. Three additional variables are incorporated to the estimation: the public foreign debt to reserves ratio, as a measure of the degree of external vulnerability of the economy, the misalignment of terms of trade and the change in the gap between the parallel and the official exchange rate. As in the estimation of the exchange market pressure, the misalignment captures the impact of transitory aggregate income due to oil prices variations. The change in the exchange rate gap, when expressed as the difference between depreciations in the parallel and the official market, allows testing for the response of capital inflows to both markets.

[13] Sovereign risk is empirically approximated by the difference between the return of Venezuelan debt in foreign markets minus the return of U.S. T-bills.

According to the estimation results (table 3), an increase in sovereign risk, external vulnerability, and oil windfalls, cause capital outflows. It is also found that capital movements responds to the behavior of both the parallel and the official exchange rate, indicating that outflows are financed in both markets[14].

Table 3. Net Capital Private Inflows Estimation

Dependent variable: K (millions of U.S. dollars)
Method: GMM
I Q 1994 - II Q 2004

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.973,51	534,78	3,690	0,001
@TREND	-56,05	10,07	-5,565	0,000
D[RISK(-1)]	-676,06	161,23	-4,193	0,000
D[DI(-1)]	77,08	20,81	3,703	0,001
D[FD_R(-1)]	-638,10	263,49	-2,422	0,022
DL[E(1)]	-7.242,58	3.086,63	-2,346	0,026
D[GPE]	-3.826,89	1.632,46	-2,344	0,026
MLTT	-2.640,63	643,03	-4,107	0,000
R-squared	0,405	Mean dependent var		-762
Adjusted R-squared	0,262	S.D. dependent var		1.589

Instruments: C @TREND D[RISK(-1)] D[DI(-1)] D[FD_R(-1)] D[R] V DUM_CC DUM_POL D[GPE(-1)] MLTT

Variables: K: net private capital inflows; RISK: sovereign risk; DI: domestic interest rate; FD_R: ratio of foreign debt to international reserves; E: nominal official exchange rate; GPE: gap between the parallel and the official nominal exchange rate; MLTT: misalignment of terms of trade; V: Central Bank net sales of dollars; R: international reserves; DUM_CC: dummy that takes value 1 for starting and ending periods of exchange rate controls; DUM_POL:dummy that takes value 1 for political events in 2002; D[.]: refers to the first difference operator; DL[.]: refers to the log difference operator.

To complete the external sector model of the economy, it is necessary to estimate the behavior of other variables that are crucial such as growth, inflation and the stance of public policies measured through the estimation of government expenditures and money supply. These estimations are shown in table 8 of appendix 1, together with other equations required to complete the model (auxiliary regressions, in table 9 of appendix 1). It stands out from the different equation results that accumulation of international reserves does reduce the pass-through of nominal exchange rate depreciations to inflation, as it was pointed out by Mendoza (2004). In appendix 2 a graphic representation of the main relationships working in the model are drawn.

[14] It is interesting to note that the response of capital outflows to depreciations of the exchange rate is similar in both markets, i.e. around $ 3.500 millions for an exchange rate variation of 100%.

A Methodology for Measuring Risk

In this section, first we present our operational definition of risk. Then we show the construction of the indicators that summarize information about international reserves and measure risk over probability distributions of these indicators.

i) Operational Definition of Risk.

To provide an operational definition of risk, we need two elements: the probability distribution of variables over which preferences are established and the preferences of decision makers.

Most of the variables which policy makers analyze, decide upon or commit to, come from complex relationships with other variables, that is to say, they can be understood as the set of endogenous variables of a small scale macroeconomic model, as the one presented in the previous section. This idea allows us to introduce a more general representation of the model, and to retrieve probability distribution of these endogenous variables.

Define *Y* and *X* as the set of endogenous and exogenous variables respectively. Divide the endogenous variables according to their nature: variables that come from an economic definition (*YD*); variables to be estimated through a functional relationship (*YF*), and state variables that come from a first order differential equation or movement equation (*YS*). The preceding model can then be represented as a system of difference equations:

$$YD_t = \phi\left(YD_{t-1}, YF_t, YS_t, X_t\right) \quad (12)$$

$$YS_t = YS_{t-1} + A\, YD_t + B\, YF_t + C\, X_t \quad (13)$$

$$YF_t = D\, YF_{t-1} + \sum_{i=-1}^{1} E_i\, Y_{t-i} + \sum_{i=0}^{1} F_i\, X_{t-i} \quad (14)$$

where *A*, *B*, *C*, *D*, *E*, and *F* are matrices of coefficients, some of which are estimated (*D*, *E* and *F*) and $\phi(.)$ refers to a non-linear function.

The exogenous variables of the model are considered random. These variables are: the relative change in oil prices, oil export quantities, and public foreign debt, and the absolute change in country risk. We assume that each of them can be characterized by a Beta probability distribution with parameters α y β. We select the Beta distribution since it is continuous, it has a finite support and it can be shaped easily according to the maximum, minimum and mode expected. This versatility of the Beta distribution allows to incorporate both, objective and subjective information available, into the generating process of these exogenous variables. As a consequence, the retrieved probability distribution of endogenous variables, will be efficient since they also contain all information available on the shocks that are expected to hit the economy for the forecast horizon.

The realizations of each of the exogenous variables can be ordered in a matrix of dimension (*N*,*T*), being *N* the number of simulations or scenarios and *T* the forecast horizon:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1T} \\ \vdots & \vdots & \cdots & \vdots \\ x_{N1} & x_{N2} & \cdots & x_{NT} \end{bmatrix} \tag{15}$$

where $X \sim i.i.d.\ Beta\ (\alpha, \beta)$.

When incorporating the realizations of the exogenous random variables into the model, we similarly obtain a matrix of realizations for each of the endogenous variables[15], such that:

$$Y = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1T} \\ \vdots & \vdots & \cdots & \vdots \\ y_{N1} & y_{N2} & \cdots & y_{NT} \end{bmatrix} \tag{16}$$

where each column of the matrix describes the probability distribution for the variable in period *t*, which evolves through time according to the relations of the model. Notice that each column can also be understood as a marginal probability density function that is retrieved from the joint density function of all endogenous variables of the model.

[15] The solution of our system of difference equations was solved by the method Gauss-Siedel provided in E-views.

Therefore, for any endogenous variable y and any forecast period $t=1,\ldots,T$, we can describe a sequence of empirical probability distributions $\{F_1(y), F_2(y), \ldots, F_T(y)\}$. Moreover, we can also define any sequence of values of an endogenous variable $\{y_1^\lambda, y_2^\lambda, \ldots, y_T^\lambda\}$ such that $F_t(y_t^\lambda) \equiv \Pr(Y_t \le y_t^\lambda) = \lambda$ for $\lambda \in (0,1)$, or define a probability interval $(y_T^{\lambda_0}, y_T^{\lambda_1})$ such that $\Pr(y_T^{\lambda_0} \le Y_t \le y_T^{\lambda_1}) = \lambda_1 - \lambda_0$ for $\lambda_0 < \lambda_1$.

Policy makers and in particular Central Bankers, most of the times describe their policies as trying to achieve a certain range of these endogenous variables, i.e. inflation or growth. Sometimes commitments are not explicitly recognized, but monitoring of variables are made taking into account a reference interval. In these sense, we might generalize that decision makers indeed have preferences over these variables in such a way that they only care about the fact that variables end up in their target or reference zone. That is, we base all our work under the assumption that decision makers can always tell their preferences, dividing the support of the variable in question in two set of values: the preferred ones and the unwanted outcomes. Although this might sound as a very restrictive theoretical assumption, in practice, decision makers are willing to reveal their preferred values or outcomes most of the times. Another totally different discussion is to determine whether or not these values can be achieved or which instruments are the most suitable for this purpose.

The above assumption is formalized by saying that policy makers can reveal preferences on any endogenous variable Y, in such a way that for values $(\underline{y}, \overline{y})$ and (y_0, y_1), $y_0 \succ y_1$ if $y_1 \in (-\infty, \underline{y})$ *or* $y_1 \in (\overline{y}, \infty)$ and $y_0 \in (\underline{y}, \overline{y})$.

Finally, risk is defined as the probability of obtaining outcomes that are outside the range of preferred values:

$$Risk_t^F(Y) = F_t(\underline{y}) + 1 - F_t(\overline{y}) \qquad (17)$$

where $F_t(\underline{y})$ is usually referred as the downside risk and $1 - F_t(\overline{y})$ as the upside risk of the variable[16].

[16] Although no formal considerations will be further made, it is important to notice that this definition suggests that individuals could rank probability distributions according to their risk, and that the notion of second order stochastic dominance is compatible with this one.

ii) Forecasted International Reserves.

The most intuitive and simple measure of risk of international reserves is given by the changes that its forecast probability distribution suffers through time. If we choose λ, in a way that $\lambda = 0{,}05\,;\, 0{,}1\,;\,\ldots;\, 0.95$, we can obtain different sequences of international reserves $\{r_1^{\lambda}, r_2^{\lambda}, \ldots, r_T^{\lambda}\}$, and construct a "fan chart" that summarizes all the information contained in the probability distributions. In matrix form, the "fan chart" of international reserves can be written as:

$$FC_r = \begin{bmatrix} r_0 & r_1^{0,05} & r_2^{0,05} & \cdots & r_T^{0,05} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ r_0 & r_1^{0,95} & r_2^{0,95} & \cdots & r_T^{0,95} \end{bmatrix} \qquad (18)$$

From the same information we constructed the fan chart, we could also retrieve that $Risk_t^F(R) = F_t(\underline{r}) + 1 - F_t(\overline{r})$, for any forecast period and for preferred values belonging to the interval $(\underline{r}, \overline{r})$.

However, preferences on international reserves are usually indirect, i.e. they are based on the relationship that reserves have with other more crucial decision variables, such as inflation. If this is the case, then risk can be redefined as the probability that inflation exceeds its target zone, conditional on a variation or level of reserves. This procedure would only imply a "reshaping" of our definition of risk, which will reduce to:

$$Risk_t^F(PI) = \begin{cases} \Pr\left(PI_t \leq \underline{pi} / R_t \leq r^*\right) + \Pr\left(PI_t \geq \overline{pi} / R_t \leq r^*\right) \\ \Pr\left(PI_t \leq \underline{pi} / R_t \geq r^*\right) + \Pr\left(PI_t \geq \overline{pi} / R_t \geq r^*\right) \end{cases} \qquad (19)$$

where r^* is a cut-off value for the support of international reserves[17]. The advantage of this definition of risk is that highlights the intuition built in the model: when comparing the magnitude of conditional probabilities we can infer which values of reserves level or variation has associated a higher risk in terms of inflation[18].

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[17] Consider that the support of international reserves can be divided in as many mutually exclusive regions as desired for analytical purposes.

[18] Risk can be computed in terms of other variables, such as growth. The election of the variable will depend on policy makers preferences and on the structure of the model estimated.

iii) Probability of an External Crisis.

The probability of an external or currency crisis is defined on the basis of the behavior of the exchange market pressure. Theoretically, the probability of a crisis is a monotonic increasing function of the exchange market pressure since high levels of pressure can imply the depletion of international reserves, an extreme depreciation of the domestic currency, or a combination of both events.

Departing from the standard procedure described in the literature, we do not compute the probability of a crisis through the direct estimation of a logit or a probit model, but through the following process[19]. Using the historical information of the exchange market pressure (*EMP*), we define its empirical c.d.f. as $F(emp) \equiv \Pr(EMP \leq emp)$. Since $F(emp)$ is also a monotonic increasing function of the exchange market pressure, then it can be directly interpreted as the probability of an external crisis. Because the empirical c.d.f. of the exchange rate pressure is not sufficiently smooth, we calibrate a logit function to fit it. Operationally, the calibration consists in minimizing the vertical distances between the two distribution functions such that:

$$\min_{\gamma,\delta} \quad \sum_{ipe} \left[F_{\lg}(\gamma\ emp - \delta) - F(emp) \right]^2 \qquad (20)$$

where $F_{\lg}(\gamma\ emp - \delta) = \dfrac{e^{(\gamma\ emp - \delta)}}{1 + e^{(\gamma\ emp - \delta)}}$, is the c.d.f. of a logistic function and $F(emp)$ is the empirical c.d.f.. The quadratic minimization function in (20) results from the application of the measure of discrepancy proposed by Anderson and Darling, which belongs to family of Cramer-von Misses measures of discrepancy[20]. The estimated values of the parameters are γ= 2,94 y δ= -1,98.

It is important to mention that the rationale for this procedure is to avoid imposing ad hoc thresholds for the exchange market pressure in order to construct the binary variable

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[19] See García and Soto (2004) as an example of the standard procedure for the estimation of the probability of a crisis.

[20] The general quadratic measure of discrepancy is given by $\sum \left[F_{\lg}(x) - F(x) \right]^2 \psi(x) dF_{\lg}(x)$, where $\psi(x) = \left\{ F_{\lg}(x)\left[1 - F_{\lg}(x)\right]\right\}^{-1}$, according to Anderson and Darling. Since for the logistic function $f_{\lg}(x) = F_{\lg}(x)\left[1 - F_{\lg}(x)\right]$, this measure reduces to the one proposed in expression (18).

typically used to estimate logit and probit models of crises. However, it can be argued that when using all the historical exchange market pressure information, the interpretation of this probability might be slightly different than the one used in standard procedures. In particular we could theoretically define a crisis as the occurrence of an extreme event in the exchange rate market, that in practice is equivalent to or worse than the worse crisis experienced during the time period considered.

It follows from the above definitions that any forecasted path for the probability of a crisis (PC) is described by the sequence $\{pc_1, pc_2, \ldots, pc_T\}$ where $pc_t = F_{\lg}\left(\hat{\gamma}\ emp_t - \hat{\delta}\right)$. Similarly to the way information on reserves is organized, we can compute a "fan chart" for the probability of an external crisis:

$$FC_{pc} = \begin{bmatrix} pc_0 & pc_1^{0,05} & pc_2^{0,05} & \cdots & pc_T^{0,05} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ pc_0 & pc_1^{0,95} & pc_2^{0,95} & \cdots & pc_T^{0,95} \end{bmatrix} \tag{21}$$

Analogously, we can quantify risk as $Risk_t^F\left(PC\right) = 1 - F_t\left(\overline{pc}\right)$, considering that only an upper threshold value $\overline{pc}$ is established.. Also we can compute, conditional on a level or variation of reserves, the chances that the crisis probability will exceed this threshold:

$$Risk_t^F\left(PC\right) = \begin{cases} \Pr\left(PC_t \geq \overline{pc} / R_t \leq r^*\right) \\ \Pr\left(PC_t \geq \overline{pc} / R_t \geq r^*\right) \end{cases} \tag{22}$$

Since the external market pressure is negatively related to the level of international reserves (see table 1), high (low) levels of reserves will tend to have associated low (high) levels of external market pressure, and therefore a low (high) probability of an external crisis. In short, the correlation between reserves and crisis probability is negative, and the upside risk of the chance of a crisis is slim, when reserves are high enough.

iv) Optimality of International Reserves.

Another informative indicator associated to international reserves is their distance respect to a reference level for policy making purposes. Typically this reference level addresses to "optimal reserves", and the particular definition employed will depend on which is believed to be the most suitable loss/utility function for decision makers, given the structure of the economy.

We chose to compute optimal reserves following García and Soto (2004) since it combines a very stylized optimization problem with the estimation of a crisis probability in a macroeconomic context. According to their work, optimal reserves (R^*) are the result of the following minimization problem:

$$R_t^* = \arg\min_R \left[PC_t\ C + \left(1 - PC_t\right) \varphi_t\ R_t \right] \tag{23}$$

where *PC* is the probability of a crisis, *C* the expected cost of a crisis measured in millions of dollars, φ_t the opportunity cost of international reserves and *R* international reserves also expressed in millions of U.S. dollars.

For computational purposes, we estimate the expected cost of a crisis as the average gap between the real GDP (measured in dollars) and its log term trend, across different currency crises years in Venezuela[21], as in Ben Bassat and Gottlieb (1992). The estimated average value of a crisis ranges between $2.000 and $3.000 millions depending on the values of the exchange rate used. The opportunity cost of reserves is theoretically defined as the difference between the marginal return of capital and the return of reserves, as pointed out in Ben Bassat and Gottlieb (1992). Empirically, we proxy this cost as the difference between the return of the public foreign Venezuelan debt and the return of U.S. Treasury Bills.

Assuming that the expected cost of a crisis is invariable to the level of reserves, the first order condition to the above problem is:

$$R_t^* = \left(\frac{\partial PC_t}{\partial R} \right)^{-1} \left(1 - PC_t\right) + \frac{C}{\varphi_t} \tag{24}$$

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[21] These crises refer to the ones occurred in 1983, 1986 and 1994, which register the highest values for the exchange market pressure (*EMP*).

where $\frac{\partial PC}{\partial R}$ refers to the rate of change of the probability of a crisis when reserves are marginally increased. Acknowledging the fact that according to our model the probability of a crisis is increasing in the exchange market pressure (*EMP*), and this one is inversely related to international reserves, we can write:

$$\begin{aligned} \frac{\partial PC_t}{\partial R} &= F_{\lg}\left(\hat{\gamma}\ emp_t - \hat{\delta}\right)\left[1 - F_{\lg}\left(\hat{\gamma}\ emp_t - \hat{\delta}\right)\right]\frac{\partial EMP_t}{\partial R} < 0 \\ \frac{\partial EMP_t}{\partial R} &= g\left(\overset{-}{R}, \overset{+}{FD}\right) < 0 \end{aligned} \qquad (25)$$

where $\frac{\partial EMP}{\partial R}$ is the rate of change of the exchange market pressure with respect to reserves. The expression $g\left(\overset{-}{R}, \overset{+}{FD}\right)$ denotes that the stock of outstanding foreign debt (*FD*), and the stock of reserves (*R*) are arguments of the function that defines the rate of change of market pressure with respect to reserves (see *EMP* estimation in table 1). According to the estimated model, this derivative is negative and becomes smaller as an increase in international reserves, or a reduction in foreign debt, occurs. That is, a reduced ratio of foreign debt to reserves will drive a more significant reduction in the exchange market pressure per unit of additional reserves.

Once estimated a level of optimal international reserves, which is associated to a given crisis probability, forecasted level of international reserves and foreign debt, we can define a sequence $\{d_1, d_2, \ldots, d_T\}$ where $d_t = \frac{R_t - R_t{}^*}{R_t}$, which indicates the proportion of the forecasted reserves in excess (or defect) to the counterfactual optimal level. Since for each time period there exists a probability distribution of relative distances, we can as well construct a "fan chart" to synthesize this information:

$$FC_d = \begin{bmatrix} d_0 & d_1^{0,05} & d_2^{0,05} & \cdots & d_T^{0,05} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ d_0 & d_1^{0,95} & d_2^{0,95} & \cdots & d_T^{0,95} \end{bmatrix} \qquad (26)$$

Likewise, having preferences on the variable *D*, summarized in threshold values $\left(\underline{d}, \overline{d}\right)$, we can define risk as $Risk_t^F(D) = F_t(\underline{d}) + 1 - F_t\left(\overline{d}\right)$, or as:

$$Risk_t^F(D) = \begin{cases} \Pr\left(D_t \le \underline{d} / R_t \le r^*\right) + \Pr\left(D_t \ge \overline{d} / R_t \le r^*\right) \\ \Pr\left(D_t \le \underline{d} / R_t \ge r^*\right) + \Pr\left(D_t \ge \overline{d} / R_t \ge r^*\right) \end{cases} \qquad (27)$$

An Application of the Methodology

In this section we simulate the performance of the Venezuelan economy for the year 2005 subject to a stochastic external shocks. On the basis of this performance, we present the different indicators proposed for the evaluation of risk on reserves, and interpret the results. In particular, we run 1.000 simulations or scenarios from which we construct the different probability distributions.

The assumptions to calibrate the Beta probability distributions of shocks are summarized in the following table:

Table 4. Assumptions on Probability Distributions of External Shocks

	DL[FD]	D[RISK] (bp)	DL[OP]	DL[OQ]
MIN	-1,0%	-1500	-9,5%	-1,8%
MODA	2,0%	500	-1,5%	0,0%
MAX	3,0%	1500	5,7%	3,6%

FD: foreign debt; RISK: sovereign risk; OP: oil prices; OQ: quantities of oil exports; D[.]: first difference operator; DL[.]: log difference operator

These assumptions, although not necessarily adjusted to real expectations of policy makers, suggest that for the most likely scenarios, the foreign debt and the sovereign risk will tend to grow over time, while oil prices will tend to fall[22].

The policy rule is calibrated in such a way that the actual variation of international reserves in 2004 matches the prediction of the model. We additionally impose that the proportion of imports financed by the Central Bank be greater than the proportion of capital outflows. The calibrated parameters for the rule are 88% for imports, and 65% for capital outflows:

The results of the principal variables for the domestic and external sector of the economy are:

[22] The fact that probability distributions on variations are identical and independent across the forecasted horizon (four quarters), implies that the variables in levels, i.e. oil prices, oil quantities, sovereign risk and foreign debt, are all random walks.

Table 5. Forecasts for the Domestic Sector

	DL[GR]	MPS_GDP	GROWTH	PI
2.004	19,2	15,0	17,3	17,8
Lambda: λ	**2.005 λ-percentiles**			
0,05	14,9	15,8	2,0	16,4
0,25	16,9	17,0	2,3	17,4
0,50	18,3	18,0	2,5	18,1
0,75	19,7	18,8	2,7	18,8
0,95	21,6	19,8	3,0	19,8

GR: government real expenditures; MPS_GDP: ratio of money supply of the public sector to GDP; GROWTH: annual variations of real GDP; PI: average inflation; DL[.]: log difference operator

Table 6. Forecasts for the External Sector

	GPE	DL[ER]	ONX_R	FD_R
2.004	26,3	-2,6	17,5	110,9
Lambda: λ	**2.005 λ-percentiles**			
0,05	48,9	-5,9	8,2	97,0
0,25	51,8	-5,0	9,8	100,8
0,50	54,0	-4,3	10,9	103,7
0,75	55,6	-3,6	12,0	106,2
0,95	58,3	-2,6	13,5	110,9

GPE: gap between the parallel and the official nominal exchange rate; ER: real exchange rate; ONX_R: ratio of oil net exports to reserves; FD_R: ratio of foreign debt to reserves; DL[.]: log difference operator

These forecasts suggest that, when the economy is most likely hit by negative shocks in terms of oil prices, foreign debt and risk, the performance of the external sector tends to deteriorate, showing increasing gaps between the parallel and the official nominal exchange rate, greater appreciations of the real exchange rate and consequently a reduced balance of oil net exports. This is because the distortions already in place with the exchange rate control exacerbate, causing an increase in the demand for imports and capital outflows. However, the rate of accumulation of foreign debt is lower than that of reserves, causing with probability of 0,95, a reduction in the ratio of foreign debt to reserves with respect to 2004. The fact that this ratio decreases, tends to compensate for the negative shocks and relatively prevents distortions for growing excessively over time[23]. The graphic representations of the different "fan charts" proposed are shown in figures 3, 4 and 5.

[23] It is important to stress that, the rate of accumulation of international reserves depends heavily on the magnitude of the oil shocks, which are sized according to the combination of objective and subjective expectations.

Figure 3. Fan Chart of Forecasted International Reserves

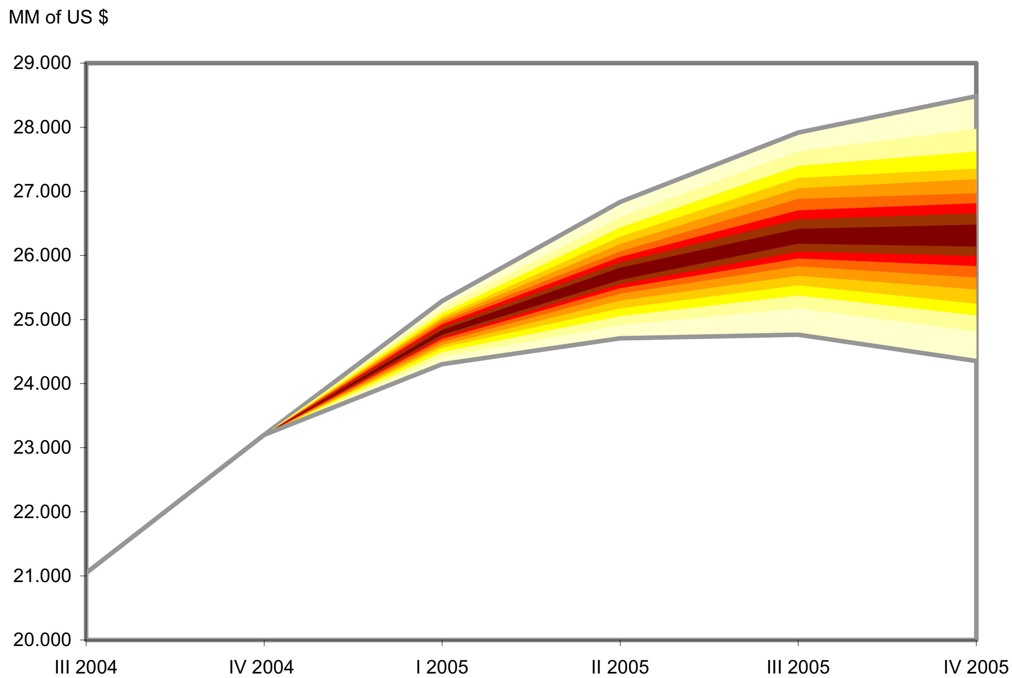


Figure 4. Fan Chart of Forecasted Probability of a Crisis

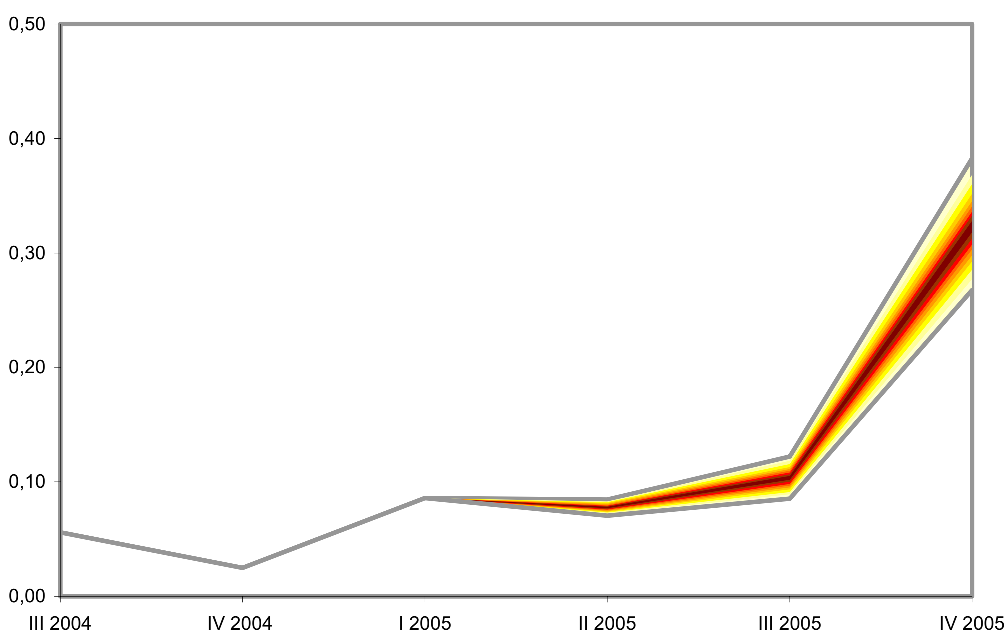
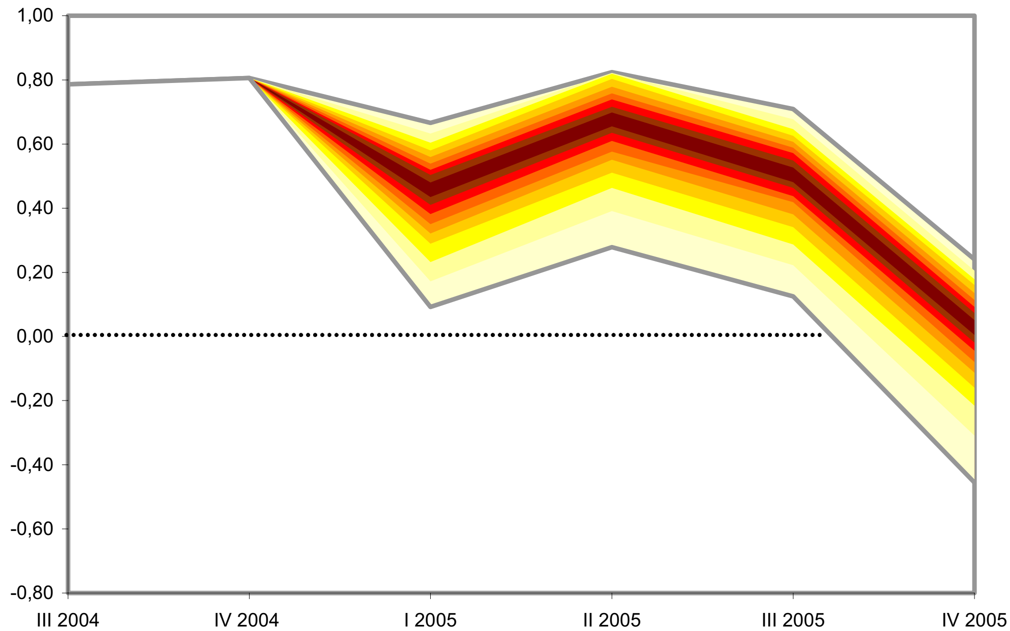


Figure 5. Fan Chart of Forecasted Indicator of Reserve Optimality



In the forecasted international reserves figure 3, the fan chart reveals that, although the existence of negative oil shocks, the probability of reducing the stock of reserves for year 2005 is practically zero. If we assume that central bankers dislike the excessive accumulation reserves because of the implicit opportunity costs (let us say that they prefer to accumulate less than \$ 3.000 millions in a year), then the probability of trespassing this threshold at the end of 2005 is of 0,55. However, the risk on reserves is not usually related to their levels, but to the economic conditions behind these levels. According to the model, high oil prices tend to bring about expansionary monetary and fiscal policies that increase income above its trend, causing as well inflationary pressures. If policy makers would like to achieve an inflation rate equal to or lower than the observed in 2004 (18%), then risk is quantified as the probability of the inflation being higher than this threshold, conditional to the possible scenarios of reserve accumulation. Simulations indicate that, the probability of exceeding the inflation threshold is 0,77, given an accumulation of reserves greater than \$ 3.000 millions, but it is 0,3, given a lower accumulation of reserves, i.e. $\Pr(PI \geq 0{,}18/\Delta R \geq 3.000) = 0{,}77$ and $\Pr(PI \geq 0{,}18/\Delta R \leq 3.000) = 0{,}30$. This implies that exists an upside risk for inflation (which translates in a higher probability of missing the inflation threshold), related to the greater accumulation of reserves.

In terms of an external crisis, estimations show that during 2005 this probability tends to increase throughout the year due to a higher exchange market pressure, most likely caused by the greater demand of imports and capital outflows. This increased pressure translates symmetrically in a bigger depreciation of the domestic currency and in higher sales of dollars by the Central Bank, both of which are undesirable in terms of macroeconomic stability. For the last quarter of 2005, the chances of having a crisis probability greater than 0,30, are equal to one, given an accumulation of reserves smaller than $ 3.000 millions, but these chances are 0,5, given a greater accumulation of reserves, i.e. $\Pr(PC \geq 0{,}30/\Delta R \leq 3.000) = 1$ and $\Pr(PC \geq 0{,}30/\Delta R \geq 3.000) = 0{,}5$. This implies that there is a upside risk for the crisis probability (which reflects greater chances of having an external crisis), related to a small or moderate accumulation of reserves.

A growing crisis probability also leads to a progressive increase of optimal reserves levels, which need to be compared to forecasted reserves in order to assess the degree of optimality of reserve holdings. For the first three quarters, with probability 1, the stock of reserves is excessive with respect to its optimal value. For the last quarter, a greater crisis probability indicates that, in approximately 50% of the scenarios, forecasted reserves will be below its optimal level. Moreover, in 20% of the scenarios, reserves should grow at least 15% respect to its forecasted value to achieve its optimum. For this indicator, risk can be measured as the probability of the indicator taking extreme positive or negative values, conditional on reserve accumulations. Simulations show that the probability of the indicator taking values greater than 10% is 0,23, conditional on the accumulation of a large amount of reserves, while the probability of taking values smaller than -10% is 0,11, given a moderate accumulation of reserves, i.e. $\Pr(D \geq 0{,}1/\Delta R \geq 3.000) = 0{,}23$ and $\Pr(D \leq -0{,}10/\Delta R \leq 3.000) = 0{,}11$.

This analysis shows that with some probability, a huge accumulation of reserves increases the risk of excessive inflation for demand pressures, but reduces the risk of an external crisis, while a moderate accumulation of reserves increases the risk of an external crisis but reduces the risk of inflationary pressures. All the above suggests that the ultimate decision to accumulate a given quantity of international reserves will depend on decision makers preferences of facing different types of risks.

However, it might also be the case that under different shock probability distributions or an alternative policy rule, tradeoffs in the economy turn out different. For example, if the ratio of public foreign debt to reserves is reduced enough due to more favorable oil shocks and less expansionary domestic policies, pressures on the exchange rate market might also be reduced, causing smaller depreciations of the nominal exchange rate in the parallel market. This combination of events will minimize simultaneously the upside risk of inflation and of crisis probability, under scenarios of important accumulation of reserves. That is, the upside demand risk related to the accumulation of reserves could disappear, but an upside optimality risk might turn out important because of the hoarding of excessive reserves.

This latest example illustrates that the nature of risks borne by decision makers are different because the structure of external shocks are also different. Therefore, the reserve management decisions will depend, to some extent, on the preferences that policy makers or society have over different types of risks, but will also be constrained by the structure of external shocks.

Conclusions

Policy makers generally do not consider in their analysis of international reserves the effects of stochastic shocks. Such misperception of uncertainty could introduce a bias in their decision making process, which can be costly for the economy. In this paper we show that, given an operational measure of risk and taking into account the effects of these shocks, we are able to evaluate the different types of risks related to the management of international reserves.

These risks are measured on the expected probability distributions of: reserves, external crisis probability, and degree of optimality of forecasted reserves. Since these probability distributions are generated from a dynamic model of the economy, they are not only time dependent, but also provide important insights regarding the effects of reserves on the economy. Also, since the probability distributions of shocks may incorporate both, objective and subjective information available, the resulting indicators can be considered efficient.

The resulting risks in any analysis will depend on several factors: the structure of the model of the economy, the preferences of policy makers, and the probability distributions of shocks. It follows from the simulations for the Venezuelan economy for 2005, that varying the accumulation of reserves causes a tradeoff between the upside risk of inflation and upside risk of the probability of an external crisis. Under a different probability distribution of shocks with more favorable oil prices, there could be instead a tradeoff between the upside risk of the crisis probability and the upside risk for optimality.

The interesting lesson from these examples is that reserve management decisions will depend, to some extent, on which type of risks policy makers or society desire to bear, but these decisions will also be constrained by the structure of external shocks that hit the economy.

Additionally, the specification of a policy rule for the participation of the Central Bank in the exchange rate market, allows comparing the implicit risks in different policy regimes. This exercise, although not shown in this paper, could provide additional insights to understand the consequences of decisions, specially in the context of exchange rate controls.

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Apendix 1.

Table 7. Unit Root Tests

Augmented Dickey-Fuller Test					
Variables	**Order of Integration**	**Constant**	**Trend**	**Statistic**	**α**
DI	I(0)	no	no	-8,803195	1%
EMP	I(0)	no	no	-8,254956	1%
K	I(0)	yes	yes	-6,434049	1%
MLER	I(0)	no	no	-3,581952	5%
MLGDPR	I(0)	no	no	-3,652999	5%
MLTT	I(0)	no	no	-5,055943	1%
MPS_GDP	I(0)	yes	yes	-6,478545	1%
PI	I(0)	yes	no	-4,030484	5%
V	I(0)	yes	no	-3,759030	5%
FD_R	I(1)	no	no	-8,021506*	1%
GPE	I(1)	no	no	-1,357856*	1%
L[E]	I(1)	no	no	-12,56619*	5%
L[EP]	I(1)	yes	no	-3,456089*	5%
L[ER]	I(1)	yes	no	-2,737040*	10%
L[GDPR]	I(1)	yes	no	-5,65555*	1%
L[GR]	I(1)	no	no	-4,19400*	5%
L[M]	I(1)	no	no	-6,675902*	1%
L[OP]	I(1)	yes	no	-7,088893*	1%
L[OQ]	I(1)	no	no	-9,215829*	1%
L[OX]	I(1)	no	no	-7,401254*	1%
L[WSP]	I(1)	no	no	-4,826312*	5%
RISK	I(1)	no	no	-6,696902*	1%

* These statistics correspond to variables in first differences

L[.]: refers to the natural logarithm operator
DI: domestic interest rate
EMP: exchange market pressure
K: net capital inflows
MLER: misalignment of the real exchange rate
MLGDPR: misalignment of the real GDP
MLTT: misalignment of terms of trade
MSP_GDP: ratio of public sector of money supply to GDP
PI: average domestic inflation
V: net sales of dollars of the Central Bank to the private sector
FD_R: ratio of foreign debt to reserves
GPE: gap between the parallel and the official exchange rate
E: official nominal exchange rate
EP: parallel nominal exchange rate
ER: real exchange rate
GDPR: real GDP
GR: real government expenditures
M: imports of goods and services
OP: oil prices
OQ: oil export quantities
OX: oil exports
WSP: domestic whole sale prices
RISK: sovereign risks

Table 8. Domestic Sector Estimations

II Q 1989 - II Q 2004				
	MLGDPR	**PI**	**MPS_GDP**	**DL[GR]**
Method	GIV	GMM	LS	LS
R^2	0,737	0,110	0,462	0,690
MLGDPR		0,296 (0,101)		
MLGDPR(-1)	0,338 (0,009)		0,517 (0,000)	
PI(-1)		0,641 (0,000)		
MPS_GDP	0,181 (0,044)			
DL[GR]	0,101 (0,000)			
DL[GR(-2)]				-0,254 (0,032)
DL[EP]		0,617 (0,025)		
DL[EP]*DUM_R		-0,425 (0,089)		
MLER	-0,120 (0,046)			
MLTT			0,057 (0,093)	
MLTT(-1)				0,107 (0,035)
DL[OX]				0,336 (0,000)
DL[OQ]	0,146 (0,017)			
D[RISK]			0,020 (0,013)	
DUM_STRIKE	-0,064 (0,014)			
DUM_Q				-0,253 (0,006)
MA(1)				-0,474 (0,000)
MA(4)				0,652 (0,000)

Variables: MLGDPR: gap of real GDP; PI: inflation; MPS_GDP: ratio of public sector money supply to GDP; GR: real government expenditure; EP: parallel nominal exchange rate ; MLER: misalignment of real exchange rate; MLTT: misalignment of terms of trade; OX: value of oil exports; OQ: quantities of oil exports; RISK: sovereign risk; DUM_R: dummy that takes value 1 when the fall of reserves is smaller than 12%; DUM_STRIKE: dummy that takes value 1 during the general strike in 2002-2003; DUM_Q: quaterly dummy; D[.]: refers to the first difference operator; DL[.]: refers to the log-diference operator.

*Values in parenthesis refer to p-values

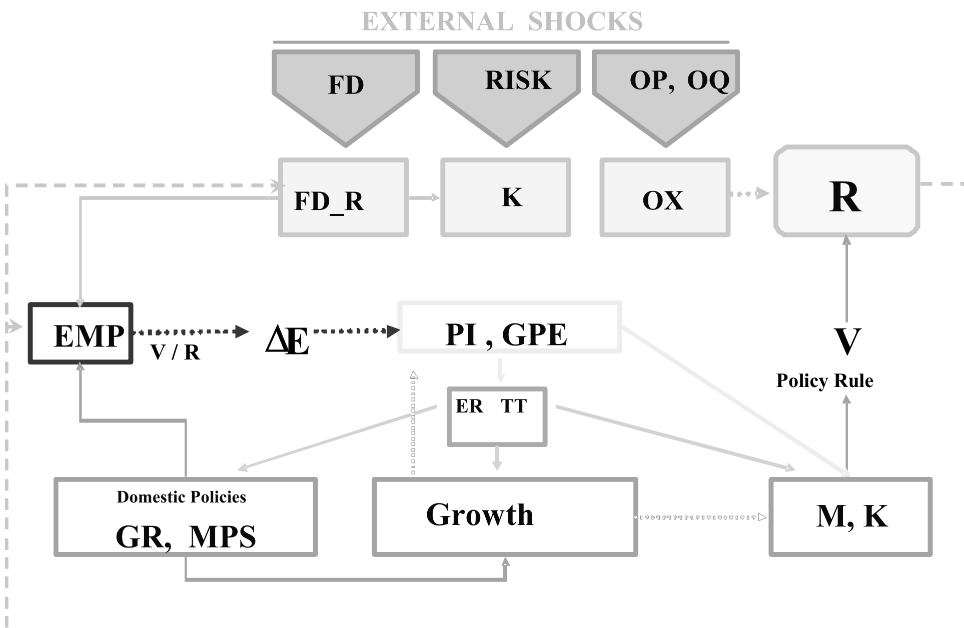
Table 9. Auxiliary Regressions

II Q 1989 - II Q 2004				
	DL[WSP]	HP_LER	HP_LTT	HP_LGDPR
Método Estimación	GIV	LS	LS	LS
R^2	0,547	0,998	0,997	0,997
DL[WSP(-1)]	0,269 (0,099)			
PI	0,556 (0,109)			
LER(-1)		-0,002 (0,000)		
LER(-2)		-0,001 (0,090)		
HP_LER(-1)		2,054 (0,000)		
HP_LER(-2)		-1,064 (0,000)		
LTT(-1)			-0,002 (0,000)	
LTT(-2)			-0,001 (0,052)	
HP_LTT(-1)			2,031 (0,000)	
HP_LTT(-2)			-1,037 (0,000)	
LGDPR(-1)				-0,002 (0,000)
LGDPR(-2)				-0,001 (0,002)
HP_LGDPR(-1)				1,970 (0,000)
HP_LGDPR(-2)				-0,970 (0,000)

Variables: WSP: whole sales prices ; PI: inflation; LER: log of real exhange rate; LTT: log of terms of trade; LGDPR: log of real GDP; HP_*Variable* Hodrick-Prescott filtered *Variable* ; DL[.]: refers to the log difference operator.

*Values in parenthesis refer to p-values

Appendix 2. Stylized Representation of the Complete Model



FD: foreign debt
RISK: sovereign risk
OP: oil prices
OQ: oil export quantities
FD_R: ratio of foreign debt to reserves
EMP: exchange market pressure
V/R: ratio of Central Bank net sales to international reserves
PI: inflation
GPE: gap between the parallel and the official nominal exchange rate
ER: real exchange rate
TT: terms of trade
GR: government real expenditures
MPS: money supply of the public sector
V: Central Bank net sales of dollars to the market
R: international reserves
M: imports of goods and services
K: net capital private inflows