<u>CAPITAL CONTROLS, MANAGED EXCHANGE RATES, AND VULNERABILITY</u>

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1. Introduction

A number of authors have recently argued that increased capital mobility has created a highly unstable international financial system. According to this view, unrestricted capital mobility is particularly harmful for the emerging countries; it leaves them vulnerable to external shocks and to speculators' attacks. Moreover, supporters of this perspective maintained that a premature liberalization of the capital account played an important role in the currency crises of the 1990s and early 2000s. Based on this interpretation of recent crises, some analysts have pointed out that market-based restrictions on capital movement would reduce the emerging countries' vulnerability to external disturbances. By fostering a more stable macroeconomic environment, the argument goes, these countries will be able to improve their overall macroeconomic performance. Many of authors seeking a less volatile international financial system have focused on controls on (short term) capital *inflows* as a potentially useful and effective policy tool. These types of controls were in effect in Chile during most of the 1990s, and have been praised by Krugman (1999), Stiglitz (1999), and Eichengreen, among others. Krugman (1999, p. 74), for instance, has said that "[s]ooner or later we will have to turn the clock back at least part of the of the way back: to limit capital flows for [emerging] countries…" And according to Stiglitz (1999, p3), "you want to look for policies that discourage 'hot' money but facilitate the flow of long term loans, and there is evidence now that the Chilean approach, or some version of it, does it." Recent discussions on the "new" financial architecture have also focused on the merits of controls on capital inflows. Ito (2000) and De Gregorio, Eichengreen, Ito and Wyplosz (2000), for example, have endorsed some variant of Chilean-type controls on inflows. Rogoff (1999) and Kenen (2001), on the other hand, appear to be more skeptical on the benefits of restricting capital inflows.

During most of the 1990s the Chile had one of the best economic performances in the world – GDP growth averaged 7% per year --, and that many analysts have attributed this success to a stable macroeconomic environment. This stability, in turn, has been mainly associated with three aspects of macroeconomic policy: (a) The market-based controls on capital inflows discussed above; (b) a limited-flexibility exchange rate system, based on a wide exchange rate band aimed at maintaining the real exchange rate within certain bounds. And (c), the generalize use of indexation in the domestic financial system. In this paper we use high frequency data to evaluate the functioning of Chilean-type capital controls. We are particularly interested in understanding whether, as some authors have claimed, these controls reduced Chile's vulnerability to external shocks. More specifically, we focus on the way in which changes in U.S. interest rates and in emerging markets country risk (measured by JP Morgan's EMBI index) affected Chile's domestic interest rates and exchange rates during the 1990s. A detailed evaluation of Chile's experience would provide useful information for those seeking to reform the international financial architecture and, in particular, it would provide information on whether market-based controls on short term capital inflows really reduce a country's vulnerability to external disturbances.[1]

The rest of the paper is organized as follows: In section I we provide a brief description of Chile's experience with controls on capital inflows during the 1990s. In Section II we develop an empirical model for analyzing the effect of external shocks on a small country's with limited market-based restrictions on capital inflows. The model is relatively complex, and incorporates the fact that until late 1998 Chile had limited-flexibility exchange rate system, based on a wide exchange rate band. In Section III we present our main econometric results, obtained using high frequency data. We consider two types of external shocks and three domestic macroeconomic variables. The external disturbances are changes in U.S. interest rates, and changes in the emerging markets' country risk premium, measured by JP Morgan's EMBI indexes. The tree endogenous variables are peso-denominated nominal interest rates, inflation-adjusted "real" interest rates, and the Chilean Peso/US Dollar nominal exchange rate. Finally, in Section IV we present some concluding remarks.

2. Market-Based Controls on Capital Inflows: Chile's Experience during the 1990s

Chile introduced market-based controls on capital inflows in June 1991.[2] Originally, all portfolio inflows were subject to a 20% reserve deposit that earned no interest. If the inflow had a maturity of less than a year, the deposit applied for the duration of the inflow; for longer maturities, the reserve deposit was for one year. In July 1992 the rate

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[1] Some studies have attempted to analyze empirically the effects of these controls on the Chilean economy. Their focus, however, has not been vulnerability or the international transmission of disturbances. Instead they have analyzed whether the controls allowed the Central Bank to undertake an independent monetary policy, and whether they helped avoid a steep real exchange rate appreciation. See, for example, Valdes-Prieto (19xx), De Gregorio et al (2000), Edwards (1999) and the references cited therein.

[2] Chile also implemented controls on inflows during the 1980s. That episode was clearly unsuccessful. For details see Edwards and Edwards (1991) and Edwards (1999a, b).

of the reserve requirement was raised to 30%, and its holding period was set at one year independently of the length of stay of the flow. Also, at that time its coverage was extended to trade credit and to loans related to foreign direct investment. New changes to this policy were introduced in 1995, when the reserve requirement coverage was extended to include Chilean stocks traded in the New York Stock Exchange (ADRs), "financial" foreign direct investment (FDI), and bond issues. In June of 1998, and as a result of the sudden slowdown of capital inflows, the rate of the reserve requirement was lowered to 10%, and in September of that year the deposit rate was reduced to zero. Throughout this period Chile also regulated foreign direct investment: Until 1992, FDI was subject to a three years minimum stay in the country; at that time the minimum stay was reduced to one year. There are no restrictions on the repatriation of profits from FDI.

When the controls were imposed the authorities hoped to reduce Chile's external vulnerability through two channels. First, it was expected that the controls would reduce the volume of inflows, at the same time as they would increase their maturity. Second, it was expected that the controls would help avoid (or at least reduce) the extent of real exchange rate appreciation that usually accompanies capital inflows. This last objective was particularly important, since most analysts associated Chile's external crisis of 1981-82 with an acute overvalued real exchange rate that, eventually, triggered a massive speculative attack.[3]

Chile's system of unremunerated reserve requirements is equivalent to a tax on capital inflows. The rate of the tax depends both on the period of time during which the funds stay in the country, as well as on the opportunity cost of these funds. As shown by Valdés-Prieto and Soto (1996) and De Gregorio, Edwards and Valdes (2000), the tax equivalent for funds that stay in Chile for k months, is given by the following expression:

(1) $$\tau(k) = \frac{r^* \lambda}{1-\lambda} \frac{\rho}{k}$$

[3] See Edwards and Edwards (1991) for a discussion of that period.

where r^* is an international interest rate that captures the opportunity cost of the reserve requirement, λ is the proportion of the funds that has to be deposited at the Central Bank, and ρ is the period of time (measured in months) that the deposit has to be kept in the Central Bank.

Figure 1 contains estimates of this tax-equivalent for three values of k: six months, nine months, one year and three years. Three aspects of this figure are particularly interesting: first, the rate of the tax is inversely related to the length of stay of the funds in the country. This, of course, was exactly the intent of the policy, as the authorities wanted to discourage short-term inflows. Second, the rate of the tax is quite high even for a three year period. During 1997, for example, the average tax for 3 year-funds was 80 basis points. And third, the tax equivalent varied through time, both because the rate of the required deposit was altered and because the opportunity cost changed.

Between 1988 and 1998 shorter-term flows into Chile –- that is, flows with less than a one year maturity-- declined steeply relative to longer term capital. The percentage of the county's liabilities in hands of foreigners maturing within a year also declined in the period following the imposition of controls (De Gregorio et al 2000). By late 1996 Chile had a lower percentage of short-term debt to G-10 banks than any of the East Asian countries, with the exception of Malaysia. Surprisingly, perhaps, by 1996 Chile's short-term debt was higher than that of Mexico a Latin American country without controls (Edwards 1999b). A traditional shortcoming of capital controls (either on outflows or inflows) is that it is relatively easy for investors to avoid them. Valdés-Prieto and Soto (1998), for example, have argued that in spite of the authorities' efforts to close loopholes, Chile's controls have been subject to considerable evasion. Cowan and De Gregorio (1997) acknowledged this fact, and constructed a subjective index of the "power" of the controls. This index takes a value of one if there is no (or very little) evasion, and takes a value of zero if there is complete evasion. According to them this index reached its lowest value during the second quarter of 1995; by late 1997 and early 1998 this index had reached a value of 0.8.

Some authors have used regression analysis to investigate the determinants of capital flows in Chile. Soto (1997) and De Gregorio et al (2000), for example, have estimated a system of VARs using monthly data to analyze the way in which capital controls have affected the volume and composition of capital inflows. Their results suggest that the tax on capital movements discouraged short-term inflows. These analyses indicate, however, that the reduction in shorter-term flows was fully compensated by increases in longer term capital inflows and that, consequently, aggregate capital moving into Chile was not altered by this policy. Moreover, Valdés-Prieto and Soto (1998) have argued that the controls only became effective in discouraging short-term flows after 1995, when its actual rate increased significantly.[4]

A particularly important question is whether, by imposing these market-based controls on inflows, Chile reduced its financial vulnerability and was spared from financial "contagion" during the 1990s. More specifically, did these controls isolate Chile's key macroeconomics variables – and especially interest rates – from externally generated financial turmoil? In Figure 2 I present weekly data on the evolution of Chile's 30 and 90-day deposit interest rates for 1996-1999.[5] As may be seen, both interest rates experience a dramatic jump in late 1997, at the time when the East Asian crisis became generalized. In the rest of this paper we develop a model to address this issue formally.

3. Measuring the effectiveness of capital controls

As was mentioned before, the objectives of capital controls are to provide stability to the exchange rate, to minimize the impact of capital outflows, to allow the country to conduct an independent monetary policy, etc.

One of the most difficult aspects of measuring the effectiveness of capital controls is the fact that exchange rates are managed at the same time the capital controls are in place. The question becomes, then, how much of the stability of the exchange rate is due to the exchange rate regime, and how much to the capital controls? The easiest example is the existence of a credible target zone exchange rate regime – close to any of the bands

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[4] These results are consistent with Montiel and Reinhart (1999).

[5] While the data for 30-day rates refer to nominal rates, those for 90 day deposits are in Chile's "real" (inflation-corrected) unit of account.

the observed behavior of the exchange rate is less volatile than within the band. But this feature is mainly due to the bands and not to the capital controls.

In this paper we offer a methodology that allow us to disentangle the two effects. We take seriously the announced exchange rate regime by the Chilean Central Bank and estimate the implied "fundamental" determining the exchange rate – this is equivalent to a shadow exchange rate. Using the shadow exchange rate we evaluate the effectiveness of the capital controls.

3.1. Data

The properties of the data are the following: Mean, standard deviation, etc.

	e	e_l	e_h	t	Embi
Mean	410.9	392.9	475.7	2.64	221.5
Stdev	41.2	31.8	46.9	1.66	76.7
Max	519.8	457.7	548.4	4.70	358.8
Min	336.7	336.0	371.4	0.00	96.7
Median	411.5	402.2	485.5	2.49	192.1

3.2. Estimation

To derive the exchange rate as a function of the shadow exchange rate (or fundamental) we follow Bertola and Caballero (1992) closely. Assume that money demand in each country is given by

$$m_t^* - p_t^* = -\alpha i_t^*$$
$$m_t - p_t = -\alpha i_t$$

and where PPP and the UIP hold. This implies that the exchange rate is

$$e_t = m_t - m_t^* + \alpha \frac{E[de_t]}{dt} \qquad (2)$$

where we have substituted the money demands in the PPP equation and use the fact that the interest rate differential is equal to the expected exchange rate depreciation.

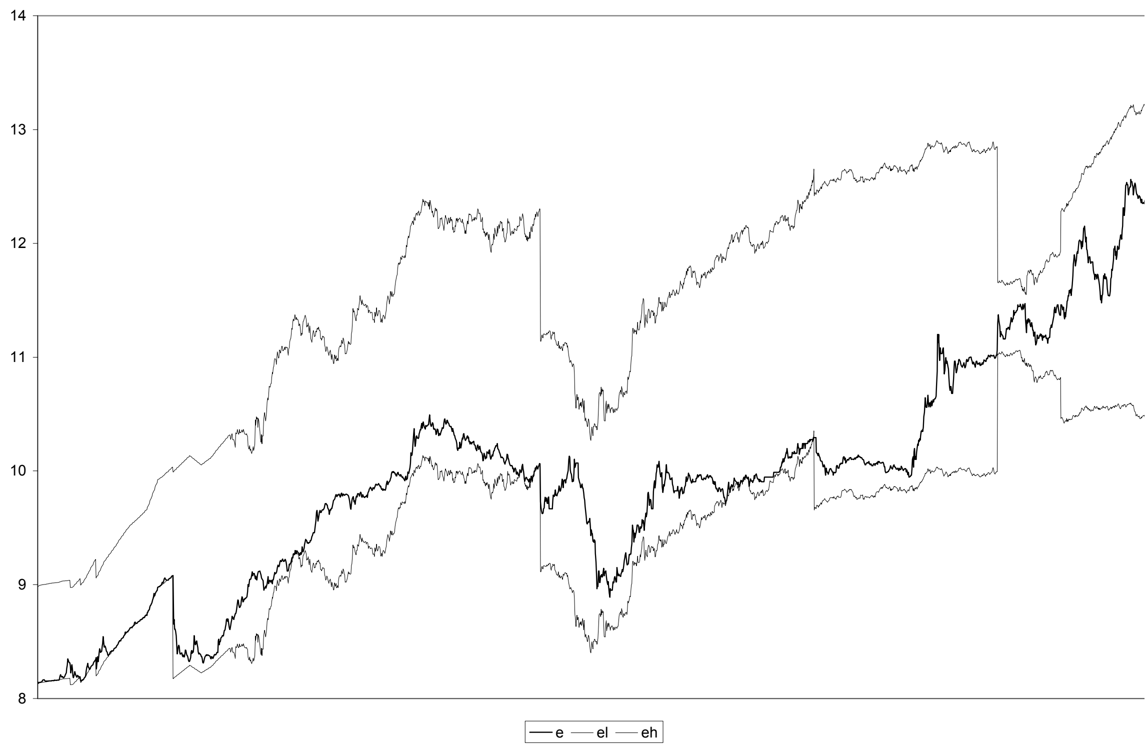
A more complex model would have the same form as the stochastic differential equation in (2). There are some fundamentals that govern the exchange rate dynamics. Assume that those fundamentals are

$$f_t = \mu_t dt + \sigma_t dz_t \qquad (3)$$

Using Ito's lemma it is easy to show that the exchange rate satisfies the following differential equation

$$e_t = f_t + \alpha\left[\mu_t \frac{\partial e_t}{\partial f_t} + \tfrac{1}{2}\sigma_t \frac{\partial^2 e_t}{\partial f_t^{\,2}}\right]$$

The bands in Chile moved frequently. However, this movement is predictable in the sense that if depended on a central parity that was a computed as some weighted average of past realizations. Which means that they are measurable according to the information available at time *t*. Indeed, there are only 4 realignments: (exact dates here XX XX XX and XX). Hence, we assume, in the first pass to the problem, that most of the time the bands are credible.



The solution to the differential equation is

(3) $$e_t(f_t) = \alpha\mu_t + f_t + A_t \exp(\lambda_{1t} f_t) + B_t \exp(\lambda_{2t} f_t)$$

where λ_{1t} and λ_{2t} are that satisfy

(4) $$\lambda_t = -\frac{\mu_t}{\sigma_t} \pm \sqrt{\left(\frac{\mu_t}{\sigma_t}\right)^2 + \frac{2}{\alpha\sigma_t}}$$

Finally, the constants and the bands where the fundamentals fluctuate satisfy the value matching condition

$$
(5)\qquad
\begin{aligned}
& f_t \in \left[\underline{f_t}, \overline{f_t}\right] \\
& \underline{e_t} = \alpha\mu_t + \underline{f_t} + A_t \exp\left(\lambda_{1t}\underline{f_t}\right) + B_t \exp\left(\lambda_{2t}\underline{f_t}\right) \\
& \overline{e_t} = \alpha\mu_t + \overline{f_t}_t + A_t \exp\left(\lambda_{1t}\overline{f_t}\right) + B_t \exp\left(\lambda_{2t}\overline{f_t}\right)
\end{aligned}
$$

and the smooth pasting conditions:

$$
(6)\qquad
\begin{aligned}
& 0 = 1 + A_t\lambda_{1t}\exp\left(\lambda_{1t}\underline{f_t}\right) + B_t\lambda_{2t}\exp\left(\lambda_{2t}\underline{f_t}\right) \\
& 0 = 1 + A_t\lambda_{1t}\exp\left(\lambda_{1t}\overline{f_t}\right) + B_t\lambda_{2t}\exp\left(\lambda_{2t}\overline{f_t}\right)
\end{aligned}
$$

In the data we have the following information: the actual exchange rate, and the prevailing bands at every time. The objective, first, is to estimate the fundamentals f_t and its bands $\left[\underline{f_t}, \overline{f_t}\right]$ that explain the observed behavior of the exchange rate.

3.3. Estimating the shadow exchange rate

The procedure of estimation is by iteration.

a) Initialize the fundamentals equal to the observed exchange rate: $f_t^0 = e_t$, This is the first iteration.

b) Compute the mean return in the fundamentals (we are assuming that the mean return is constant $\mu_t = \mu$) and the rolling variance of the fundamentals ($\sigma_t = \text{var}(f_{t-n}^i : f_{t-1}^i)$). For some *n* that represents a reasonable window.

c) Using the mean return and the rolling variance we compute the series of λ_{1t} and λ_{2t}.

d) Using the observed bands $\left[\underline{e_t}, \overline{e_t}\right]$ and the λ_{1t} and λ_{2t} previously computed note that for each time *t* equations (5) and (6) form a system of four equations in four unknowns ($A_t, B_t, \underline{f_t}, \overline{f_t}$). Hence, for each time we solve the system of equations.

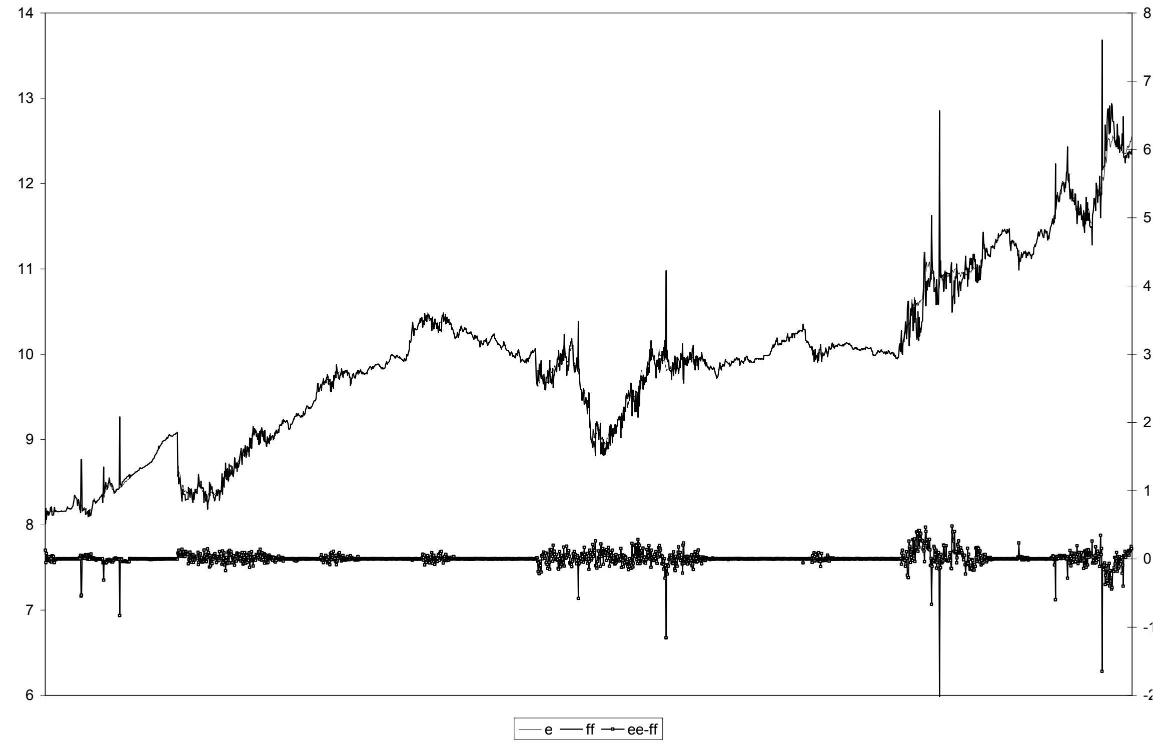
e) Finally, using equation (4) we solve for the implied fundamental that explains the exchange rate. This provides f_t^{i+1}.

f) Jump to b) and continue iterating until convergence has been achieved.

This procedure allows us to estimate the fundamentals, the fundamental's bands, and the conditional variance of the fundamentals that are consistent with the observed exchange rate and the announced bands.

This procedure has made several simplifying assumptions that are important to highlight: first, it has been assumed that the bands are fully credible. This is clearly a short cut, but in the Chilean economy, they were indeed quite credible. The estimation procedure can be extended to include this possibility by using the fact that within sample there are only a couple of realignments. Second, it has been assumed that the mean returns are constant. This is mainly for convenience. The reason why we assumed this is because it is well known that mean returns are extremely badly estimated when the time horizon is short. In our case, the data runs from the mid 80's to the end of the 90's. If we were to estimate a yearly mean return we would introduce a noisy estimate in the procedure. Third, we are assuming that the central bank only intervenes when the exchange rate is close to the band. A simple extension of the procedure (and the information about the daily interventions) can be implemented to take into account this issue.

The results are shown in Figure . As can be seen, the shadow exchange rate and the actual are close.



The exchange rate and the shadow exchange rate (*ff*) are measured on the left hand axis, while the difference is measured on the right hand side. It is easy to detect that the main differences occur when the actual exchange rate is close to the bands, as should be expected.

After the shadow exchange rate has been computed, the second step is to estimate a simple GARCH model to evaluate the importance of capital controls in the propagation of external shocks.

The external shocks are measured as the Latin American EMBI+ excluding Chile. The equivalent tax rate is computed using equation (1). The GARCH specification is the following:

$$
\begin{aligned}
&f_t = c_0 + \beta_0 x_t + \beta_1 \tau_t + \beta_2 x_t \cdot \tau_t + \varepsilon_t \\
&\varepsilon_t \sim N(0, h_t) \\
&h_t = \eta_0 + \eta_1 h_{t-1} + \eta_2 \varepsilon_{t-1}^2 + \eta_3 x_t + \eta_4 \tau_t + \eta_5 x_t \cdot \tau_t
\end{aligned}
$$

where f_t is the shadow exchange rate computed in the first step, x_t is the external shock, τ_t is the equivalent tax rate on capital inflows, and ε_t is the heteroskedastic residual. All variables have been demeaned and normalized by their standard deviations. We run other specifications in first differences and with lags, with the data normalized or not. The results are qualitatively the same and are reported in the appendix. The results from the estimation are:

Mean Equation	Base
C	6.06505
	0.04178
	145.2
EMBI+	1.38209
	0.01389
	99.5
Tax	1.25095
	0.01549
	80.8
Tax * EMBI+	-0.46753
	0.00515
	-90.8

For the coefficient in the mean equation and for the variance equation

Variance Equation	
Eta0	0.03921
	0.01247
	3.1
GARCH	0.39797
	0.07524
	5.3
ARCH	0.21126
	0.02437
	8.7
EMBI+	0.00188
	0.00372
	0.5
Tax	-0.01323
	0.00469
	-2.8
Tax * EMBI+	-0.00100
	0.00142
	-0.7

The GARCH was estimated using MLE. There are several remarks that can be extracted from these results. First, note that the coefficient on the EMBI+ implies that an increase in the emerging market interest rate implies a depreciation of the exchange rate. Indeed, a one standard deviation shock of the EMBI+ depreciates the exchange rate in

1.38 standard deviations. This coefficient is highly significant and suggests that the pass through of foreign shocks is larger than one. This is a sensible result given the structure of emerging markets.

Second, an increase in the implied tax rate of the capital controls produces a depreciation of the exchange rate. The coefficient shows that a one standard deviation increase in the tax rate depreciates the exchange rate is 1.25 standard deviations. Ther coefficient is statistically significant and with the predicted sign. The theory would predict exactly this effect. In particular, assume a small open economy with positive capital inflows and with equilibrium in the balance of payments. An increase in the tax on those inflows produces a reduction in those flows and a balance of payments deficit. To return to equilibrium, the current account needs a surplus, which is achieved by a real exchange rate depreciation. As far as we know, we are the first ones to find that indeed the capital controls depreciate the exchange rate on impact.

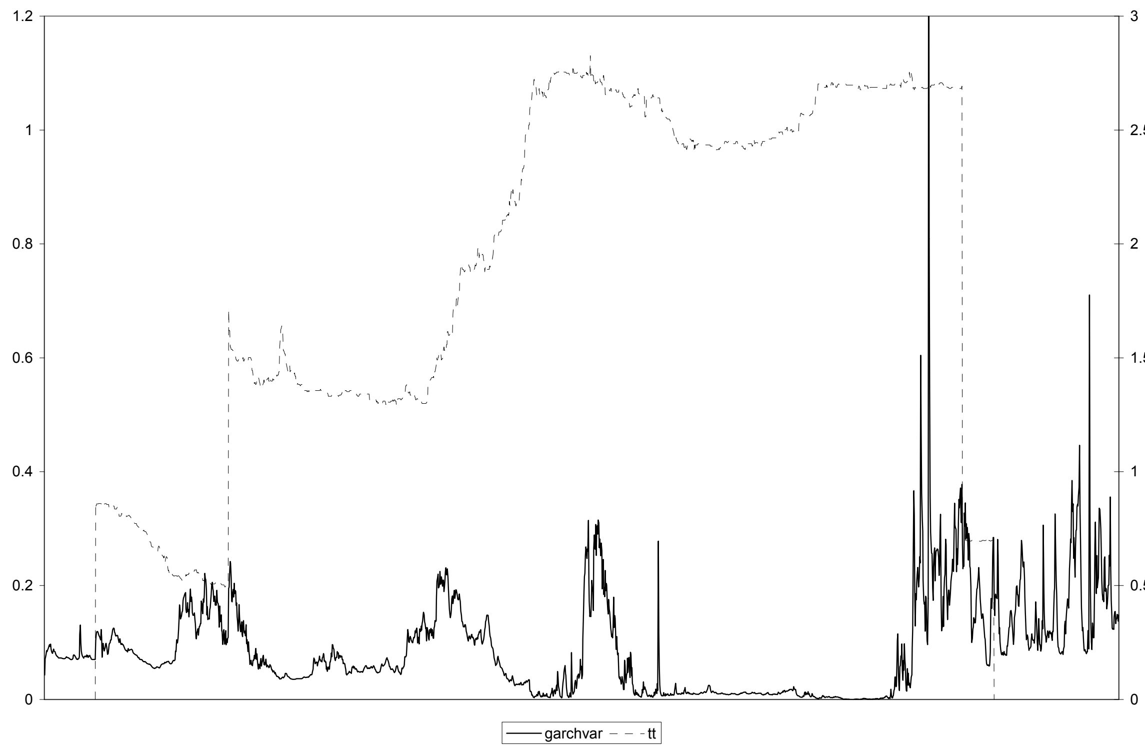
Third, the interaction term in the mean equation shows that an increase in the capital controls tax reduces the pass-through of the external shocks. In the sample, the average value of the normalized tax rate is 1.58 with a minimum of zero and a maximum of 2.82. The interpretation of the coefficient is the following: when the capital controls do not exit, the pass-through of external shocks to the exchange rate is 1.38. On the other hand, if the 6 months tax rate is increased in one standard deviation (1.66 percent) then the pass-through is 0.91, and if the tax is increased by two standard deviations (3.12 percent) it is reduced to 0.45 percent. Finally, the maximum tax in the sample is 4.70 percent, which is equivalent to 2.82 standard deviations. In this case the pass-through is almost zero: 0.06 percent.

The results on the mean equation are quite sensible, so are the coefficients in the variance equation. The ARCH and GARCH coefficients are not discussed, given that their signs and significance are as expected. We concentrate on the impact of foreign shocks and capital controls.

First, an increase in the international interest rate increases the variance of the shadow exchange rate. This coefficient has the right sign but unfortunately it is not statistically significant.

Second, an increase in the tax rate has a level effect on the variance of the exchange rate – reducing it. And has a pass-through effect that reduces the impact of foreign shocks in the variance. The level effect on the variance is statistically significant and implies that a one standard deviation increase in the tax rate reduces the variance of the shadow exchange rate in 0.01323. The other coefficients are not statistically significant, but have the expected signs.

One very interesting result from our estimation is the relationship between the predicted variance of the shadow exchange rate and the tax rate. In the next figure we plot both. The tax rate is measured on the right hand axis and the variance is measured on the left hand side.



Note that, clearly, increases in the volatility of the shadow exchange rate preceed changes in the tax policy.

SEBASTIAN!!!!

NEXT???? LET ME KNOW

1. I have more robustness stuff. Results are quite robust.

2. We use the shadow exchange rate and the stock market building the pressure index stuff and corroborate most of the results presented here.