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INTEREST RATE VOLATILITY, CONTAGION AND CONVERGENCE: AN EMPIRICAL INVESTIGATION OF THE CASES OF ARGENTINA, CHILE AND MEXICO

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I. Introduction

Interest rates are, arguably, one of the most important macroeconomic variables. They provide a key transmission channel for the propagation of shocks throughout the economy, and play a fundamental role in asset pricing. And yet, over the years there has been relatively little work aimed at trying to understand the way in which interest rates behave in emerging economies. This state of affairs contrasts sharply with that in the advanced countries, where there have been a large number of empirical studies – many of them in the finance tradition – that have tried to carefully understand interest rate behavior along the yield curve.[1]

Surprisingly, perhaps, most of these advanced-nation studies have tended to ignore the role of open economy factors and have assumed, either implicitly or explicitly, that the economy in question is not subject to significant

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[1] See, for example, the studies discussed in Roll (1997).

influences from the rest of the world. For example, the book by Campbell, Lo and MacKinlay (1997), a required reference for anyone doing empirical work in finance these days, does not even list the terms “exchange rate risk”, “devaluation”, “international”, or “interest parity” in the index.[2] The literature in the macroeconomics tradition, on the other hand, has been somewhat more receptive to incorporating open economy issues, and a number of studies have indeed investigated the way in which the existence of international linkages across financial markets impacts on interest rate behavior in the world economy.[3] There is also a small literature on interest rates in developing countries that takes into account the role of international factors. Much of this literature has tried to understand the extent to which open economy variables – and more specifically, world interest rates and expectations of devaluation – affect a country’s domestic interest rates, in a world where there is imperfect capital mobility. Invariably, this literature has concluded that the “actual” degree of financial openness of a country exceeds its “legal” degree of openness.[4]

In this paper I use, weekly and monthly data to analyze in some detail interest rate behavior in three Latin American countries during the 1990s – Argentina, Chile and Mexico. These three countries provide a unique opportunity for investigating the way in which interest rates behave under alternative institutional arrangements. In particular, these countries’ experiences allow us to analyze interest rate dynamics under alternative exchange rate regimes and rules regarding capital mobility. During the period under study Argentina had a fixed exchange rate, backed by a currency board-type of monetary system; Mexico moved from a narrow, upward sloping, exchange rate band to a floating regime; and Chile had a band system with a

[2] There are, of course, exceptions in this tradition. My colleague Richard Roll has considered the open economy angle in a number of his studies.

[3] See, for example, Marston (1993).

[4] See, for example, Edwards (1985), Dooley (1995) and Dooley et al (1998).

changing width.[5] Moreover, while in Argentina and Mexico free capital mobility was allowed, in Chile there were unremunerated reserve requirement on international capital inflows throughout most of the period. Additionally, the time period considered – 1992 through mid 1998 – allows us to investigate the way in which interest rates in these countries were affected by the major currency crises that occurred during this turbulent years. In should be pointed out at the outset that the use of high frequency data introduces some limitation into the analysis, since very few macroeconomics variables have data at the weekly frequency. For this reason the analysis concentrates on those variables for which the adequate information is available, placing a special emphasis on *nominal* interest rates – both in domestic and foreign currency.

The paper is organized as follows: Section I is the introduction; in Section II I briefly discuss the most important issues and I present the key characteristics of the data. In Section III I deal with interest rate volatility in some detail. I estimate a series of statistical models using Argentine, Mexican and Chilean data in an effort to understand the extent and determinants of interest rate volatility. More specifically, I investigate whether external factors, such as third-country instability, have affected interest rate variability in these countries. This is an important issue for the contagion debate that has emerged in the aftermath of the Mexican, East Asian and Russian crises. Section IV deals with international interest rate differentials and convergence. I compute uncovered interest differentials and analyze their dynamic behavior. In this section I investigate, for the case of Chile, whether the imposition of controls on capital mobility have affected interest rate differentials as the authorities had hoped.

[5] Due to space considerations I don't provide a detailed discussion of these three countries exchange rate regimes during this period. On Argentina see, for example, Rodriguez (1994); on Mexico see Edwards (1998a) and Edwards and Savastano (1998); on Chile's exchange rate band see Dornbusch and Edwards (1993).

II. The Data and the Issues: A Preliminary Discussion

The main interest of this paper is to understand interest rate behavior under Argentina's "currency convertibility" exchange rate regime. In order to do this I analyze interest rate behavior in three Latin American countries – Argentina, Chile and Mexico — during the 1990s.

In Figure 1 I present weekly data for short term (30 days) deposit interest rates for the three countries. The data were obtained from the **Datastream** data set. For Argentina and Chile I used average nominal interest rates paid by commercial banks on 30 days deposits; for Mexico I used interest rates on 28 days certificates of deposits. For Argentina and Mexico the series start on the first week of 1992, while for Chile the series start on the first week of 1994. For all three countries the series end on the first week of June, 1998. All data are annualized.[6] Figure 2, on the other hand, contains for all three countries the nominal exchange rate, at weekly intervals, between January 1992 and the first week of June, 1998.

Several interesting facts emerge from these Figures. First, all three countries exhibit very large increases in interest rates in late December, 1994. These jumps correspond to the Mexican currency crisis, and subsequent "tequila effect." Interestingly enough, however, and as captured in Figure 2, in neither Argentina, nor in Chile was the exchange rate devalued following the Mexican crisis. In fact, the increase in interest rates was a fundamental element in these countries' defense of their exchange rate strategy in the months following the Mexican crisis. Second, in all three countries there is also a spike – although a much smaller one — in interest rates in October of 1997, at a time when the East Asian crisis intensified, and Hong Kong's stock market tumbled. Third, Chile's short term interest rates appear to revert to their mean at a faster rate than in either Argentina or Mexico. In fact, the

[6] For Argentina and Mexico the data are provided on annual terms. For Chile, data on monthly returns are provided. The yearly returns reported in the table were obtained by compounding.

Figure 1. Short Term Nominal Interest Rates: Argentina, Mexico and Chile (Weekly Data, 1992-98)

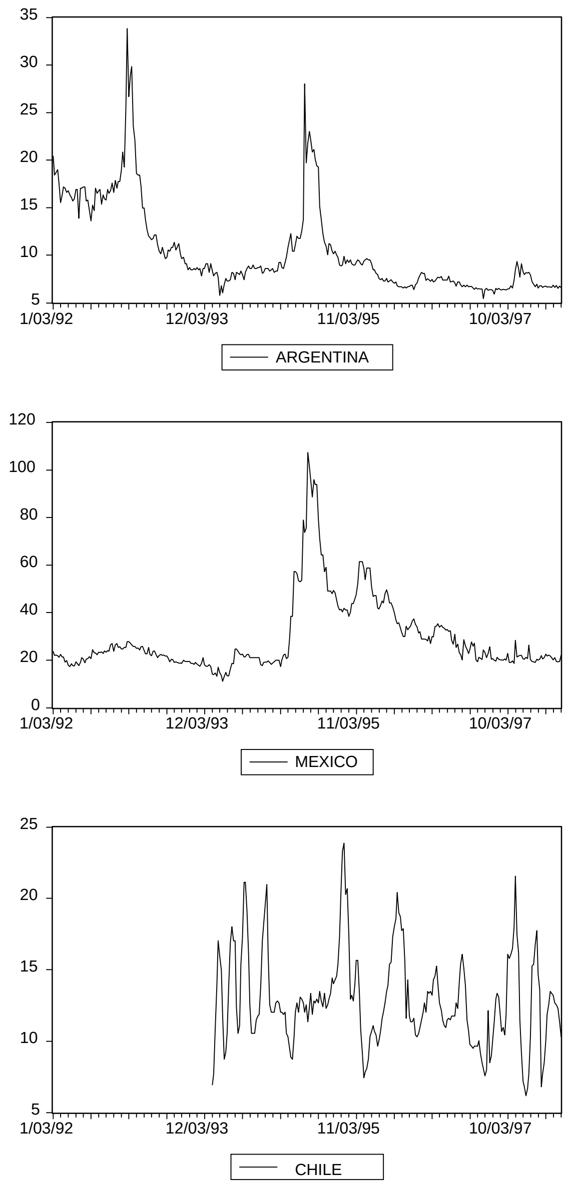
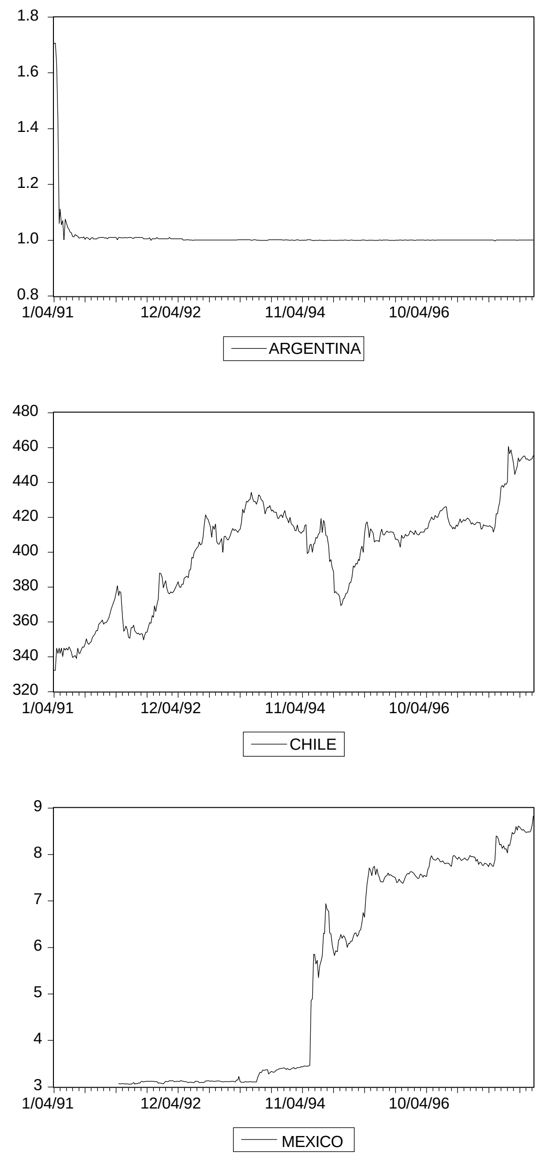


Figure 2. Exchange Rates with Respect to U.S. Dollar in Argentina, Chile and Mexico, Weekly Data, 1991-98



AR(1) coefficient for Chile's weekly nominal interest rate for 1994-1998 is 0.87, while that for Argentina is 0.93. For Mexico this coefficient was, during 1995-98, 0.97.[7] Third, throughout most of the period Mexican short term nominal interest rates were higher than those of Chile and Argentina.

Table 1 contains descriptive statistics for all three countries. Data are provided for interest rates, the annualized rate of devaluation, and the rate of inflation for the complete period, as well as for each year since 1992. The rate of devaluation has been computed as the annualized rate of devaluation during the holding period for each of these securities. The rate of inflation is the year-over-year rate. As may be seen, during the full period under study (1992-98), Argentina had the lowest overall nominal interest rates, and in 1996-98 the less volatile ones. Chile's rates gradually declined throughout the period, while maintaining a similar degree of volatility (as measured by the standard deviation) year after year. This contrasts with Chile's exchange rate movements during these years, a period of rather low rates of devaluation but high volatility. The data on Mexico show both high interest rates, as well as a high degree of volatility, especially after the 1994 devaluation. An interesting feature of these data – not reported in detail due to space considerations – is that the weekly distributions of interest rates and devaluation rates appear to be significantly skewed. This is particular the case for Mexico in 1994, where, for example, there was a significant divergence between the mean of the weekly annualized rate of devaluation (68.9%) and its median (7.9%).

The data in Table 1 also show that during the years of Mexico-induced turmoil – during 1994, and especially 1995 —, Argentina's nominal interest rates were more volatile than Chile's rates. As time passed by, however, and tranquility and confidence returned to Argentina's financial markets, Argentina's volatility became the lowest of the three countries. Interestingly enough, after October 1997, when the East Asian crises finally impacted on

[7] A high degree of persistence is a well known feature of short term interest rates in the U.S. See, for example, Bekaert et el (1997).

Table 1. Nominal Interest Rates: Descriptive Statistics

	ARGENTINA					CHILE					MEXICO				
	Interest Rates		Nominal Devaluation		Inflation	Interest Rates		Nominal Devaluation		Inflation	Interest Rates		Nominal Devaluation		Inflation
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
1992-98	10.6	4.8	0	0	6.2	12.9	3.3	3.1	23.0	9.1	29.6	16.0	18.9	92.0	19.5
1992	17.8	3.6	0	0	24.9	—	—	—	—	15.4	22.5	2.9	1.4	9.3	15.5
1993	12.1	4.9	0	0	10.6	—	—	—	—	12.7	21.2	2.8	-0.3	11.9	9.8
1994	8.3	5.8	0	0	4.2	13.6	3.5	-5.8	13.8	11.4	19.0	3.3	7.9*	197.5	7.0
1995	12.6	4.7	0	0	3.4	13.4	3.5	1.4	32.0	8.2	57.6	19.3	37.9	99.3	35.0
1996	7.4	0.7	0	0	0.2	13.1	2.8	4.3	8.8	7.4	37.4	7.7	3.8	22.4	34.4
1997	6.9	0.8	0	0	0.5	11.8	3.2	6.7	22.2	6.1	23.2	3.8	4.7	28.9	20.6
1998 (till June)	7.03	0.6	0	0	1.8	11.7	3.5	3.4	22.5	3.2	21.1	19.4	17.1	25.1	17.2

the Latin American region, Chile's interest rates became more volatile, while Argentine rates did not exhibit a significant change. In Section III of this paper I investigate in greater detail the factors affecting short term interest rate volatility in each of these countries.

The interest rate data presented in Figure 1 and Table 1 refer to 30 days nominal interest rates. The data on inflation presented in Table 1 show that, for most years and countries, average real deposit interest rates were positive. An important question from an open economy perspective refers to foreign currency denominated returns; these returns play a crucial role in determining capital movements, and are related to the cost of capital faced by the country's exporters. Figure 3 displays the annualized realized return expressed in dollars for the three countries in the sample. In Table 2 I present the average annualized weekly rate of return in dollars. For the cases of Argentina and Mexico these figures should be interpreted as the dollar return actually obtained on average, in dollars, by an investor who bought these securities every week during the sample period.[8] For these two countries the investor could be either a domestic resident or a foreign national. In Chile, however, due to the existence of controls on capital mobility, these figures should be interpreted as pertaining only to local investors. For comparison purposes, in Table 2 I have also included data on the 30 days CDs in the U.S.

As Figure 3 shows, Argentina, was the only country where realized dollar returns were positive throughout the period. In Mexico, for example, during 1994 (the year of the devaluation crisis) the average weekly dollar returns were very negative (-53.8). It would be tempting to think that these negative (ex post) realized returns in Mexico were exclusively the results of the collapse in the value of the peso in December of that year. This, however, was not the case; for almost every 4 week-period during 1994 actual realized dollar returns were negative. Interestingly enough, however, with the exception of 1994 and the first five months of 1998, realized ex-post average dollar returns in Mexico exceeded by a significant margin those obtained in

[8] Notice that I am not assuming reinvestment in the same security.

Figure 3. Annualized Returns in Dollars, Argentina, Chile, and Mexico, 1992-98

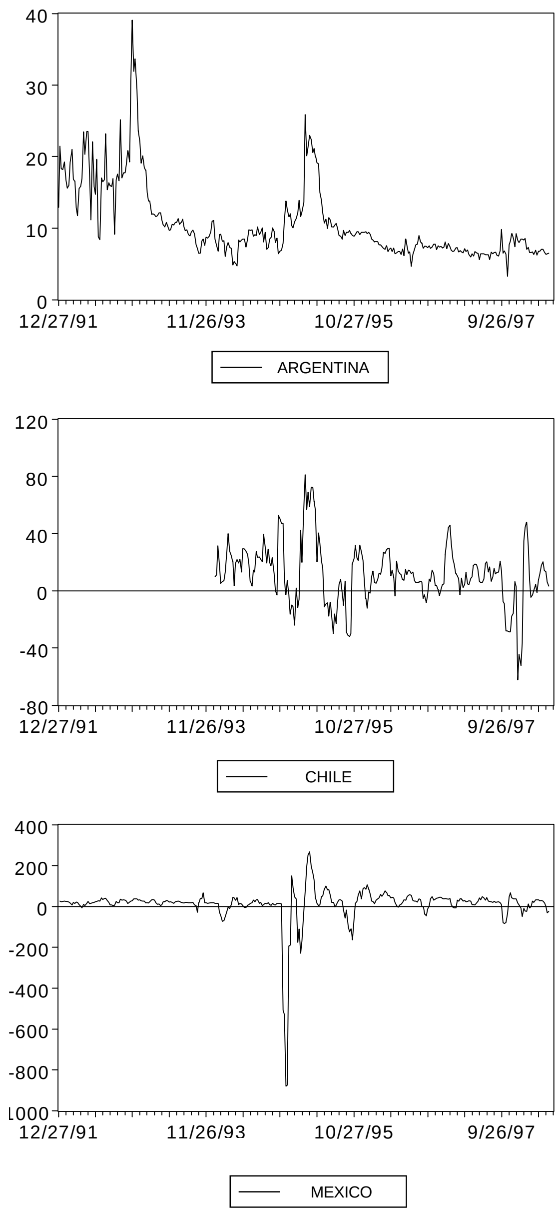


Table 2 : Realized (Ex Post) Dollar Returns

	ARGENTINA		CHILE		MEXICO		UNITED STATES	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
1992-1998	10.7	5.3	11.5	21.1*	10.8*	94.4	4.16	1.06
1992	18.6	5.8	n.a.	n.a.	21.1	10.6	3.18	0.38
1993	11.7	4.4	n.a.	n.a.	21.2	12.0	2.6	0.06
1994	8.5	1.8	19.4	14.2	-53.8	197.7	3.7	0.77
1995	12.6	4.6	12.3	31.4	23.8	106.4	5.2	0.10
1996	7.4	0.8	8.9	9.2	33.5	27.2	4.75	0.07
1997	6.9	1.0	6.2	20.1	19.0	29.8	5.15	0.14
1998	7.0	0.8	8.3	23.5	3.9	25.2	5.22	0.04

the U.S. These high Mexican returns, however, came at the cost of very high risk – indeed, as may be seen in Table 2 the standard deviations of short term Mexican rates were several orders of magnitude higher than standard deviations for U.S. CDs during that period.

In light of the preliminary data analysis presented here, in the sections that follow I investigate a number of issues regarding interest rate behavior of interest rates in Latin America during 1992-98. In Section III I concentrate on interest rate volatility, while in Section IV I deal with deviations from uncovered interest parity.

III. Nominal Interest Rate Volatility and External Contagion

The data in Table 2 clearly indicate that for all three countries interest rate volatility changed markedly over time. An important question is whether this volatility has been the result of domestic factors, or whether it has been influenced – at least partially – by some form of international contagion. In the context of the current turmoil in international financial markets, it is particularly interesting to explore whether there has been “volatility contagion” coming from other *emerging* markets.

The changing degree of volatility displayed in Table 2 suggests that, during this period, interest rate volatility in the three countries can be explained by models in the generalized autoregressive conditionally hetereoskedastic (GARCH) tradition. Most GARCH-based empirical work on changing returns volatility in the industrial countries has tended to ignore, both in the mean and conditional variance equations, open economy factors (Bollerslev et al 1992).[9] In this section I explicitly deal with international issues, and I investigate the extent to which there has been "volatility contagion" across emerging Latin American countries. More specifically, I analyze whether volatility in Mexico – a country that is not only financially important, but one that has also unleashed major global crises in the past – has affected interest rate volatility in Argentina and Chile.[10]

Consider the following GARCH model of interest rates in a particular country:

$$\Delta r_t = \theta + \Sigma \phi_j x_{t-j} + \eta_t \tag{1}$$

$$\sigma^2_t = \varphi + \alpha \eta^2_{t-1} + \beta \sigma^2_{t-1} + \Sigma \gamma_j y_{t-j} \tag{2}$$

Where r is the nominal interest rate; the xs are variables that affect changes in the interest rate, and may include lagged values of Δr, as well as other domestic or international variables; η are innovations to interest rate changes; σ^2_t is the conditional variance; and the y_{t-j} are variables, other than past squared innovations or lagged forecast variance, that help explain interest rate volatility.

In this section I report results obtained from the estimation of models based on equations (1) and (2) for Argentina and Chile during the 1990s. My main interest is to investigate whether there has been "volatility contagion", or "volatility spillovers" from Mexico to the two South American

9 There is, however, a long literature on exchange rate volatility based on GARCH models.

10 See Campbell et al (1997) for the use of GARCH to model changing volatility in financial markets.

nations.[11] I do this by including Mexico-specific volatility variables in the estimation of the conditional variance equation (2). In the first step of the analysis I estimated, by ordinary least squares, a number of versions of equation (1) for Argentina and Chile. The analysis of the residuals clearly showed the presence of conditional heteroskedasticity. In every case Engel's LM test indicated that the null hypothesis of absence of ARCH was rejected at conventional levels: its value, with four lags, was 29.3 for Argentina, and 9.56 for Chile.

The second step in the analysis consisted in selecting a group of indexes on Mexican volatility to be included in the estimation of the conditional variance equations for Argentina and Chile. In order for volatility to be positive at all times, these indexes should be nonnegative, as should be their estimated coefficient. For this reason I focused on the following four indicators of Mexican volatility: (1) The estimated conditional variance from a fourth order GARCH model for Mexican short term interest rates.[12] This variable was called *Garchmex*. (2) A dummy variable that took the value of one in any week when the Mexican peso depreciated by 3 percent or more, and zero otherwise (*Dummex)*. (3) The absolute value of weekly changes in Mexican short term nominal interest rates (*Absdmex*). And (4), the estimated conditional variance from a GARCH(1,1) model of Mexico's rate of devaluation. This variable was called *Garchmexdev*.

The system actually estimated for Argentina and Chile is given by equations (1') and (2'):

$$\Delta r_t = \theta + \phi_1 \Delta r_{t-1} + \phi_2 \text{time} + \eta_t \qquad (1')$$

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[11] There is an important literature on stock markets "volatility spillover." See, for example, King and Wadhwani (1990).

[12] The mean equation included a constant, a once lagged change in the nominal interest rate and a dummy variable that took the value of one in any week when the peso depreciated by more than three percent. The results from this estimation for Mexico is not reported here due to space considerations.

$$\sigma^2_t = \varphi + \alpha\, \eta^2_{t-1} + \beta\, \sigma^2_{t-1} + \gamma \text{ MEXVOL}, \qquad (2')$$

where MEXVOL refers to the Mexican volatility indicators defined above. When more complicated specifications for equation (1') were used, very similar results were obtained.[13]

The estimation of these equations allows us to address a number of issues: first, parameters α and β provide an idea of the nature of volatility in these countries, including its degree of persistence; and second, and more important, the estimation of (2') will provide information on whether during this period there has been an emerging markets "volatility contagion." If such effect exists, the estimated coefficient of MEXVOL will be positive and significantly different from zero. Third, the comparison of the estimated value of γ for Chile and Argentina will provide some information on the interest rate volatility process in these two countries. If, as the authorities expected, Chile's capital controls have been effective we would expect a smaller coefficient of γ in Chile than in Argentina. And fourth, the estimation of these equation will allow us to compute estimated series of conditional interest rate volatility in the two countries. The evolution of these series through time will shed some light – but only some — on how the different institutional settings affect interest rate volatility in these two nations.

To the extent that there is some kind of international arbitrage, nominal interest rates in a particular country will be linked to world interest rates, expectations of devaluation and risk premia. This means, then, that Δr_t will capture changes in these open economy variables, and that η_t will reflect innovations related to these variables. My interest, in estimating (1') and (2') is to investigate whether there is an *independent* role for emerging market volatility contagion. If this is the case the estimated value of γ will be significantly positive.

[13] For both countries I also estimated an equation for the mean that included, in addition to an AR(1) term, changes in US short term interest rates and an indicator for expectations of devaluation. The results obtained for the conditional variance equation were very similar to those reported here.

Tables 3 and 4 contain the conditional variance estimates for Argentina and Chile. N is the number of observations; LM test is Engel's test for the presence of residual conditional heteroskedasticity; and Wald χ^2 is a test for the null hypothesis that $\alpha + \beta = 1$.[14] Several interesting results emerge from these tables. First, a GARCH(1,1) model seems to perform rather well, with the coefficients of both lagged squared innovations and the lagged variance being always significantly different from zero. Higher order GARCH representations did not perform as well, when measured by the value of the log likelihood function. Second, and related to the previous point, according to Engel's LM test, the hypothesis that some conditional heteroskedasticity remains in the residuals is rejected in all cases.

Third, and more important for the current study, these results show a very different effect of Mexico's volatility spillovers on Argentina and Chile's conditional variances. While in the case of Argentina the coefficients of Mexican volatility indexes are significantly different to zero in *every* regression, they are *never* significant in the case of Chile. This suggests, quite strongly, that while Argentina was subject to "volatility contagion" during this period, Chile was spared from it.[15] There are two possible explanations for these results. First, it is possible that during this period international investors considered that Chile had a stronger economy and that, as a consequence, they did not pass onto Chile apprehensions stemming from Mexico. Another way of putting this, is that while during this period international investors differentiated between Chile and Mexico, they did not differentiate between Argentina and Mexico. The second possible explanation is that the existence of capital controls in Chile during this period

[14] The results in Tables 3 and 4 were obtained when contemporaneous Mexican volatility was considered. If these indexes are entered with one period lag, the basic results are still maintained.

[15] This result is independent of the sample used. When the Argentine equations are reestimated for the shorter period for which there are data for Chile, the basic results did not change.

Table 3. Interest Rate Volatility in Argentina*
(GARCH Estimates: Weekly Data 1992-1998)

	EQ 3.1	EQ 3.2	EQ 3.3	EQ 3.4
C	0.010	0.020	-0.002	0.010
	(1.37)	(6.245)	(-0.456)	(3.045)
ε_{t-1}^2	0.864	0.439	1.248	0.507
	(7.669)	(8.706)	11.301)	(7.806)
σ_{t-1}^2	0.407	0.588	0.377	0.556
	(7.669)	(26.548)	(14.295)	(18.109)
GARCHMEX	0.008	—	—	—
	(7.847)			
DUMMEX	—	6.586	—	—
		(11.001)		
ABSDMEX	—	—	0.018	—
			(4.593)	
GARCHMEXDEV	—	—	—	0.034
				(10.238)
N	333	333	333	332
LM Test	4.41	4.84	13.865	4.41
Wald χ^2	15.01	0.56	13.10	1.89

* The figures in parentheses are the t-values. See text for details.

partially insulated the country from short term external shocks. Naturally, these two possible explanations are not contradictory, and both of them could, indeed, play a role in explaining the results in Tables 3 and 4. In next section I investigate in some detail the extent to which Chile's capital controls actually succeeded in insulating the country from external disturbances.

Tables 3 and 4 show that in six out of the eight regressions it is not possible to reject the hypothesis that $\alpha + \beta = 1$, suggesting that we are really in the presence of IGARCH(1,1) models. In this case the unconditional variance does not converge to $(\varphi/ (1- \alpha - \beta))$, as in the most common case when $\alpha + \beta < 1$. As Campbell et al (1997) have argued, however, there will still be a nondegenerate stationary distribution for σ^2_t. In the regressions on Argentina and Chile in Tables 3 and 4, the conditional expected value of volatility k weeks in the future will be equal to $(\sigma^2_t + k\,\varphi)$.

Table 4. Interest Rate Volatility in Chile*
(GARCH Estimates: Weekly Data 1994-1998)

	EQ 4.1	EQ 4.2	EQ 4.3	EQ 4.4
C	0.401	0.400	0.348	0.406
	(4.188)	(4.209)	(3.019)	(4.313)
ε_{t-1}^2	0.489	0.486	0.505	0.491
	(3.807)	(3.788)	(3.901)	(3.755)
σ_{t-1}^2	0.462	0.465	0.456	0.454
	(5.686)	(5.662)	(5.776)	(5.483)
GARCHMEX	-0.001	—	—	—
	(-0.623)			
DUMMEX	—	-0.501	—	—
		(-0.946)		
ABSDMEX	—	—	0.011	—
			(0.267)	
GARCHMEXDEV	—	—	—	-0.001
				(-0.552)
N	227	227	227	228
LM Test	4.57	8.487	8.37	8.29
Wald χ^2	0.38	0.35	0.22	0.44

* The figures in parentheses are the t-values. See the text for details

An interesting question is whether the conditional volatility reacts to innovations on interest rate in a symmetric way. The estimation of threshold GARCH models suggest that in both countries negative innovations to nominal interest rates have a negative effect on the conditional variance. These estimates, not reported here due to space considerations, do not alter the findings regarding "volatility contagion" in Tables 3 and 4.[16] Finally, an analysis of the determinants of Mexico's interest rate volatility suggests that there is no "Argentine effect".

[16] On threshold GARCH models see, for example, Glosten et al (1990). The results on the threshold Garch for Chile and Argentina are available on request.

IV. Interest Rate Differentials, Convergence and Capital Controls

If there are no restrictions to capital mobility, and under the assumption of risk neutrality and in the absence of country risk, the uncovered interest arbitrage condition will hold, and deviations from it would be white noise and unpredictable. The speed at which these deviations from interest arbitrage are eliminated is an empirical question, but in a well functioning market one would expect it to happen rather fast. The existence of restrictions to capital mobility and of country risk, however, alter this basic equation in a fundamental way. In this case there will be an equilibrium interest rate differential (δ):

$$\delta_t = r_t - r^*_t - E\Delta e_t = k + R + u_t \qquad (3)$$

Where r_t is the domestic interest rate, r^*_t the international interest rate for a security of the same maturity and risk characteristics, $E\Delta e$ is the expected rate of devaluation, k is the tax equivalence of the capital restriction, R is the country risk premium, and u_t is an iid random variable. As in the case of free capital mobility, if at any moment in time the actual interest rate differential exceeds (k + R), there will be incentives to arbitrageurs to move funds in and/or out of the country. This process will continue until the equilibrium interest rate differential is reestablished. The speed at which this process takes place will, in principle, depend on the degree of development of the domestic capital market, as well as on the degree of capital mobility existing in the country in question. Countries with stiffer restrictions will experience slow corrections of deviations from the equilibrium interest rate differential (Dooley 1995, Dooley et al 1997). Additionally, as equation (3) shows, the degree of capital restrictions (that is, k) will also affect the value towards which the interest rate differential will converge. In this section I provide some evidence regarding uncovered interest rate differentials in our three

Latin American countries. I use monthly data to analyze the speed at which these differentials tend to disappear, and I investigate whether the imposition of capital controls in Chile in 1991 allowed the monetary authorities to have greater control on short term interest rates.[17]

Table 5 contains summary data on weekly deviations from uncovered interest parity between the three countries and the U.S. for 1992-1998. In calculating these data I have assumed that the public has rational expectations and that $\Delta e_t = E\Delta e_t + \mu_t$, where μ_t is a forecasting error with the usual characteristics. Thus, in the computation of interest rate differentials the expected rate of devaluation was replaced by the actual (annualized) rate of devaluation during the month in question. As may be seen, the average deviations declined steadily in Argentina between 1995 and 1998. Moreover, for the case of Argentina these series had the lowest standard deviations. A second interesting feature of these data is that the annual standard deviations are rather large and that, as a consequence, the 95% confidence interval are large, including in many years the zero value.

IV. 1. Uncovered Interest Rate Differentials and Convergence

In a world where there is (some) capital mobility one would expect that interest rate differentials would tend to converge to some equilibrium level determined by country risk considerations. This means that these series should be stationary and should not exhibit unit roots. Table 6 contains Augmented Dickey Fuller and Phillips-Perron unit root tests for monthly interest rate differentials for the three countries in the sample. For the case of Mexico two periods were considered, in order to avoid the effects of the 1994 devaluation on the computation of the test statistics. As may be seen, in all cases the null hypothesis of the presence of a unit root is rejected at conventional levels. Moreover, it is not possible to reject the alternative hypothesis that these series converge through time.

[17] Parts of this section draw partially on Edwards (1998b).

Table 5. Deviations from Uncovered Interest Parity with USA

	ARGENTINA					CHILE					MEXICO				
	Max	Min	Mean	SD	t	Max	Min	Mean	SD	t	Max	Min	Mean	SD	t
1992-98	36.14	-2.00	6.54	5.78	1.13	75.91	-67.49	6.78	21.24	0.32	262.71	-885.71	6.63	94.47	0.07
1992	36.14	5.40	15.63	5.97	2.62	na	na	na	na	na	37.89	-9.49	18.20	10.76	1.69
1993	26.52	3.96	9.12	4.37	2.09	na	na	na	na	na	63.88	-30.80	18.55	12.02	1.54
1994	8.61	1.38	4.80	1.62	2.96	48.42	-21.62	15.67	14.31	1.10	41.81	-885.71	-57.57	198.07	0.29
1995	20.54	3.35	7.29	4.50	1.62	75.91	-37.22	6.63	31.23	0.21	262.71	-235.11	20.17	105.94	0.19
1996	4.42	-0.07	2.64	0.79	3.34	24.93	-17.21	4.06	9.21	0.44	100.25	-51.20	28.80	26.90	1.07
1997	4.58	-2.00	1.78	1.07	1.66	40.88	-67.49	-0.82	22.30	0.04	61.37	-90.86	11.69	31.10	0.38
1998 (till June)	3.34	0.97	1.75	0.71	2.46	42.60	-41.83	6.30	19.30	0.33	28.17	-54.97	-0.59	25.73	0.02

Table 6. Unit Root Tests

	ARGENTINA	CHILE	MEXICO *92:1-94:11*	MEXICO *95:11-98:5*
ADF	-4.35	-4.56	-3.80	-5.18
Phillips-Perron	-4.37	-5.16	-4.42	-13.11

Note: All tests reject the hypothesis of a unit root at conventional levels of confidence.

An interesting question is whether the speed at which interest rate differentials tend to disappear differs across countries. Generally speaking, one would expect that countries where capital can move more freely will exhibit a more rapid convergence towards equilibrium. One way to test this proposition is by estimating some form of autoregressions for each country.

Assume that interest rate differential can be represented by the following univariate process:

$$B(L)\,\delta_t = \alpha + G(L)\,u_t, \tag{4}$$

where L is the lag operator, B(L) and G(L) are polynomial functions of L, and α is a coefficient. The form of these polynomials will determine the dynamics of δ_t, including whether it will converge to a steady state value. This steady state, in turn will be determined by the form of the two polynomials and by α. The simplest case is obtained when:

$$B(L) = 1 - \beta L; \quad G(L) = 1. \tag{5}$$

In this case interest rate differentials are characterized by an AR(1) process, and to the extent that β lies inside the unit circle, δ will converge to $(\alpha / (1 - \beta))$. In the absence of controls and with a zero country risk premium, we would expect $(\alpha / (1 - \beta)) \cong 0$, with interest rate differentials converging to zero. Moreover, in this case, we would expect that β would be rather low, with interest rate differentials disappearing very rapidly. With country risk and capital restrictions, however, α would be different from zero, β will be rather high, and interest rate differentials will converge to a positive value.

Table 7 presents results from the estimation, using Seemingly Unrelated Regressions, of AR(1) equations for Argentina and Chile, for 1995-1998:6.[18] "Wald" is a test for equality of the AR coefficients across the two countries. A number of interesting features emerge from this table. First, in both countries the AR coefficient is significantly smaller than one. Second, and contrary to expectations, the point estimate of the AR coefficient is larger for Argentina than for Chile. As pointed out above, due to the existence of capital restrictions in the latter country, the opposite result was expected. However, as the Wald statistic shows, in spite of this difference in the point estimates, it is not possible to reject the hypothesis that these coefficients are equal across countries. Third, the R^2 coefficient is much higher for Argentina than for Chile. This is possibly the result of the high monthly variability exhibited by Chile's exchange rates – and thus rate of devaluation – during this period. In order to address this issue, in the analysis of Chile's interest rate differentials that follows I used estimated one step-ahead forecasts of devaluation to construct alternative series for uncovered interest rate differentials.

IV. 2. Capital Controls and Interest Rate Convergence: Chile's Experience

Since the mid 1980s Chile's monetary authorities have used interest rate targeting as one of the main – if not the main – antinflationary tool. More specifically, as a way to reduce inflation the central bank has systematically attempted to maintain relatively high interest rates. This policy, however, became increasingly difficult to sustain during the late 1980s and 1990s when,

[18] Due to the break introduced to the series by the 1994 devaluation, Mexico was excluded from this estimation.

Table 7. Convergence of Uncovered Interest Rate Differentials in Argentina and Chile: Monthly Data, 1994-98* (Seemingly Unrelated Regressions)

	ARGENTINA	CHILE
Constant	3.224	17.072
	(3.197)	(0.975)
δ_{t-1}	0.523	0.383
	(4.440)	(2.318)
Time	-0.037	-0.216
	(-2,816)	(-0.858)
R^2	0.631	0.132
Durbin Watson	1.722	1.896
Wald	1.173	—

*The numbers in parentheses are t-statistics. See text for details.

as a result of Chile's improving stance in international financial markets, higher domestic rates started to attract increasingly large volumes of capital. A fundamental objective of the capital restrictions policy in effect since 1991, then, has been to allow the country to maintain a higher interest rate. According to Cowan and de Gregorio (1997), "capital controls allowed policy makers to rely on the domestic interest rate as the main instrument for reducing inflation…[T]he reserve requirement has permitted maintaining the domestic interest rate above the international interest rate, without imposing excessive pressure on the exchange rate (p.16)". In this subsection I use a battery of time series estimates to formally investigate the way in which capital restrictions have, in fact, affected interest rate differentials, and thus the ability to perform independent monetary policy, in Chile.

Equation (3) provides a useful, and very simple, framework, for evaluating the extent to which Chile's capital controls, affected the authorities' ability to control – at least partially – interest rates. In a world with changing policies, k is not constant through time. With other things given, it would be expected that the imposition (or tightening) of capital restrictions will have two effects on the behavior of the interest rate differential. First it will increase the value towards which this differential converges; second, it will reduce the speed at which this convergence takes place. This means, under stricter restrictions on capital mobility the monetary authority gains greater control over domestic interest rates in two ways: first, it can maintain a higher interest rate differential – that is, the steady state value of δ will be higher than what it would have been otherwise — , and second, δ can deviate from its long run equilibrium for longer period of times.

If there are policy changes – and, in particular, if there are changes in the extent of capital restrictions – we would expect that the parameters in equation (4) will change. The extent and importance of these changes can be analyzed empirically by identifying and estimating univariate models of interest rate differentials for different periods of time. Table 8 presents the results obtained for Chile from the estimation of a number of alternative ARMA processes for δ for four different time periods.[19] Since in all cases the AR(1) representation proved to be adequate, in the discussion that follows I will concentrate on these results. It is particularly interesting to compare the no-restrictions period (1988:01-1991:06) with the restrictions period (1991:07-1996:12). As may be seen, the AR coefficient is slightly lower in the second (no capital restrictions) subsample (0.40), than in the first one (0.46). This is contrary to what was expected; however, the difference is not statistically significant, as a test statistic rejects strongly the hypothesis of different AR coefficients across samples. According to these results the point estimate of the α coefficient is higher in the first subsample, although once again the difference is not statistically significant.

The results obtained from this specific splitting of the sample, then, may be interpreted as suggesting that there are very few, if any, differences in the dynamics of interest rate differentials in these two periods. These results, however, should be interpreted with care, since they are subject to at least

[19] Since Datastream only has Chilean data since 1992, the data in these regressions were taken from the International Financial Statistics. Expected devaluation was calculated as a one step ahead forecast from and ARMA(1,1) model for devaluation in Chile.

Table 8. Measure Of Persistence: Chile - Different Samples

Model Specification	Constant	Inverted	AR Roots	Inverted	MA Root	Q-Stat	
						p=5	p=10
1982:11-1996:12							
AR(1)	0.06	0.45			1.35	4.56	
AR(2)	0.06	0.42	0.04		1.20	4.25	
MA(1)	0.06			-0.40	8.65	10.65	
MA(2)	0.06			-0.23+0.37i	-0.2-0.37i	1.35	4.27
ARMA(1,1)	0.06	0.43		-0.03		1.24	4.35
ARMA(2,2)	0.06	0.31	-0.12	-0.14+0.26i	-0.14-0.26i	0.93	3.99
1982:11-1991:06							
AR(1)	0.05	0.18				8.35	18.87
AR(2)	0.04	0.13-0.29i	0.13+0.29i			8.18	19.51
MA(1)	0.04			-0.26		6.73	17.31
MA(2)	0.04			-0.14+0.24i	-0.14-0.24i	5.46	15.77
ARMA(1,1)	0.04	-0.02		-0.28		6.85	17.46
ARMA(2,2)	0.04	0.05+0.32i	0.05-0.32i	-0.09+0.37i	-0.09-0.37i	5.06	15.75
1988:1-1991:06							
AR(1)	0.12	0.46				2.30	4.83
AR(2)	0.12	0.26-0.31i	0.26+0.31i			1.00	3.29
MA(1)	0.12			-0.61		0.25	2.13
MA(2)	0.12			0.05	-0.64	0.38	2.25
ARMA(1,1)	0.12	-0.31		-0.84		2.05	3.86
ARMA(2,2)	0.17	0.87	-0.55	0.97	-0.98	4.19	8.54
1991:7-1996:12							
AR(1)	0.09	0.40				7.65	9.82
AR(2)	0.09	0.25+0.4i	0.25-0.4i			5.33	6.90
MA(1)	0.09			-0.44		8.18	10.02
MA(2)	0.09			-0.26-0.22i	-0.26+0.22i	6.10	7.92
ARMA(1,1)	0.09	0.15		-0.35		6.62	8.34
ARMA(2,2)	0.09	0.53+0.28i	0.53-0.28i	0.80	-0.17	1.96	3.81

two limitations: first, during the period under analysis the country risk premium associated with Chile experimented some important changes. This means that α in equation (4) will tend to change through time. Additionally, α will also tend to change since the implicit tax on the restriction capital mobility (k) is a function of r*. Second, it is possible that the dynamics of interest rate differentials did not change exactly at the time of the imposition of the restrictions – after all the implicit tax was rather small at first, and there was substantial evasion.

These issues were addressed in two ways: First, I added Chile’s ranking in Euromoney’s Country Risk Ratings as a proxy for the country risk premia, as well as the US interest rate to the regression. And second, I considered two alternative dates for splitting the sample: July, 1992 and January 1993. Both of these dates correspond to a tightening of the inflows restrictions. The inclusion of the country risk proxy and of the international interest rates had no significant effects on the estimation; in fact, the sign of the country risk proxy was the opposite of what was expected and non significant, while that of the international interest rate was non significant. Changing the dates did, on the other hand, have an effect on the estimation. This may be seen in Table 9, where the results from an augmented equation for the dynamics of interest rate differentials are presented. In this equation dummy variables that take the value of one for the post restrictions period have been included. Two interesting features emerge from this table. First, the coefficient of lagged differentials is higher for both post restrictions periods. Moreover, as may be seen the results indicate that the (δ DUMMY) variable is marginally significant. This suggests that during (at least some of) the post restrictions period interest rate differential were more sluggish than in the pre-restrictions period. This supports the notion that the restrictions allowed the monetary authorities greater short term control over domestic interest rates. The fact, however, that the estimated valued of the constant experienced a slight decline in the post restrictions period suggests that the authorities may not have had as much control over interest rates in the longer run.

In order to investigate the dynamic behavior of interest rates further I estimated the following equation using a rolling regressions technique and monthly data:

$$\delta_t = \alpha + \beta \, \delta_{t-1} + u_t \tag{6}$$

Table 9. Dynamics of Interest Rate Differential: in Chile, 1988-96 (monthly data)

	(EQ 2.1)[a]	(EQ 2.2)[b]
Constant	0.12	0.15
	(1.76)	(1.85)
Dummy	-0.042	-0.051
	(-1.239)	(-1.323)
δ_{t-1}	0.311	0.324
	(2.763)	(2.792)
δ_{t-1} * Dummy	0.218	0.152
	(1.887)	(1.787)
Risk	-0.002	-0.003
	(-1.081)	(-1.049)
r*	1.183	0.807
	(1.343)	(0.822)
DW	1.81	1.81
R^2	0.23	0.23
N	108	108

Two alternative windows for 24 and 36 months were considered. The estimated coefficients were then used to estimate a rolling value of the steady state interest rate differential. These results are presented in Figure 4, 5 and 6. In constructing these figures I dated each coefficient by the last observation included in the sample. For example, in the case of the 24 months window, the observation for 1995:06 corresponds to the respective coefficient estimated using a sample spanning from 1993:06 through 1995:06. To the right of the vertical lines, then, the complete sample used to estimate the coefficients corresponds to the post restrictions period. These results suggest the following: in the post restrictions period the degree of persistence of interest rate differentials (the estimated value of β) has increased slightly. This happened after a period (1990-93) of gradual decline in persistence, which largely corresponded to the decline in Chile's risk premium. Although the increase in β has been rather small, the trend is quite clear, and supports the view that, as the authorities had intended, the imposition of restrictions

Figure 4. Chile: Alpha in AR(1) Process

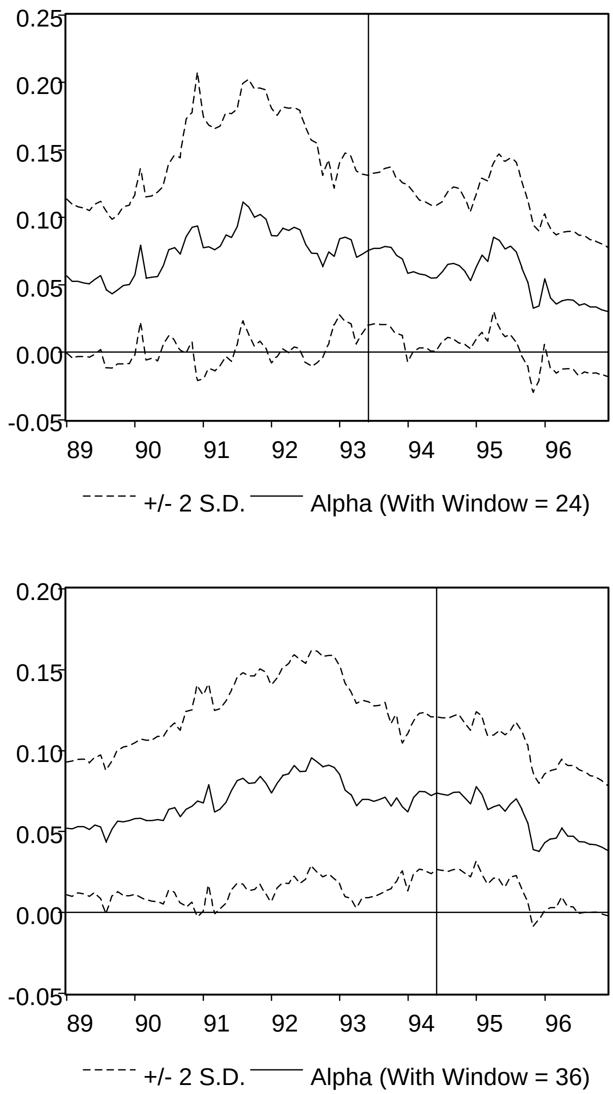
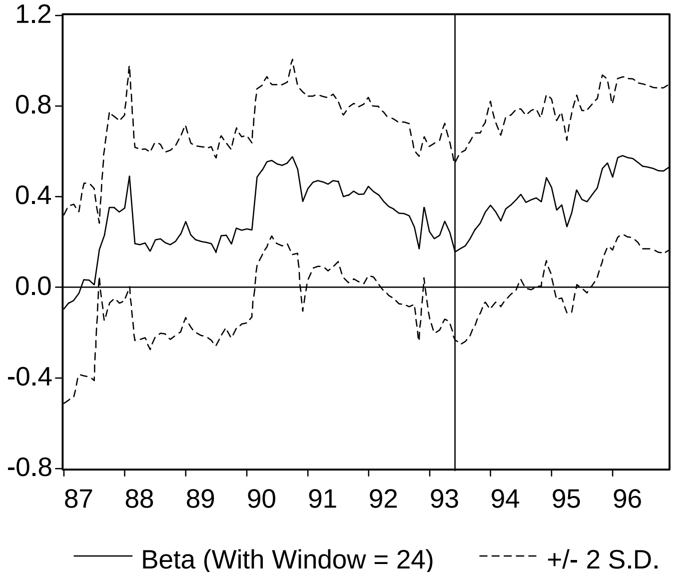


Figure 5. Chile: Beta in AR(1) Process



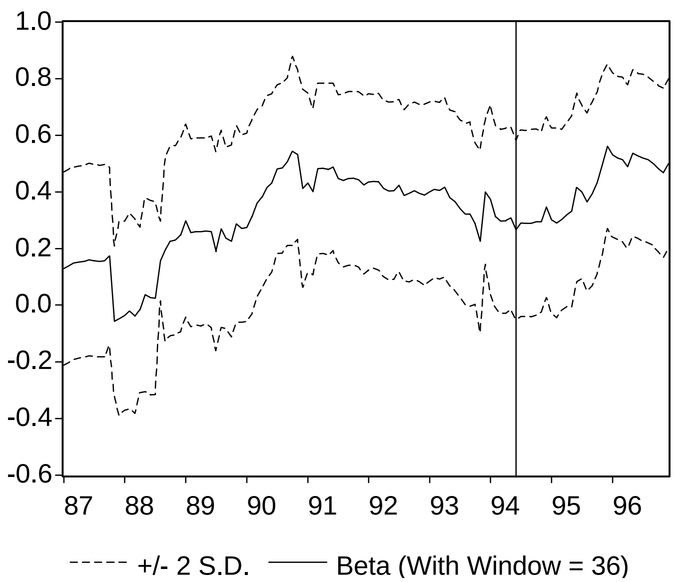
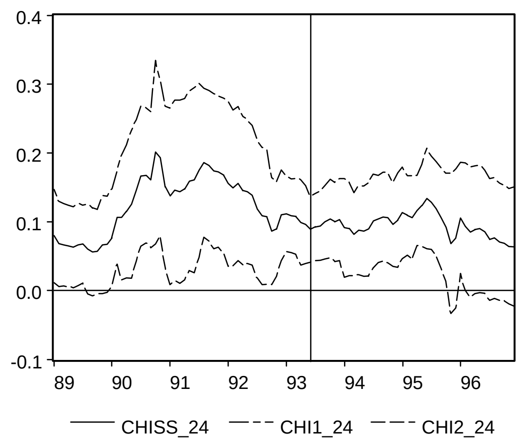
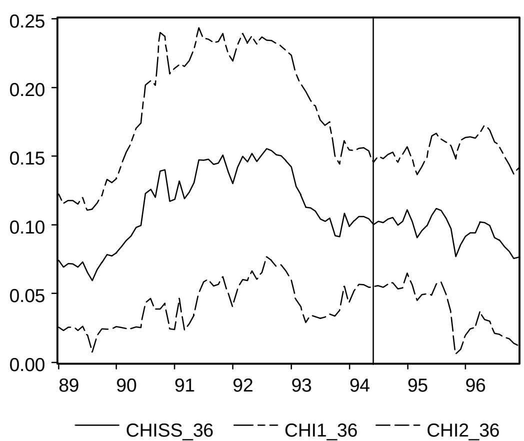


Figure 6. Chile: Steady State in AR(1) Process





on capital movements increased their short term control over domestic interest rates. The results in Figure 6 on the rolling estimates of the steady state interest rate differentials are less clear cut. However, regarding the post restrictions period, these estimates (and in particular the 24 months window estimates) suggest that the steady state differential trended gently upward until mid 1995; from that time onward a decline is observed. The most likely explanation for this reduction in the equilibrium differential is the recent improvement in Chile's country risk position. Although these results cannot be considered as conclusive or definitive, they do provide a note of skepticism on Chile's ability to control interest rate differentials over the longer run.

References

Bekaert, G., R.J. Hodrick and D. A. Marshall (1997), "On Biases in Tests of the Expectations Hypothesis of the Term Structure of Interest Rates", *Journal of Financial Economics*

Bollerslev, T., R.Y. Chou and K.F. Kroner (1992), "ARCH Modelling in Finance: A Review of the Theory and Empirical Evidence", *Journal of Econometrics*, 52

Campbell, J. Y., A. Lo and MacKinlay (1997) *The Econometric of Financial Markets*, Princeton University Press

Cowan, K. and J. de Gregorio (1997). "Exchange Rate Policies and Capital Account Management: Chile in the 1990s", Departamento de Ingenieria Industrial, Universidad de Chile Working Paper.

Dooley, Michael (1995). "A Survey of Academic Literature on Controls over International capital transactions", IMF Working Paper 95/127.

Dooley, Michael, D. Mathieson and L. Rojas_Suarez 1997 "Capital Mobility and Exchange Market Intervention in Developing Countries", NBER Working Paper, 6247.

Dornbusch, R. and S. Edwards (1993) "Exchange Rate Policy and Trade

Strategy" in B. Boswoth et al (eds) *The Chilean economy: Policy Lessons and Challenges*, Brookings Institution

Edwards, Sebastian. 1985. "Money, the Rate of Devaluation, and Interest rates in a Semi-open Economy: Colombia, 1968-82." *Journal of Money, Credit and Banking*, 17 no.1. 59-68.

Edwards, S. (1995) *Crisis and Reform in Latin America: From despair to Hope*, Oxford University Press

Edwards, S. (1998a) "The Mexican Peso Crisis: What did we Know? When did we Know it? *The World Economy*

Edwards, S. (1998b) "Capital Flows, Real Exchange Rates and Capital Controls: Some Latin American Experiences: *NBER Working Paper*

Edwards, S. and M. A. Savastano (1998) "The Morning After: The Mexican Pesos in the Aftermath of the 1994 Devaluation", *NBER Working Paper*

Glosten, L.R., R. Jagannathan and D. Runkle (1990), "On the Relationship Between the Expected Value and the Volatility of Excess Returns on Stocks", *Journal of Finance*, 48

King M.A. and S. Wadhwani (1990) "Transmission of Volatility Between Stock Markets" *The Review of Financial Studies*, 3,1

Marston, R. (1993), "Interest Differentials Under Bretton Woods and the Post-Bretton Woods Float", in M. Bordo and B. Eichengreen (eds) *A Retrospective on the Bretton Woods System*, University of Chicago Press

Rodriguez, C.A. (1994), "Interest Rates in Latin America", *CEMA Working Paper* 98

Roll, R. (1997) *Nominal Interest Rates and Loan Volume with Heterogeneous Beliefs*, New York University Solomon Center, 6, 3