Indian Capital Control Liberalization: Estimates from NDF Markets *

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Abstract

The Indian government has taken a number of incremental measures to liberalize legal and administrative impediments to international capital movements in recent years. This paper analyzes the extent to which the effectiveness of capital controls in India, measured by the domestic less net foreign interest rate differential (deviations from covered interest rate parity) have changed over time. We utilize the offshore non-deliverable forward (NDF) market to measure the effective foreign interest rate (implied NDF yield). Using the self exciting threshold auto-regressions (SETAR) methodology, we estimate a no-arbitrage band width whose boundaries are determined by transactions costs and capital controls. Inside of the bands, small deviations from CIP follow a random walk process. Outside the bands, profitable arbitrage opportunities exist and we estimate an adjustment process back towards the boundaries. We allow for asymmetric boundaries and asymmetric speeds of adjustment (above and below the band thresholds), which may vary depending on how arbitrage activity is constrained by capital controls. We estimate these parameters over the pre- and post-liberalization periods in order to capture the *de facto* effect of capital control liberalization. We find that *de facto* capital control barriers: (1) are asymmetric over inflows and outflows, (2) have relaxed over time due to a relaxation in constraints on outflows, and (3) have little measurable impact on inflows. We also find that arbitrage activity rapidly closes deviations from UIP when the threshold boundaries are exceeded.

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1. Introduction

In the 1980s, India began to liberalize its economy to increase its market orientation. Market-oriented reforms were expanded beginning in 1991, after a balance of payments crisis and a rapid economic expansion supported by expansionary fiscal policy and current account deficits. Key components of the reforms were removal of government licensing controls on domestic industrial activity and trade liberalization. Trade liberalization reduced tariffs dramatically and replaced quantitative trade restrictions with tariffs.

As a complement to the trade liberalization, effective current account liberalization, as measured by acceptance of IMF Article VIII was achieved by August 1994. However, Indian policy-makers have proceeded with caution in liberalizing capital flows as there is less theoretical agreement on the economic benefits of capital account liberalization, and in light of the recent externally-triggered financial crises in emerging economies. Various steps have been taken liberalize the capital account and to allow certain kinds of foreign capital flows, but a host of restrictions and discretionary controls remain. In fact, according to the popular Chinn-Ito (2007) index of capital account openness, which relies on measured *de jure* controls, India remains one of the most closed economies on the capital account, scoring the second lowest score on the index in the year 2006.[1]

In this paper we examine the *de facto* effects of India capital account liberalization by measuring deviations from covered interest parity (CIP) over time. An extensive literature investigates deviations from CIP, inferring market segmentation to

[1] China, Turkey, Pakistan and South Africa were other emerging markets that had the same score as India in 2006, the last for which Chinn-Ito rankings are available.

capital controls, transactions costs and other institutional impediments to arbitrage. Studies that have estimated deviations from CIP as an indication of international financial market integration in various contexts include Frankel and Levich (1975), Taylor (1989), Frankel (1991) and others. Our approach follows one strand of this literature by measuring a no-arbitrage band for small deviations from CIP where the upper and lower threshold points are determined by the intensity of capital controls and transaction costs. Within the bands, we expect deviations from CIP to be random, and outside the bands we expect arbitrage (profit opportunities) pressures to systemically return deviations to the band thresholds. We divide the sample into pre- and post-liberalization periods to examine the effects of liberalization on the threshold boundaries of the no-arbitrage band and speeds of adjustment. A narrowing of the bands over time is an indication of greater de facto capital account openness, as is an increase in the speed of adjustment to the band threshold points (indicating arbitrage acts more rapidly in returning the market closer to CIP).

A central problem in estimating bands and adjustment speeds is that it requires a non-linear estimation methodology. An innovation of our work is to employ the self exciting threshold auto-regressions (SETAR) methodology in order to obtain consistent estimates of the upper and lower threshold points of the no-arbitrage band, as well as estimates of the speeds of adjustment (possibly asymmetric) to the boundaries. The SETAR model is a particular class of piece-wise autoregressive models and may be seen as a parsimonious approximation of a general non-linear autoregressive model (Hansen, 1999). Another distinguishing feature of our empirical work is to measure the CIP relationship using the net foreign interest rate from the implied yield derived from the off-shore non-deliverable forward rate (NDF) and the LIBOR dollar interest rate. The off-shore NDF rate is a market determined forward rate free of capital controls and the implied yield represents the net covered rate of return that would be available on Indian short-term financial instruments in the absence of capital controls. The domestic onshore rate to which the implied NDF yield in compared is the Mumbai Interbank Offer Rate (MIBOR). We consider one- and three-month maturities.

Ma et al. (2004) and Misra and Behera (2006) have examined variations in deviations from CIP arbitrage conditions in India over time using simple summary statistics and qualitative methods, but not with more formal statistical modeling. They find that smaller deviations from covered interest parity are an indication of greater capital account openness since the advent of India’s capital control liberalization. Pasricha (2007), investigating interest rate differentials, also finds that India is *de facto* more open than *de jure* measures such as the Chinn-Ito index suggest.

The next section discusses the liberalization of capital controls in India and the development of the NDF market. Section 3 presents some summary and preliminary analysis of the data, including unit root tests, and investigates structural change in the speed by which deviations from CIP reduced in the context of linear autoregressive models. Section 4 presents the SETAR non-linear model and reports our main empirical results, i.e. estimates of the upper and lower threshold points of the no-arbitrage bands and the speed of adjustment to bands. Section 5 presents our conclusions.

2. Non-Deliverable Forward Markets and Covered Interest Parity

Capital Account Liberalization in India

While measures aimed at current account convertibility in India were implemented early in the reform process, there was concern about possible linkages between capital account and current account transactions, such as capital outflows masked as current account transactions through mis-invoicing. As a result, certain foreign exchange regulations stayed in place, including requirements for repatriation and surrender of export proceeds (allowing some fraction to be retained in foreign currency accounts in India for approved uses), restrictions on dealers and documentation for selling foreign exchange for current account transactions, and various indicative limits on foreign exchange purchases to meet different kinds of current account transactions.[2]

In 1997, a government-appointed committee on Capital Account Convertibility (CAC) provided a road map for liberalization of capital transactions. The committee's report emphasized various domestic policy measures and changes in the institutional framework as preconditions for full CAC. These included fiscal consolidation, low inflation, adequate foreign exchange reserves, and development of a more robust domestic financial system. On the matter of the exchange rate regime, however, the report did not squarely tackle the issue of the "impossible trinity," and the challenge of managing domestic monetary policy and an effectively pegged exchange rate in the face of large foreign capital flows has plagued the RBI in recent years. While the Asian crisis and subsequent contagion that spread through 1997-98 derailed the committee's recommended timetable, significant liberalization of the capital account has occurred in

[2] Jadhav (2003) provides a review of India's experience with capital controls and capital account liberalization through 2002. In general, like the RBI, Jadhav is relatively cautious about the benefits of such liberalization, and sympathetic to a gradualist approach.

the last decade, particularly with respect to inward foreign investment, aided in part by improved macroeconomic indicators and financial sector reform.

As pointed out by Shah and Patnaik (2005), the easing of capital controls, particularly on portfolio inflows, has been a series of small changes, within a continuing web of detailed quantitative restrictions operated by the RBI. Similar complex restrictions apply to FDI inflows. There are also restrictions on outflows, including external commercial borrowing, and these restrictions have fluctuated over time (sometimes easing, sometimes tightening). Furthermore, as noted by Shah and Patnaik (2005), foreign investment in bonds remains considerably restricted. Another feature of capital controls in India is that foreign entities sometimes have more leeway than domestic institutions in engaging in certain kinds of forward transactions.

Non-deliverable Forward Market

A consequence of these capital controls is the development of a Non-Deliverable Forward (NDF) market. An NDF market develops when the onshore forward markets are either not developed or have restricted access (evidence of exposure requirements in the Indian case). These markets, which are located offshore - i.e. in financial centers outside the country of the restricted currency - and involve contract settlement without delivery in the restricted currency, allow offshore agents with the restricted-currency exposures to hedge their exposures and speculators to take a position on the expected changes in exchange rates or exchange rate regimes. Also active in the NDF markets are arbitrageurs who have access to both forward markets. Volumes in the NDF market increase with increasing interest or investment in the currency and with increasing restrictions on convertibility. When currencies are fully convertible, NDF markets are not observed.

The Indian rupee NDF market is most active in Singapore and Hong Kong, with Dubai as an emerging center. The dominant players in this market are the speculators who want to take a position in the currency, and the arbitrageurs, mainly Indian exporters and importers who have access to both the onshore forward market and the NDF market (Misra and Behera, 2006). The NDF rate therefore, serves as an important indicator of the expected future exchange rate of the rupee. This rate also implies a corresponding interest rate, which is called the NDF implied yield, calculated as follows:

$$r = \frac{F_N}{S}(1 + i_\$) - 1,$$

where S is the spot exchange rate of the US dollar in terms of rupee, F_N is the NDF rate of a certain maturity and $i_\$$ is the interest rate on dollar deposits of corresponding maturity (LIBOR rates). Then, r is what the onshore yield would be, if there were no capital controls and if CIP held. The (annualized) difference between the actual onshore yield (i, the MIBOR rate for the corresponding maturity) and r is our measure of the covered interest parity differential.

Without restrictions on capital flows between two countries, deviations from covered interest parity (CIP), which is basically a "no-arbitrage" condition, would be small and simply reflect transactions costs. Large and persistent positive onshore-offshore differentials (i-r), on the other hand, reflect effective stemming of capital inflows and a negative differential suggests an effective stemming of capital outflows. The speed with which deviations from CIP are eliminated is then an indicator of how effective that arbitrage is between the two markets, and therefore of how effective the capital controls are.

As described by Shah and Patnaik (2005), Indian banking regulations restrict banks' ability to arbitrage deviations from CIP. Although importers and exporters are allowed to use the onshore forward market ("permitted hedgers"), they do not themselves have the financial capabilities to arbitrage as financial institutions would if permitted to do so. Hence, deviations from CIP persist systematically.[3] At the same time, if there are *some* arbitrage avenues for market participants, then the speed with which deviations from CIP are eliminated (or reduced) should be an indicator of how effective that arbitrage is in the actual working of the market.

3. Preliminary Survey of the Data

Figure 1 shows the evolution of the annualized deviations from covered interest parity (CIP), as defined in the previous section, calculated for NDF contracts and interest rates of 1-month maturity[4]. The graph starts in January of 1999 and ends in January of 2008. Figure 2 shows a similar series calculated using 3-month instruments. Large and persistent deviations from CIP are evident, indicating large transactions costs and the effectiveness of capital controls. In 2005, the 1-month series exhibits a 1000 basis point deviation from CIP indicating that, in the absence of capital controls and transactions costs that an arbitrageur could have received over $100,000 per year for every $1 M of

[3] If forward rates are determined primarily by expected future currency needs from importers and exporters, rather than by pure arbitrage, the direction of deviation from CIP can be an indicator of market expectations with respect to future currency appreciation or depreciation. Shah and Patnaik (2005) give examples in India in 1993-94 and 1997-98 where expectations as implied by the direction of CIP deviation turned out to be incorrect. However, their regression analysis indicates that, barring some outlier events, expectations of currency movements as implied by CIP deviations have been correct on average.

[4] The data on NDF contracts is from Bloomberg and the MIBOR rates and sport rates are from Global Financial Database and LIBOR rates are from Federal Reserve Board's online database.

volume transacted completely risk free and without committing any capital. Clearly, these deviations indicate that capital controls must have some effect on these markets as the deviations are much too large to be explained by typical transaction costs or inattention.

As a preliminary statistical analysis, Table 1 contains the results of Augmented Dicky-Fuller (ADF) tests for evidence of unit root behavior in the CIP deviation series and the component interest rate series. The series labeled *NDF 1-mon* and *NDF 3-mon* are the implied Rupee returns to the LIBOR series, adjusted for the cost of cover in the non-deliverable forward exchange market.[5] The series labeled *Differential 1-mon* and *Differential 3-mon* are the differences between the Mumbai Interbank Offer Rate (MIBOR) series and the NDF series – i.e. the deviations from CIP. The results show that – as one would expect – that the CIP differential series do not exhibit evidence of a unit root whereas the interest rate series do.[6] The fact that the CIP series are stationary indicates that when the deviations get too large, arbitrage gradually reduce them towards zero. This very rough base line indicates that geographic market segmentation is not absolute.

To get closer to a measure of the *de facto* strength of capital controls, and especially the evolution of the strength of capital controls over time, we next analyze the speed at which CIP deviations tend back towards zero in the context of a linear autoregressive model. This is a preliminary analysis leading to our non-linear SETAR model presented in the next section. Here we estimate rolling regressions measuring the

[5] Essentially, these series are one half of the CIP relationship, the implied returns to an Indian investor or transacts in the sport exchange market, invests in LIBOR, and covers the transaction in the forward market.
[6] The exception is the 1-month NDF series which rejects the NULL of a unit root at shorter lag lengths but not at longer lengths.

autoregressive parameter of the CIP series and charting how it changes over time.[7] The AR(1) parameter of the CIP series is a measure of how fast the series converges to a constant, and when we measure it in a relatively short, two year window, we expect that it is a measure of the level of arbitrage activity during that period.[8] The level of arbitrage activity is likely to be a function of the costs to arbitrage, imposed by capital controls, and the profitability to arbitrage, which is proportional to the magnitude of the deviation. The AR(1) parameter is therefore a rough measure of the strength of effective arbitrage.

Figures 3 and 4 show the evolution of the AR(1) parameter over time and the +/- 95% confidence bands for both the 1-month and 3-month series. Both series show quite a bit of variation indicating that arbitrage activity in these markets has probably fluctuated quite a bit in recent years.[9] Comparing Figures 3 and 4 with Figures 1 and 2, we can see that the AR(1) parameters exhibit a cyclical pattern consistent with the notion that larger deviations from CIP (thereby increasing the profitability to arbitrage) are associated with more rapid speed of adjustment towards zero, i.e. a lower AR(1) parameter. The pattern is most prominent in the 3-month series where we can see that the three local minimum in the AR(1) parameter, in early 2002, early 2005, and late 2007, correspond to periods of greatest deviation from CIP (note that the AR(1) parameter measured in late 2007 would have come from a regression on the previous 104 weeks of data). This pattern suggests that arbitrage pressures have increased. Both series exhibit a large downward movement

[7] In Figures 2 and 3 we use 2-year windows for our rolling regressions.
[8] An AR(1) parameter near one indicates a near unit root process where the time to adjust back to zero is nearly infinite, whereas a measurement near zero indicates nearly instantaneous adjustment.
[9] It is important to note that arbitrage activity is not speculative activity (which has also fluctuated over time). The two may be related in that speculative activity may cause a widening of the CIP differential thereby increasing the incentive to arbitrage.

toward the end of 2007, indicating that deviations from CIP are reverting to zero more quickly than at previous points in the sample.

The patterns we observe in these series point to the possibility that there are time-varying levels of arbitrage that may increase as threshold levels of CIP violation are reached. They also suggest the possibility that the degree to which capital controls bind arbitrage activity may have relaxed over time. In particular, capital controls therefore appear to have become weaker over 2006-2007. The next section investigates these possibilities more formally in a non-linear setting using the Self-Exciting Threshold Autoregressive (SETAR) model.

4. Self-Exciting Threshold Auto-Regression Tests of Capital Controls

Deviations from CIP may exhibit non-linear properties that linear statistical methods are not able to model. In particular, the presence of transaction costs and capital controls are likely to create bands, within which arbitrage will not be profitable. Outside of the no-arbitrage boundaries, or threshold values, arbitrage profit opportunities will be operative, with the strength of the return to the no-arbitrage boundaries depending on the specifics of capital controls and other institutional factors. The band threshold values and the speeds of adjustment above and below the bands may be asymmetric, reflecting the institutional specifics.

Linear models of deviations from CIP fail to take into account the possibility of bands, with random deviations from CIP within the bands and systematic adjustment towards CIP outside of the bands. The SETAR model is a particular class of piece-wise autoregressive models attributed to Tong (1978). Surveys of TAR and SETAR models,[10] respectively, are given by Potter (1999) and Hansen (1999). The SETAR model may be seen as a parsimonious approximation of a general non-linear autoregressive model (Hansen, 1999). The SETAR model is an appropriate statistical methodology for the problem we face in terms of bands and adjustment parameters. Various SETAR models have been used in modeling industrial production, GDP, unemployment and, in work closest to our own, on interest rate parity conditions (Pasricha, 2007) and cross-market premia (Levy Yeyati, Schmukler and Van Horen, 2006).[11]

The Self-Exciting Threshold Autoregressive (SETAR) model that we estimate in this section allows for three regimes with differing autoregressive parameters and estimates the upper and lower thresholds which divide the three. In addition, we estimate the model over two regimes to reflect pre- and post-liberalization of capital controls. We implemented the following SETAR model:

$$\begin{aligned}
&\delta_t = \rho_i \delta_{t-1} + \varepsilon_{it} \;; && \kappa_n < \delta_{t-1} < \kappa_p \\
&\delta_t - \kappa_n = \rho_n (\delta_{t-1} - \kappa_n) + \varepsilon_{nt} \;; && \delta_{t-1} \le \kappa_n \\
&\delta_t - \kappa_p = \rho_p (\delta_{t-1} - \kappa_p) + \varepsilon_{pt} \;; && \delta_{t-1} \ge \kappa_p
\end{aligned}$$

where δ_t is our onshore-offshore differential, $\varepsilon_{nt} \sim N(0, \sigma_j^2),\ j = i, n, p$ and κ_n and κ_p are the negative and positive thresholds respectively. A model of this form assumes that within the bounds defined by κ_n and κ_p, speculative activity is not profitable

[10] As the names indicate, the SETAR model is a special case of the TAR model, in which regime-switch thresholds depend on lagged values of the autoregressive variable itself.

[11] Pasricha's study (2007) uses SETAR models to measure deviations from interest rate parity in 11 emerging market economies and, outside of crisis periods, assumes parameter stability. Levy Yeyati, Schmukler and Van Horen (2006) use data from nine emerging market economies to examine the ratio between the domestic and the international market price of cross-listed stocks, thereby providing a valuable measure of international financial integration. Note that the latter paper uses the general term TAR, but the model is in fact a SETAR model.

because of transactions costs and capital controls, so the differential inside the band may follow a unit root or otherwise non-stationary process.

With sufficiently strong arbitrage activity, however, the AR(1) process outside the bands will be stationary. This model assumes that speculative activity will push the deviations to the edges of the band, rather than to its center. If the thresholds were known, the model could be estimated by ordinary least squares applied separately to the inner and outer regime observations. The thresholds are not known, however, and we employ a grid search over possible threshold combinations. All the percentiles between the 5th and 95th percentiles are taken and separated into sets of negative and positive threshold candidates. The selected model is that combination of negative and positive threshold values that minimize the residual sum of squares. This estimation method is a type of constrained least squares, and yields estimates that are consistent (see Hansen, 1999 and Pasricha, 2007).

4.1 SETAR Results Using 1-Month Instruments

We focus initially on the behavior of prices in markets for 1-month instruments since they are the most liquid.[12] Table 4, panel A shows the measured values of the thresholds of the SETAR model using 1-month instruments. The top estimates are the full sample from early 1999 to early 2008.

Consistent with the large deviations from CIP in Figure 1, the difference between the upper and lower thresholds are 673 basis points in the AR(1) version of the model and 771 basis points in the AR(2) version. In both cases, the upper threshold and lower

[12] E.g. the majority of the volume in the inter-bank market is at relatively short maturities, less than one month.

thresholds are of very different magnitudes. When the CIP differential is positive, onshore rates are higher than covered offshore rates indicating arbitrage capital would profit by flowing into the country (going long the Rupee). The positive threshold is only 2 basis points in the AR(1) model and 77 basis points in the AR(2) model. These are relatively low barriers to arbitrage activity and are on the order of magnitude of estimates from CIP differentials in floating rate regimes.[13] The negative thresholds, on the other hand, are 671bp and 694bp for the AR(1) and AR(2) models respectively, indicating very high barriers to outflows. Given their magnitude, we find it implausible that these thresholds could represent market transaction costs or natural market barriers other than capital controls.

Below the full sample estimates in Table 4, Panel A, are SETAR estimates from both the first half and second half of the sample with the midpoint falling near the middle of 2003. Here we are testing to see if the thresholds have narrowed between the two sub-periods, indicating the capital control induced costs to arbitrage are lower. The differences between the thresholds have narrowed in both specifications, going from 760bp in the 1999-2003 period to 598bp in the 2003-2008 time period. This is a drop of 162bp, which represents a significant reduction in transaction barriers. Most of this adjustment necessarily occurs on the capital outflow threshold since the inflow threshold was very low to begin with. An even larger drop of 259bp occurs in the AR(2) specification. Despite this large drop, the lower threshold pertaining to capital outflows is still quite large in the 2003-2008 period, at between 500 and 600bp.

Turning to Table 5, Panel A, we see how the autoregressive parameters themselves have changed. Capital controls have the potential to affect the rate of mean

[13] Pasricha (2007) estimates the Dollar-Euro and Dollar-Pound bands to be around 20 bps.

reversion if they imply limits on the volume of flows that can be mobilized towards arbitrage activity or if they induce costs which increase with the scale of arbitrage (such as an increasing probability of getting caught, increasing capital losses in the event of getting caught, or timing risk if the four legs of the arbitrage peg cannot be executed simultaneously). In the full sample, we can see that the AR parameter outside the negative threshold appears to be negative and barely significant at standard levels. The same is true in both the first and second periods. A negative AR parameter would indicate an oscillatory component around the threshold value, which we interpret as instantaneous adjustment back to the threshold (the same interpretation holds if the AR parameter is zero). On the positive side, parameter values imply rapid but not instantaneous adjustment. Given the standard errors on the individual estimates, there is not much evidence of significant change in the AR parameters on the high or low regime from the pre-2003 to the post-2003 period.

In all, these results indicate a significant reduction in the barriers to arbitrage from the pre-2003 period to the post-2003 period. Moreover, most of the reduction seems to have taken place on the barriers to capital outflows, though barriers on outflows remained large. They also indicate very asymmetric transaction costs with barriers on outflows seemingly much higher than barriers on inflows, which are near zero in the AR(1) model and only 70-80bp in the AR(2) model. Finally, adjustment towards CIP is very rapid outside of the threshold values.

4.2 SETAR with 3-Month Instruments

With a few exceptions, the SETAR estimates using the 3-month instruments are qualitatively similar to those using the 1-month instruments. These are reported in Panel B of Tables 4 and 5. One point of difference is that in the 3-month, AR(1) model, the high threshold is quite a bit higher than in any of the 1-month regressions. This result seems to be driven by the threshold value in the second time period, which is 351bp and larger than the lower threshold which is only 110bp. Additionally, the change between the first and second period is much smaller with the 3-month, AR(1) model as compared with the 1-month models but the 3-month AR(2) model is of similar magnitude to the 1-month models. Finally, the size of the threshold differential seems to be somewhat smaller in the 3-month instruments for all but the full sample, AR(1) model. These smaller differences between the thresholds seem to be driven mostly by smaller barriers on the low side than were found with the 1-month instruments.

5. Conclusions and Policy Implications

This paper has investigated the effectiveness of Indian capital controls in creating a wedge between domestic and foreign implied yields using NDF rates (deviations from CIP). Our objective is to test whether the incremental moves to liberalize India’s capital controls in recent years have effectively narrowed the barriers to capital inflows and outflows. In this context, we postulate the existence of no-arbitrage bands where the boundaries are determined by transactions costs and limitations to arbitrage due to capital controls, and CIP deviations are random within the boundaries. We divide the sample into pre- and post-liberalization periods to examine the effects of liberalization on the threshold boundaries of the no-arbitrage band and speeds of adjustment. A narrowing of the bands over time is an indication of greater *de facto* capital account openness, as is an increase in the speed of adjustment to the band threshold points (indicating arbitrage acts more rapidly in returning the market closer to CIP). Inside of the bands, small deviations from CIP follow a process close to a random walk. Outside the bands, profitable and feasible arbitrage opportunities exist, and we estimate an adjustment process back towards the boundaries. We allow for asymmetric boundaries and asymmetric speeds of adjustment (above and below the band thresholds), which may vary depending on how arbitrage activity is constrained by capital controls.

We estimate this non-linear model with the self exciting threshold auto-regressions (SETAR) methodology in order to simultaneously obtain consistent estimates of a non-arbitrage band (upper and lower threshold points) and speeds of adjustment (possibly asymmetric) to the boundaries. In our data, when the series is in the interior regime its behavior is very close to a unit root indicating almost no convergence and almost no arbitrage activity. Outside the thresholds, all of our estimates indicate relatively rapid or instantaneous convergence. This pattern is consistent with the contention that capital controls imply a cost of arbitrage or induce riskiness to the arbitrage position. These unseen costs or risks induce a threshold effect where arbitrage will only become profitable (on a risk adjusted basis) outside a given level of CIP deviation.

In terms of the effects of India's liberalization of capital controls, our results indicate a significant reduction in the barriers to arbitrage from the pre-2003 period to the post-2003 period. We find very asymmetric transaction costs with barriers on outflows seemingly much higher than barriers on inflows. Although most of the reductions have taken place on the barriers to capital outflows, these barriers nonetheless remain large.

Moreover, adjustment towards CIP is very rapid outside of the threshold values. In sum, India's liberalization has had the effect of reducing the barriers to capital flows, but substantial barriers to capital outflows remain.

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Figure 1: CIP deviation series using 1-month instruments.

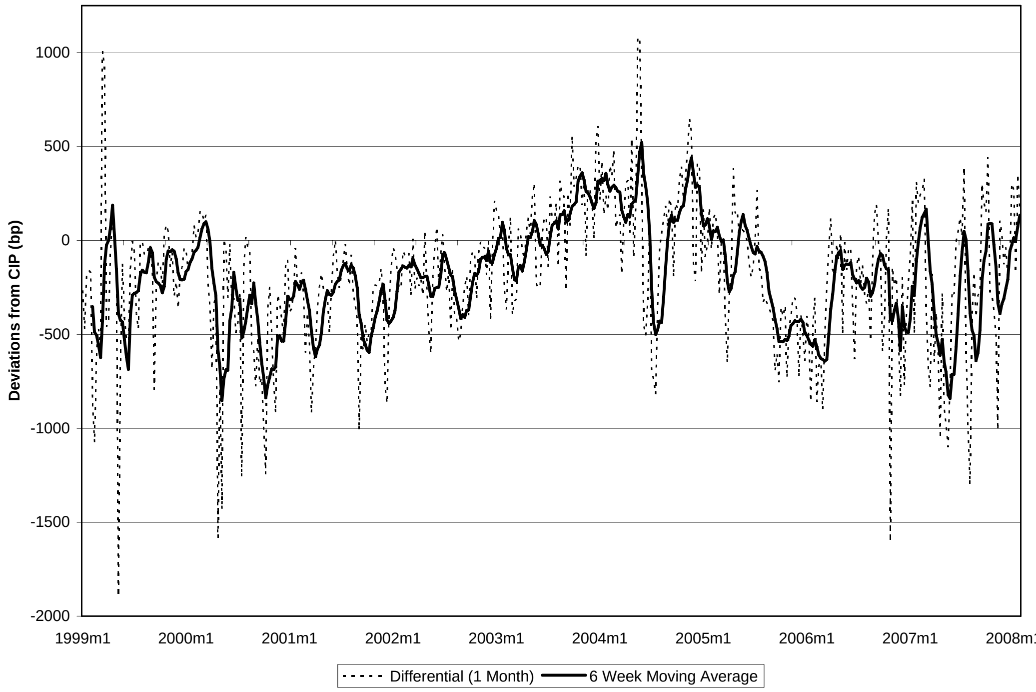

Figure 2: CIP deviation series using 3-month instruments.

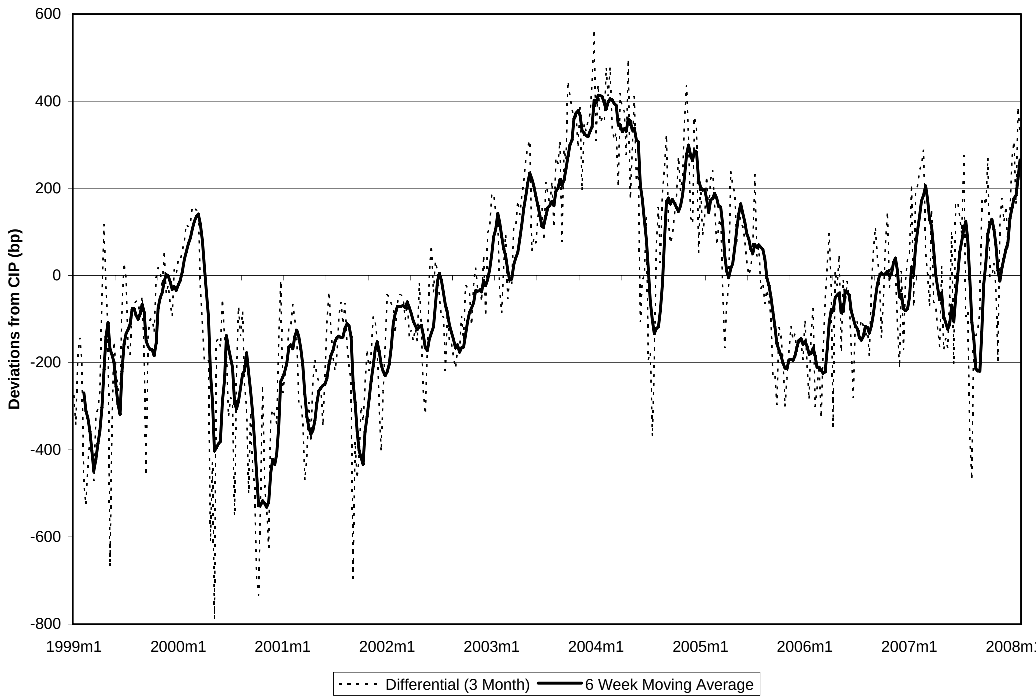

Figure 3: Plot of AR(1) parameter from rolling regressions on CIP deviation series with 1-month instruments. Rolling regression windows are 2 years (104 weeks). Dotted lines are +/-95% errors.

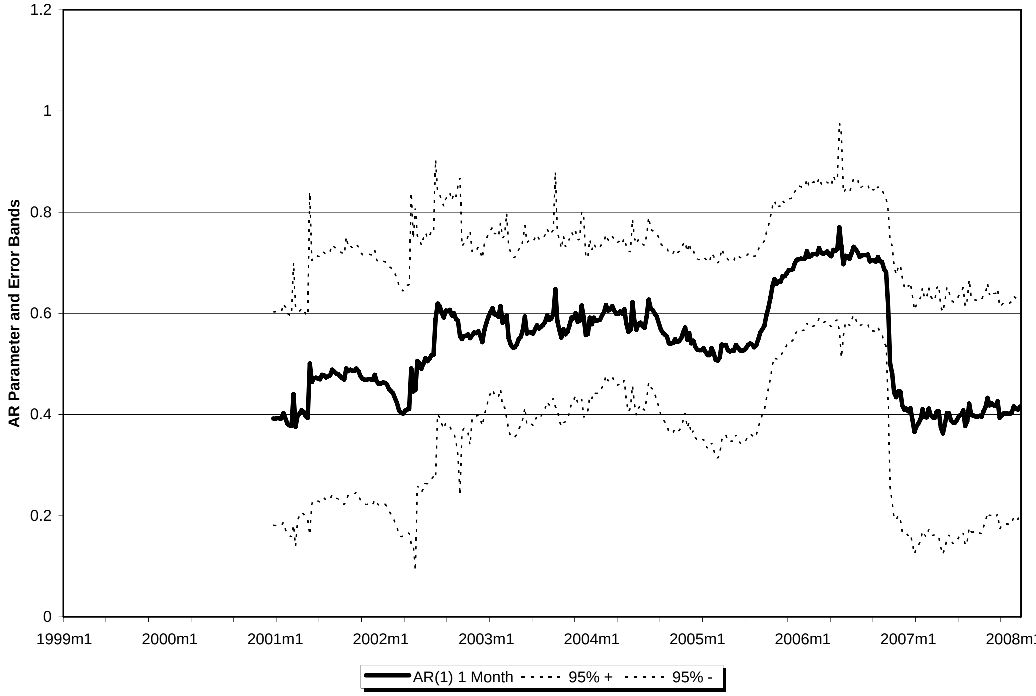

Figure 4: Plot of AR(1) parameter from rolling regressions on CIP deviation series with 3-month instruments. Rolling regression windows are 2 years (104 weeks). Dotted lines are +/-95% errors.

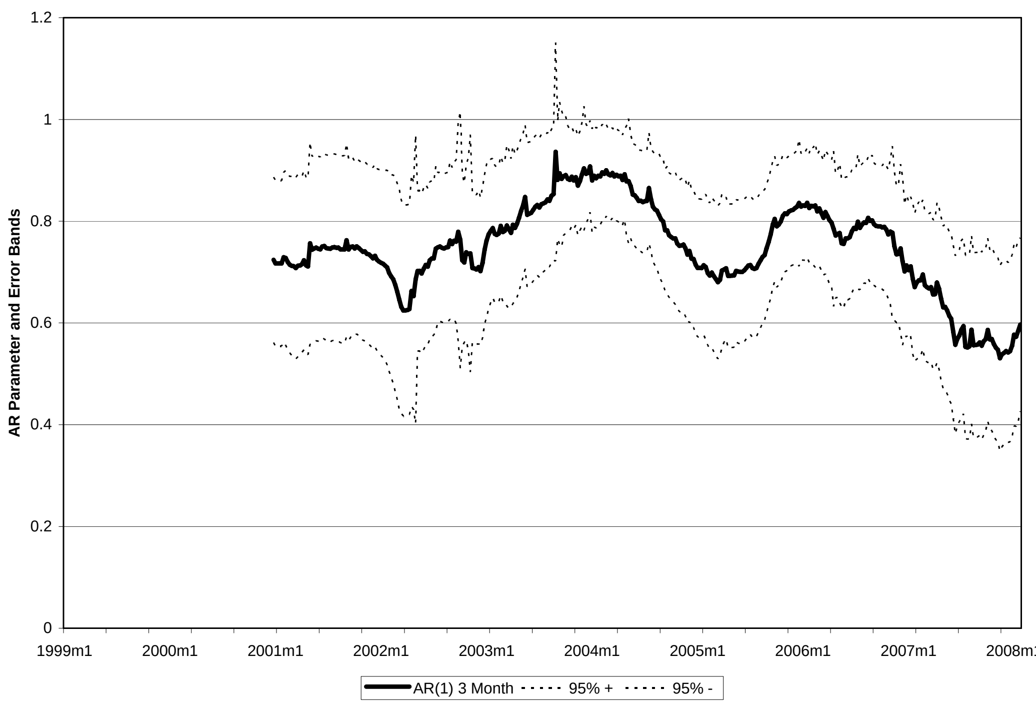

Table 1: ADF unit root tests of non-deliverable forward and spot exchange adjusted returns to LIBOR, MIBOR, and the differential between the two. The NULL hypothesis of ADF tests is of a unit root in the series.

Variable	Lags *		ADF Stat.	p-value
NDF 1-mon.	BIC	4	-3.72***	0.00
	AIC	11	-1.994	0.29
NDF 3-mon.	BIC	3	-2.275	0.18
	AIC	8	-2.043	0.27
MIBOR 1-mon.	BIC	0	-2.251	0.19
	AIC	17	-1.458	0.55
MIBOR 3-mon.	BIC	0	-1.755	0.40
	AIC	0	..	..
Differential 1-mon.	BIC	1	-9.178***	0.00
	AIC	11	-3.282**	0.02
Differential 3-mon.	BIC	1	-4.955***	0.00
	AIC	8	-2.797*	0.06

* Lags chosen by BIC and AIC criterion

* 10% ** 5% *** 1% Null = Unit Root

Table 2: Preliminary Chow tests of change in magnitude of AR parameter of CIP deviation series across four equal sub-periods. The sub-samples correspond to the time periods indicated in Table 3.

	1 Month Instruments		**3 Month Instruments**	
	AR(1) Coefficient	**t-value**	**AR(1) Coefficient**	**t-value**
Subsample 1	0.407**	5.85	0.726***	13.21
ΔSubsample 2	0.164	1.14	0.117	1.33
ΔSubsample 3	0.238**	2.23	0. 072	0.89
ΔSubsample 4	0.025	0.25	-0.086	-0.97

Table 3: AR(1) parameter of CIP deviation series. Regressions performed separately in the indicated sub-periods. Sub-periods are equally spaced.

	jan99-apr01	apr01-aug03	aug03-nov05	nov05-jan08	full sample
1 Month Series					
AR(1)	0.404***	0.570***	0.640***	0.428***	0.566***
(z-stat)	(5.73)	(8.26)	(9.20)	(5.72)	(19.22)
3 Month Series					
AR(1)	0.720***	0.841***	0.791***	0.630***	0.837***
(z-stat)	(11.23)	(20.50)	(13.73)	(9.14)	(40.53)
N=	117	117	117	116	470

Table 4: Upper and lower values of excitation thresholds from SETAR estimations. AR(2) specifications allow for AR(2) process in the three regimes.

Panel A: 1 Month Instruments

		AR(1) Specification	AR(2) Specification
Full Sample			
		Threshold Value	Threshold Value
Upper Threshold		0.02	0.77
Lower Threshold		-6.71	-6.94
	Difference:	**6.73**	**7.71**
First Period (1999-2003)			
		Threshold Value	Threshold Value
Upper Threshold		0.08	0.84
Lower Threshold		-7.52	-7.52
	Difference:	**7.60**	**8.36**
Second Period (2003-2008)			
		Threshold Value	Threshold Value
Upper Threshold		0.07	0.77
Lower Threshold		-5.91	-5.00
	Difference:	**5.98**	**5.77**

Panel B: 3 Month Instruments

		AR(1) Specification	AR(2) Specification
Full Sample			
		Threshold Value	Threshold Value
Upper Threshold		3.49	0.74
Lower Threshold		-4.07	-4.07
	Difference:	**7.56**	**4.81**
First Period (1999-2003)			
		Threshold Value	Threshold Value
Upper Threshold		0.80	0.33
Lower Threshold		-4.28	-3.13
	Difference:	**5.08**	**3.46**
Second Period (2003-2008)			
		Threshold Value	Threshold Value
Upper Threshold		3.51	0.10
Lower Threshold		-1.10	-0.63
	Difference:	**4.61**	**0.73**

Table 5: AR(1) parameter estimates in upper and lower regimes (outside thresholds) from SETAR estimations. Non-positive parameter values indicate instantaneous convergence to the threshold.

Panel A: 1 Month Instruments

Full Sample	**AR(1) Parameter**	**St. Err.**
Upper Region	0.43	(-0.09)
Lower Region	-0.28	(0.14)
First Period (1999-2003)	**AR(1) Parameter**	**St. Err.**
Upper Region	0.22	(0.15)
Lower Region	-0.37	(0.20)
Second Period (2003-2008)	**AR(1) Parameter**	**St. Err.**
Upper Region	0.47	(0.11)
Lower Region	-0.23	(0.18)

Panel B: 3 Month Instruments

Full Sample	**AR(1) Parameter**	**St. Err.**
Upper Region	-0.04	(0.22)
Lower Region	-0.03	(0.21)
First Period (1999-2003)	**AR(1) Parameter**	**St. Err.**
Upper Region	0.72	(0.15)
Lower Region	-0.11	(0.23)
Second Period (2003-2008)	**AR(1) Parameter**	**St. Err.**
Upper Region	-0.06	(0.22)
Lower Region	0.29	(0.13)