Indian Capital Control Liberalization: Evidence from NDF Markets

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Abstract

This paper analyzes the extent to which the effectiveness of capital controls in India have changed over time. We begin by calculating deviations from covered interest parity utilizing data from the 3-month offshore non-deliverable rupiah forward (NDF) market. Then, using the self-exciting threshold autoregression methodology, we estimate a no-arbitrage band whose boundaries are determined by transactions costs and by the effectiveness of capital controls. Inside 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 identify three distinct periods, and estimate the model over each sub-sample in order to capture the *de facto* effect of changes in capital controls over time. We find that *de facto* capital control barriers: (1) are asymmetric over inflows and outflows, (2) have changed over time from primarily restricting outflows to effectively restricting inflows; (3) arbitrage activity closes deviations from CIP when the threshold boundaries are exceeded in all sub-samples. In recent years, capital controls have been more symmetric over capital inflows and outflows and the deviations from CIP outside the boundaries are closed more quickly.

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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, having 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 evident in market price signals by measuring deviations from covered

[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. Work on China that is related to our concern with de facto controls includes Cheung et al (2006) and Liu and Otani (2005).

interest parity (CIP) over time.[2] An extensive literature investigates deviations from CIP, inferring market segmentation due to 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 Frenkel and Levich (1975), Peel and Taylor (2002), Obstfeld and Taylor (2004) 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 walks, 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. We 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

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[2] The Chinn-Ito index, in contrast, is a *de jure* measure, and shows no movement for India over a relatively long period, making it inappropriate for our task.

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 considered one- and three-month maturities, but focused on the latter, as better capturing significant transaction volume. [3]

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 (2008), 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

[3] Most inter-dealer transactions in the NDF market are concentrated in two- to six-month maturities, and we follow Ma et al. (2004) in focusing on the 3-month maturity. 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.

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

2.1 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.[4]

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. While the Asian crisis and subsequent contagion that spread through 1997-98 derailed the committee's recommended timetable, significant

[4] 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.

liberalization of the capital account occurred in 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.

2.2 Non-Deliverable Forward Market

A consequence of India's partial capital controls has been 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 – that is, 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.[5]

The Indian rupee NDF market is most active in Singapore and Hong Kong, though there is also trading in places such as Dubai. 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[6] 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-

[5] Lipscomb (2005) provides a useful overview of NDF markets.

[6] In August 2008, the Reserve Bank of India allowed trading on a domestic currency futures exchange to begin. Prior to this innovation, trading for those permitted to do so was over-the-counter. Restrictions remain on participation in the exchange; for example, only Indian residents can participate.

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.[7] 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 Analysis 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 3-month maturity. The graph shows weekly observations, as well as six-week moving averages, starting in January 1999 and ending in January 2008. Large and

[7] If forward rates are determined primarily by expected future currency needs from importers and exporters, rather than by pure arbitrage by currency traders or others, 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 the direction of currency movements as implied by CIP deviations have been correct on average. A related point is that variations in deviations from CIP may reflect changing relative risk premia for the two currencies. However, these risk premia are unobservable: our maintained hypothesis that the source of variation is changes in controls is consistent with the data and our estimated model.

persistent deviations from CIP are evident, indicating large transactions costs and the effectiveness of capital controls. At some points deviations from CIP exceed 400 basis points. This indicates that, in the absence of capital controls and transactions costs, an arbitrageur could have received over $40,000 USD per year for every $1 million USD of volume transacted, without investing any money. Deviations of this magnitude indicate that capital controls have affected these markets and hindered arbitrage and market integration. In addition, it appears that restrictions on capital outflows (negative deviations from CIP indicate that the MIBOR rate is lower than the offshore rate) are predominant during 1999-02, while restrictions on inflows are predominant from 2003 to mid-2005, and fluctuate since that time.

While we will ultimately estimate a non-linear model, it is instructive to apply standard diagnostics to the data series, as a guide to the subsequent analysis. We recognize that these diagnostics are merely indicative, if the true model is non-linear. Nevertheless, we perceive a value to applying these familiar tools as a preliminary exercise.

Table 1 contains the results of Augmented Dicky-Fuller (ADF) tests for evidence of unit root behavior in the CIP deviation series and the two component interest rate series (the MIBOR rate and the NDF-offshore implied yield). The results show that – as one might expect[8] – the CIP differential series do not exhibit evidence of a unit root whereas the interest rate series do. 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 there limits to geographic market segmentation.

[8] Of course, if the underlying series are subject to structural breaks or non-linearities, this could show up as a unit root (Taylor, 2001).

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 analyze in Figure 2 the speed at which CIP deviations tend back towards zero in the context of a linear autoregressive model. We estimate two-year rolling regressions measuring the AR(1) autoregressive parameter (and the +/-95% confidence bands) of the deviations from CIP. 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. An AR(1) parameter near one would indicate 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. 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.

Figure 2 indicates substantial variation in arbitrage activity in this market, based on the behavior of the AR(1) parameter over time. The AR(1) parameters appear to 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. Three local minima in the AR(1) parameter are identified – early 2002, early 2005, and late 2007—that in turn correspond to periods of greatest deviation from CIP seen in Figure 1 (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, with the AR(1) parameter declining towards the end of 2007.

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 preliminary analysis above suggests that there may be non-linearities as well as structural breaks in the data. We do an initial test for non-linearities using the Tsay test (1989). The Tsay F-statistic equals 4.1 (p-value= 0.01), hence rejecting the null of linearity. The Tsay test does not explicitly take into account distortions implied by the fact that the threshold parameter(s) are only identified under the alternative hypothesis, so when we implement the SETAR model in the next section, we use Hansen's (1999a) approach to testing for nonlinearities in this framework.

We also perform an indicative test for structural breaks. Table 2 presents the results of the Bai-Perron (2003) tests for structural change. The test indicates two structural breaks, at January 2003 and April 2005, and we therefore, in the next section, estimate a SETAR model for three sub-samples: January 1999 to January 2003; January 2003 to April 2005; and April 2005 to January 2008. Again, the Bai-Perron test is merely suggestive in this context, but it is consistent with the previous discussions of the visual examination of the data, and of policy changes implemented at these times.

While Shah and Patnaik (2005, Table 4) list a host of incremental policy changes up to November 2004, the one that is most germane to our analysis was the removal of limits placed on foreign institutional investors in their hedging in the forward currency market. This took place in January 2003, the time of our first sample break. The second sample break does not coincide with a specific policy change, but in April 2005, the RBI announced several small but significant measures to liberalize foreign exchange markets, in its Annual Policy Statement for 2005-06 (RBI, 2005, p. 10).

Finally, Table 3 shows summary statistics for CIP deviations for the full and sub-sample periods, where the sub-samples are determined by the Bai-Perron test discussed above. The largest negative deviation (foreign returns exceeding domestic returns) for the full sample is 7.88 percent per annum, and the largest positive deviation is 5.64 percent per annum. The mean absolute deviation is 1.85 percent per annum. There is quite a bit of variation across the subsamples.

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

4.1 SETAR Methodology

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,[9] respectively, are given by Potter (1999) and Hansen (1999b). The SETAR model may be seen as a parsimonious approximation of a general non-linear autoregressive model (Hansen, 1999b). 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, 2008) and cross-market premia (Levy Yeyati, Schmukler and Van Horen, 2006).[10]

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

9 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.

10 Pasricha's study (2008) 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.

that within the bounds defined by κ_n and κ_p, speculative activity is not profitable 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.[11] 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, 1999b and Pasricha, 2008).

4.2 Model Choice

As indicated in the previous section, standard diagnostic tests have the maintained hypothesis of linearity, or do not take fully account of the implications of the non-linear alternative. In particular, the threshold parameter is not identified under a null hypothesis of linearity, so classical tests have non-standard distributions. Hansen (1996, 1999a) has

[11] Thus, 5% was trimmed on each side. Every actual value of the CID between the 5th and 95th percentiles was used as a possible threshold in the unrestricted model. For the negative thresholds, the estimated values are not close to the cutoffs. For the positive, they are close to the 0-cutoff if the positive search is restricted to be between 0 and 95th percentile.

developed a bootstrapping procedure to simulate the asymptotic distribution of the likelihood ratio test.

Using Hansen's approach, we test for the number of thresholds in the SETAR model. There are no thresholds (the standard linear model), one threshold, or two (the full model given in the expressions above). The tests are conducted pairwise, with the zero threshold null first being evaluated against the alternative of one threshold. If the null is rejected in that test, a second test is conducted for the null of one against the alternative of two thresholds. For the sample as a whole, the data reject both the linear model and the one-threshold model at the 5% level or better.

However, when we applied the LR tests for the three sub-periods, we found that the null of one threshold was not rejected for the first period, and the null of a linear model was not rejected for the second or the third period. We believe that these results are somewhat driven by the low power of the tests.[12] In particular, as we see in the next subsection, the results of estimating the two-threshold models for the three subperiods give very different results across the periods, in terms of behavior inside and outside the thresholds. Hence we prefer to report the two-threshold models, with their associated confidence intervals.[13]

4.2 SETAR Estimation Results

[12] These results are available from the authors. Even if one accepts the implication of the tests that arbitrage thresholds have not been present in the latter part of our sample period, our overall conclusion that capital controls have weakened de facto remains intact. On the other hand, the two-threshold estimates we present here allow a more nuanced view on the evolution and impact of capital controls in the Indian case.

[13] As noted in Hansen (2000) in a related context, the statistical theory is asymptotic, and so may be less applicable to small samples, and the confidence intervals generated are also conservative.

The SETAR estimates are reported in Tables 4 and 5. We focus on the three sub-samples, following evidence reported above of structural breaks indicating three distinct regimes. Estimates of the lower- and upper-thresholds, and the bandwidth (no-arbitrage zones), are reported for the full sample and three sub-samples in Table 4, along with the bootstrapped confidence intervals. The estimated speed of reversions and associated statistics for each sample are reported in Table 5. The columns in Table 5 labeled "OutObs," "LCR" and "3rd Quartile" refer, respectively, to (1) the percentage of observations that lie outside of the no-arbitrage band, (2) the longest continuous run outside of the band (i.e. the number of continuous observations), and (3) the third quartile of the number of weeks that any run outside of the threshold lasts. Figure 3 shows the results visually, with the upper and lower-thresholds shown for each sub-sample together with the speed of reversion parameters and each observation (deviations from CIP) plotted.

In terms of the no-arbitrage zones estimates, controls on capital outflows were predominant in the *January 1999 to January 2003* sample. Table 4 shows that the upper threshold is very close to zero percent (i.e. no net effective restrictions on capital inflows), and -4.28 percent for the lower threshold. (The bandwidth is 4.31). This indicates that foreign yields need to exceed domestic yields by 428 basis points (annualized) to induce capital outflows from India. When the lower threshold is exceeded, shown in Table 5, the speed of reversion is almost instantaneous. Arbitrage is slower above the upper threshold, with an estimated AR(1) parameter equal to 0.68. (32 percent of the CIP yield differential in favor of domestic assets is closed within one week).[14] 23 percent of the observations fall outside of the band (OutObs) and the longest continuous run outside of the band (LCR) is 11 weeks. However, 75 percent of deviations outside the band (3rd Quartile) are arbitraged away within two weeks.

A large shift in Indian capital flows towards financial liberalization appears in the second sample, *January 2003 to April 2005*, with some effective restrictions now evident on capital inflows. The no-arbitrage band narrows appreciably to only 1.22 percent, with the lower threshold estimated to be near zero and the upper threshold estimated at 1.22 percent. The AR(1) parameter (inversely related to the speed of adjustment) for CIP deviations above (below) the upper (lower) threshold is 0.80 (0.59). Arbitrage appears effective in eventually eliminating CIP deviations (outside the bands). Given the narrow bandwidth, it is not surprising that 84 percent of the observations fall outside of the no-arbitrage zone and that the longest run outside of the band is 38 weeks. 75 percent of deviations outside the band are arbitraged away within four weeks.

Capital controls appear to be intensified somewhat in the third sub-sample, *April 2005 to January 2008*, and again are more restrictive on capital inflows. The bandwidth is 2.33 percent, the upper threshold is 1.59 and the lower threshold is -0.74. The speed of adjustment for deviations above the band increases sharply (the AR(1) parameter declines) in the third sub-sample, and is effectively instantaneous, while the speed of adjustment below the band also increases somewhat (AR(1)=0.45). 56 percent of the observations fall outside of the no-arbitrage zone and that the longest run outside of the band is 26 weeks. 75 percent of deviations outside the band are arbitraged away within four weeks.

[14] An AR(1) parameter less than unity indicates mean reversion, i.e. CIP deviations outside of the band are eliminated. A zero AR(1) parameter indicates immediate reversion to the band.

Overall, the bandwidth is much narrower in the second and third sub-samples than in the first sample, indicating substantial *de facto* weakening of capital controls in India over the sample period.[15] This finding is reflected in the summary statistics, shown in Table 1, which show the mean absolute CIP deviation has declined from 1.94 during January 1999-January 2003 to 1.32 during April 2005-January 2008. Moreover, the threshold estimates indicate a switch from strict controls on capital outflows in the early sample to moderate restrictions on inflows in the latter periods.[16] Weak restrictions on inflows, possibly the result of transaction costs rather than capital controls, are also evident in the most recent sample period. All of the adjustment parameters indicate mean reversion to the upper or lower thresholds of the no-arbitrage band. These adjustments vary depending on whether the deviations are above or below the band and on the particular sub-sample.

These changes in the speed of adjustment reflect the interaction of both capital controls and market structure/liquidity, but clearly indicate that strong forces for market arbitrage are evident that eliminate CIP deviations once they exceed a particular threshold. Average daily turnover of NDF contracts in the Indian Rupee increased from about US$35 million in mid-2001 to US$3.7 billion in early 2007 (Ma et al., 2004; Misra and Behera, 2006), indicating that market liquidity has increased markedly, with presumably stronger pressures for market arbitrage. Moreover, we would expect volume

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[15] This result is consistent with Ma and McCauley (2008) who regress the mean absolute deviations (weekly data) from CIP (12-month instruments) on three dummy variables representing different periods of time. The most recent period (July 2005-June 2008) has the lowest coefficient estimate, i.e. the lowest mean absolute value. Their sub-samples are not determined by structural break tests.

[16] For example, in 2007, increased portfolio inflows and FDI led to efforts by the Reserve Bank of India to limit capital inflows to avoid rupee appreciation, as well as a relaxation of restrictions on certain kinds of outflows. Expectations of rupee appreciation may be reflected in the sign of the CIP differential (Shah and Patnaik, 2005). Another component of policy during this period was the sterilization of inflows, resulting in reserve accumulation.

or quantity restrictions on capital inflows and outflows to have a larger impact on the speed of adjustment, while taxes on flows are more likely to increase bandwidths. The complex nature of Indian capital controls, discretionary application over time and their lack of transparency, do not allow us to disentangle these effects.

5. Summary and Conclusions

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. Using structural break tests, we divide the sample into three sub-samples and estimate 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. 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. Moreover, there has been a sharp switch in the direction of capital controls. In the pre-2003 period, controls were binding and substantial on capital outflows. Controls were reduced substantially after 2003 and the remaining restrictions (through early 2008) were mainly binding on capital inflows. In all regimes, we find that adjustment towards CIP is quite rapid outside of the threshold values. Overall, liberalization of capital controls in India has occurred in tandem with the development of domestic money and offshore markets and increases in market liquidity.

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Table 1: ADF Unit Root Tests

Variable		Lags	ADF Stat.	p-value
NDF	BIC	3	-2.28	0.18
	AIC	8	-2.04	0.27
MIBOR	BIC	0	-1.76	0.40
	AIC	0	..	..
Onshore-Offshore Gap	BIC	1	-4.96***	0.00
	AIC	8	-2.80*	0.06

Notes: Lags chosen by BIC and AIC criterion, Null hypothesis is of unit root.
* 10% ** 5% *** 1% level of significance.

Table 2: Bai-Perron Tests

$SupF_T(2\|1)$	$SupF_T(3\|2)$	$SupF_T(4\|3)$	$SupF_T(5\|4)$			
20.49***	12.71*	7.30	12.71			
Method		**Number of Breaks Selected**		**Break Dates from Sequential Method(BP)**	**90% Confidence Interval (pos.)**	**90% Confidence Interval (neg.)**
				T1	**CI+**	**CI-**
BIC		**2**		Jan-03	Mar-03	Nov-02
Sequential (Bai Perron)		**2**		**T2**	**CI+**	**CI-**
				Apr-05	Jun-05	Nov-04

Notes: * 10% ** 5% *** 1% level of significance. The SupF(*l+1*|*l*) test is a sequential proceedure developed in Bai and Perron (2003) which tests for *l+1* breaks vs. the null of *l* breaks. BIC is an information criteria selection procedure, dominated by the SupF but reported for interest.

Table 3: Summary Statistics, Onshore-Offshore Differential

	Full Sample	Jan 1999-Jan 2003	Jan 2003 – April 2005	April 2005 – Jan 2008
Minimum	-7.88	-7.88	-3.69	-4.69
Maximum	5.64	1.58	5.54	3.86
Mean Absolute Spread	1.85	1.94	2.26	1.32

Table 4: Estimated No-Arbitrage Zones

	Begin Date	End Date	Negative Threshold	Positive Threshold	Bandwidth	R-squared
Full Sample	30-Jan-99	30-Jan-08	-4.22 (-4.48, -2.17)	3.49 (0, 3.61)	8.10	0.60
Sub Sample 1	30-Jan-99	11-Jan-03	-4.28 (-5.33, -2.51)	0.03 (0.03, 0.70)	4.31	0.68
Sub Sample 2	25-Jan-03	2-Apr-05	-0.00 (-1.07, -0.00)	1.22 (0.30, 4.44)	1.22	0.61
Sub Sample 3	16-Apr-05	30-Jan-08	-0.74 (-2.97, -0.00)	1.59 (0.00, 2.40)	2.33	0.14

Notes: Thresholds estimated from SETAR models with one AR lag in each regime. A BIC criterion was employed for testing for optimal lags between 1 and 8 weeks. For all samples other than 3-month full sample, BIC criterion selected an AR(1) process. For 3-month full sample results, the BIC criterion selected 3 lags, but the BIC statistics for 1 and 3 lags were almost identical. We chose lag 1 for consistency with the other models.

Table 5: Speed of Reversion Statistics

	OutObs (%)	LCR	3rd Quartile	AR Coefficients: Inner Regime AR(1)	Inner Regime Std Error	Negative AR(1)	Negative Std Error	Positive AR(1)	Positive Std Error
Full Sample	11	7	3	0.89	0.03	-0.10	0.16	-0.04	0.30
Sub Sample 1	23	11	2	1.00	0.05	-0.11	0.16	0.68	0.28
Sub Sample 2	84	38	4	1.64	0.33	0.59	0.22	0.80	0.07
Sub Sample 3	56	26	4	0.67	0.22	0.45	0.12	0.01	0.29

Notes: OutObs is the percentage of deviations in the outer regimes. LCR is the longest continuous run outside any threshold and 3rd Quartile is the third quartile of continuous runs outside thresholds. Non-positive parameter values for the AR(1) coefficients would indicate instantaneous convergence to the threshold – none of the negative estimates .

Figure 1: CIP deviation series

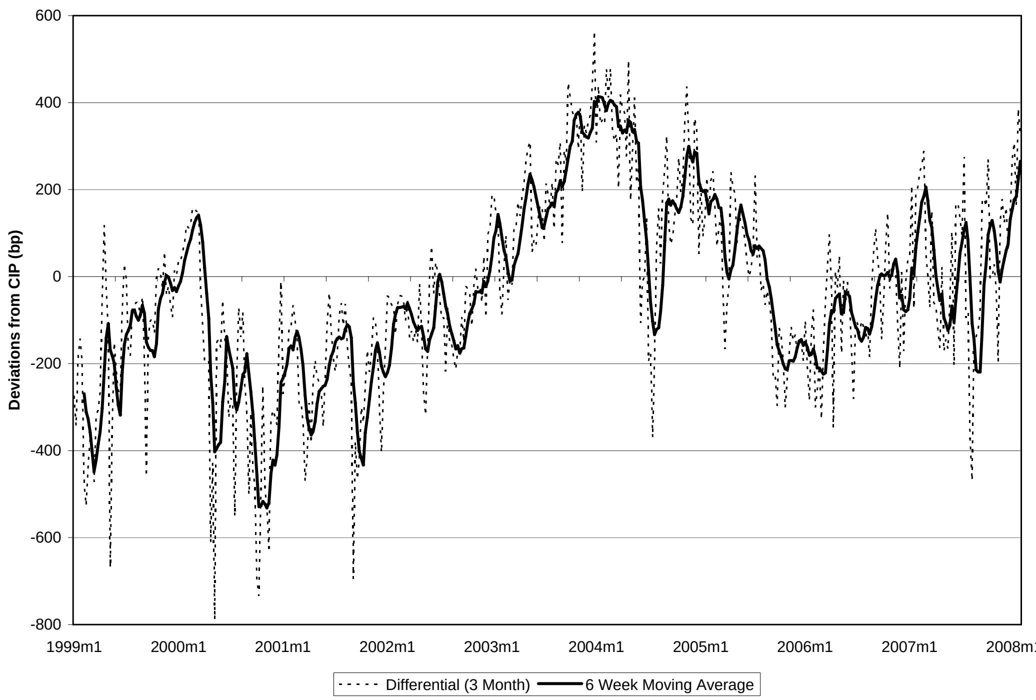

Figure 2: Plot of AR(1) parameter from rolling regressions on CIP deviation series Two-year (104 weeks) rolling regression windows (dotted lines are +/-95% errors)

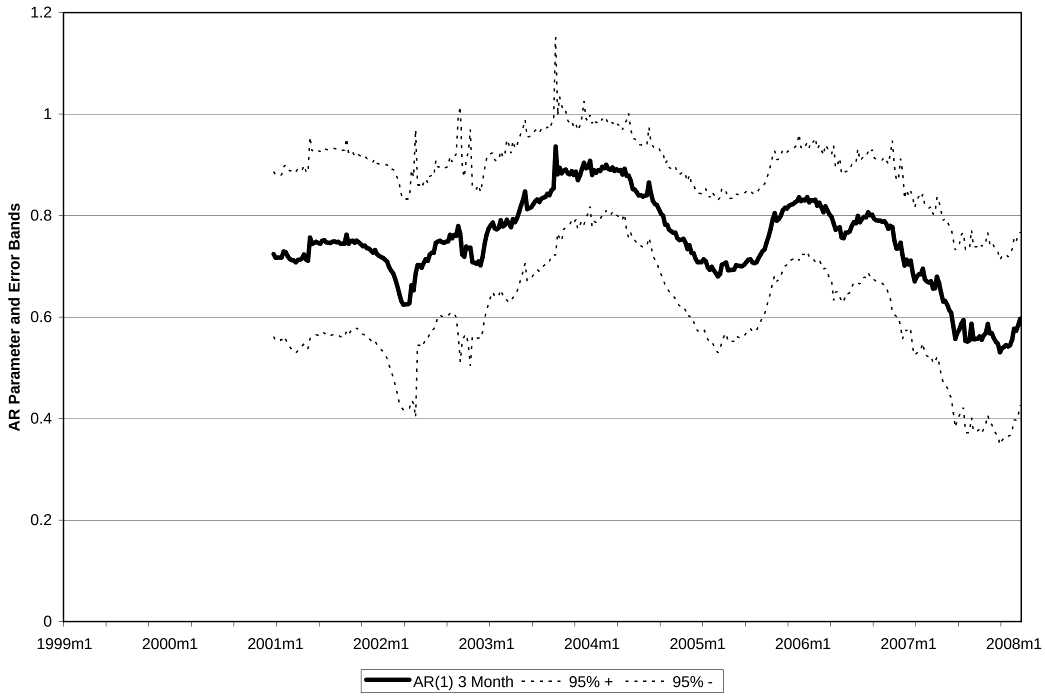

Figure 3: CIP Differentials – Estimated Thresholds