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Stopping hot money ☆

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Abstract

While high interest rates and foreign exchange sales are the most common way of dealing with a speculative attack in the foreign exchange market, several countries resorted to capital controls during recent periods of currency market turbulence. The purpose of this study is to use daily financial data to examine three of these capital controls episodes—Brazil 1999, Malaysia 1998, and Thailand 1997. We aim to assess the extent to which the capital controls were effective in delivering the outcomes that motivated their inception in the first place. We conclude that in two of the three cases (Brazil and Thailand), the controls did not deliver much of what was intended—although, one does not observe the counterfactual. By contrast, in the case of Malaysia, the controls did align closely with the priors of what controls are intended to achieve: greater interest rate and exchange rate stability and more policy autonomy.

Keywords: Capital controls; Financial crises; Contagion; Co-movement

1. Introduction

During the 1990s, many emerging market economies experienced both the highs and the lows of the international capital flow cycle. Early in the decade, many developing countries regained access to international capital markets after

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many years of debt servicing difficulties. As capital began to find its way back to emerging markets (EMs), the debate on how to manage a surge in capital inflows flourished as one of the most pressing policy topics of the day.[1] Capital controls, when they were discussed at all, were examined in the context of weighing the relative merits of discouraging certain types of capital inflows—like short-term offshore borrowing.[2]

In the end, the capital flow surge proved to be as fragile and volatile in the 1990s as it had been previously. The first prick of the capital flow bubble came with the Mexican crisis in December 1994. Subsequently, in mid-1997, much of emerging Asia was engulfed in a financial crisis of unprecedented severity for that region.[3] The Russian crisis and the near-bankruptcy of Long Term Capital Management (LTCM) in the fall of 1998 further dried up the remaining capital flows to EMs.[4] In early 1999, Brazil followed suit with a currency crisis of its own—and this list is not exhaustive.

Given this string of disruptive events in international capital markets, the discussion of capital controls began to shift markedly in emphasis. The earlier policies, which were aimed at discouraging capital inflows, were typically introduced in a "tranquil" period and were largely seen by market participants as being of a benign or "prudential" nature; the measures we examine in this paper, however, are "desperate measures" and akin to those discussed in Paul Krugman's policy advice, which appeared in the financial press in early 1998.[5] In these writings, the emphasis was on the possible usefulness of capital controls as a means to buy time during crisis periods. The policies, born out of necessity rather than precaution, were not heralded as market-friendly. Malaysia's controls in the fall of 1998 represented the most extreme example of "adverse signaling". Such signals were reinforced by Dr. Mahathir's anti-foreigners rhetoric at the time the controls were launched, which raised widespread concerns that even more drastic measures, including expropriation, would follow.[6]

The purpose of this study is to examine some of these crisis/capital control episodes, three of them in particular—Brazil, 1999, Malaysia 1998, and Thailand

[1] See Calvo et al. (1993).

[2] Much of empirical work on capital controls was devoted to assessing whether these measures were effective in achieving their stated objectives. For instance, Edwards (1998) examined whether Chile's reserve requirement policy bought its central bank some greater control over short-term interest rates; Montiel and Reinhart (1999), studied a panel of 15 EMs to determine whether these curbs or taxes on inflows affected the volume and composition of capital flows and; Cardoso and Goldfajn (1998) examined these issues for the case of Brazil.

[3] See Kaminsky and Reinhart (1998).

[4] See Bank of International Settlements (1999) for a detailed analysis of the events of the fall of 1998.

[5] See Krugman (1998).

[6] Indeed, institutional investors' anxiety that a new wind was blowing regarding official attitudes was heightened by the short-lived restrictions in Japan on short selling.

1997. We aim to assess the extent to which the capital controls were effective in delivering some of the outcomes that motivated their inception in the first place. In this regard, while our approach is different, this paper shares some of the goals of Kaplan and Rodrik (2000), who focus on the same Malaysian episode analyzed in this paper.

The frequency of the financial indicators we analyze is daily. The sample spans 1995 through July 23, 1999. In addition to these three episodes, there are two "control group countries", the Philippines and South Korea, which had crises but did not introduce capital controls. As to the empirical methodology, we employ principal component analysis—to assess contemporaneous co-movement; block exogeneity tests in a VAR framework to assess temporal international causality; and GARCH tests for the effects of controls on volatility—to assess changes in cross border volatility links, as in Edwards (1998).

There are, of course, several limitations and concerns with this kind of analysis. First, results are episode-specific because there are too few episodes to generate any kind of "stylized fact." Second, given that these kinds of controls are introduced during periods of turbulence, it is particularly difficult to parse what outcomes owe to the intensification or introduction of capital controls and what is due to the financial crisis per se. It is for that reason we examine some crises episodes for countries that did not resort to controls as part of a control group. With these caveats in mind, our key empirical findings are summarized below.

As to the central issue of insulating the economy from external shocks and gaining greater policy autonomy, our results suggest that there is little evidence that capital controls were effective in decoupling domestic interest rates from foreign interest rates—either contemporaneously or temporally. The closest episode that meets this expectation is Malaysia. A similar statement can be made about exchange rate changes where, again, Malaysia's experience comes the closest to meeting this expectation. In all cases, the evidence suggests that equity markets continue to be internationally linked, despite the introduction or escalation of capital controls.

The remainder of the paper is organized as follows. Section 2 discusses some of the pertinent theoretical predictions as to what can be expected if the controls are effective. Section 3 describes the measures and their chronology, while the section that follows describes the empirical methodology and the main results. The final section discusses possible extensions and policy implications.

2. Theoretical predictions of the effects of controls

In this section, we first review some of the reasons most often voiced by policy makers for resorting to capital controls during periods of turbulence.[7] Knowing

[7] See Dooley for a summary of the literature on capital controls.

what the stated expectations from the policy change are in the first place is essential to assess whether the policy was "effective" or "successful." Since many of these expectations are grounded on an implicit model, we then proceed to summarize the implications of capital controls for some of the variables of interest.

2.1. Reasons for resorting to capital controls during crises periods

The first line of defense by central banks dealing with speculative attacks on their currencies is usually to sell off their holdings of foreign exchange. However, central bank holdings of foreign exchange are often inadequate to support the currency and, even if the initial stock is high by international standards, recurring runs on the currency can quickly deplete the initial war chest. Raising interest rates is another possibility, but this option is also costly both in terms of potential damage to the economy and the financial sector—not to mention its significant fiscal implications.[8]

Not surprisingly, policy makers have, on occasion, cited the need to stem the drain on foreign exchange reserves as a motivation for introducing capital controls during periods of extreme market stress. Hence, capital controls are seen as a course of action which would enable the monetary authorities to maintain lower (and more stable) interest rates than would be the case under free capital mobility —especially if credibility has been lost. More generally, controls can (if they are effective) fulfill the authorities' desire to regain autonomy in monetary policy— without floating the exchange rate.

Since volatile international bond and equity portfolio flows are frequently viewed as a destabilizing force in asset markets and, more generally, in the financial system, another reason which is often cited for introducing controls is the desire to reduce the volatility in asset prices.

2.2. Theoretical priors

The Mundellian trinity suggests that fixed (or quasi fixed) exchange rates, independent monetary policy, and perfect capital mobility cannot be achieved simultaneously. Capital controls are a way of allowing the authorities to retain simultaneous control over the interest rate and the exchange rate. Capital controls may be particularly appealing when the authorities are reluctant to allow the exchange rate to float freely, which is the case in most EMs.[9] Fear of floating may arise for a variety of reasons, including the dollarization of liabilities—but for the purposes at hand, however, those reasons are not central to our analysis. The

[8] See Lahiri and Végh (2000) for a model that analyzes the fiscal implications of "interest rate defenses."

[9] See Calvo and Reinhart (2000).

important point for our analysis is that controls introduce a systematic wedge between domestic and foreign interest rates. As uncovered interest rate parity breaks down, the domestic policy interest rate (from the vantage point of a small open economy) need not follow international interest rates.[10] In principle, variation in that wedge can be introduced by the authorities to influence the exchange rate systematically. One example of this is the theoretical model of Reinhart and Reinhart (1999), who trace out the effects of one of the simplest forms of capital controls—a reserve requirement. Depending on the degree of competition among financial intermediaries, Reinhart and Reinhart show that the wedge between foreign and domestic interest rates induced by the reserve requirement influences the response of the exchange rate and the real economy to shocks.

The potential consequences of capital controls become even more persuasive in models that provide an important role for asset stocks in affecting an economy. The general mechanism at work is that, if the flow of capital is restricted in any way, then the burden of adjustment in asset markets falls more on prices. Calvo and Rodriguez (1979) first showed how sluggishness in the flow of international assets can generate overshooting of the exchange rate. Reinhart (2000) broadened that model by incorporating equity prices and introducing three different kinds of restrictions on capital flows. The implication in Reinhart's framework is that equity price volatility should increase with the imposition of controls. The generic features of such models are laid out in Fig. 1. A shock to the desired portfolio allocation generally triggers adjustments to both asset quantities and prices. Capital controls shift more of that adjustment toward prices and, to the extent that they introduce interest rate wedges, may also alter the relationship between asset prices and the policy rate.

Fig. 1 provides a summary of the predictions of theory for selected financial variables. Capital controls also have well defined predictions for central bank foreign exchange reserve losses and capital outflows. Such data, however, is only available at lower frequencies and we confine our emphasis here to financial indicators, which are observable on a daily basis.

We should expect following the introduction of capital account restrictions: Less contemporaneous movement with international variables—particularly in interest rates and exchange rates; a weaker causal (temporal) influence from foreign variables to domestic ones; a decline in volatility spillovers; and evidence of structural breaks around the introduction of controls. The implications of a decline in market liquidity—whether owing to a capital control or a generalized withdrawal from risk taking—are also straightforward. Bid–ask spreads in the market(s) where liquidity has diminished should widen and become more volatile.

[10] Of course, imperfect asset substitutability and a time varying risk premia are sufficient to explain a breakdown of uncovered interest parity—even in the absence of capital controls.

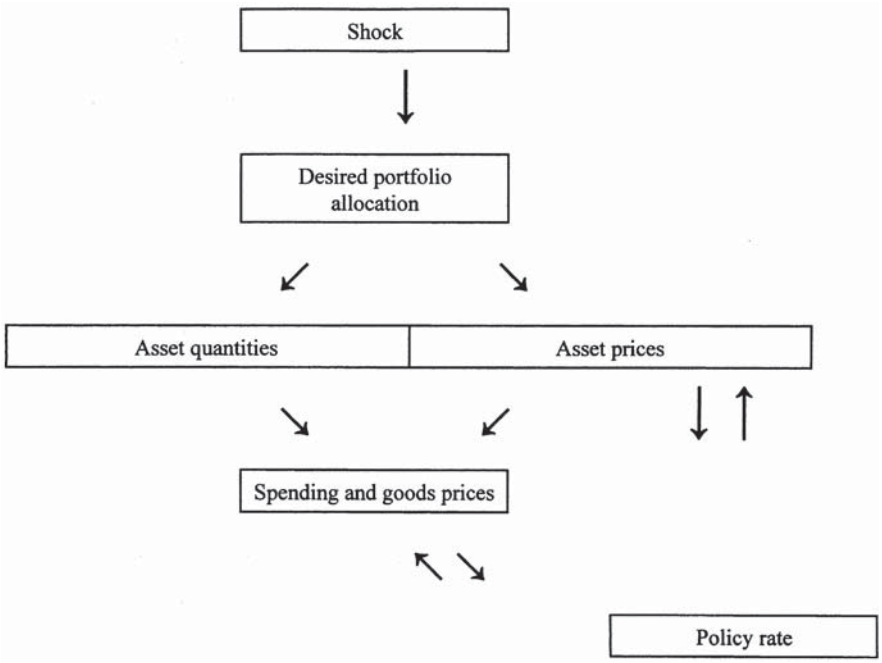

Fig. 1. Flowchart of a generic model.

A general caveat is in order, however. As the flow chart shown in Fig. 1 highlights, if asset prices are affected by the controls (as expected) *and* the policy interest rate responds to asset prices, in turn, then controls may not be the insulating mechanism that they were intended to be.[11]

3. The control episodes

In this section, we describe the timing and nature of the selected capital control episodes as well as some of the more relevant events surrounding the introduction and lifting of these measures. We then confront the theoretical predictions with the data from four recent episodes.

[11] A recent example of evidence of monetary authorities' concern with asset prices was provided by the Hong Kong Monetary Authorities large-scale intervention in the equity market in the turbulent fall of 1998.

3.1. The policy measures and chronology of events

The capital control episodes that we analyze began on: May 14, 1997 for Thailand, September 1, 1998 for Malaysia, and March 1, 1999 for Brazil. All three are recent examples of EM countries resorting to capital controls during periods of market stress. The chronology of the episodes and further details of the measures are summarized in Table 1.

In the case of Brazil, it is worth pointing out that the division between the "control" and "no-control" period is somewhat blurred by the variety of measures Brazil introduced since the mid-1990s measures that were along the lines of a Tobin tax on bond and equity purchases. As the tax is paid upon the purchase of the asset, it disproportionally falls on investors that have a very short holding period. Those measures were intended to curb what were perceived to be very volatile portfolio capital inflows. By contrast, the measures announced on February 11 were designed to force investment funds to hold more domestic government bonds—which lowered the amount of other countries' debt these fund could hold —thus restricting capital outflows.

As to the two control group countries, the Philippines and South Korea, the crisis episode is set to span from the devaluation of the Thai baht on July 2, 1997 to end-July 1998, as these countries were little affected by the Russian devaluation and the LTCM episode in the fall of 1998.

3.2. Methodology issues and limitations of the analysis

There are, of course, several limitations and concerns with the kind of analysis we undertake. First, results are episode specific—not "stylized facts." There are too few episodes for that label. Second, given that these kinds of controls are introduced during periods of turbulence, it is particularly difficult to separate what owes to the capital controls and what is due to the financial crisis per se. For instance, a generalized withdrawal from risk-taking (as what followed the Russia/LTCM episode in the fall of 1998) can have similar implications and outcomes as the introduction of capital controls. Namely, international flows dry up, spreads widen volatility in asset markets increases, and so on. Hence, the importance of having some crises episodes for countries that did not resort to controls as part of a control group. Third, our empirical methodology assumes linearities in relationships, which may break down during period of extreme market stress—an issue that is highlighted in multiple-equilibria crises models.

4. Are control periods different?

In this section, we employ several tests to examine whether the periods when capital controls are in place are, indeed, different. Specifically, we turn our

Table 1
A chronology of key events

Episode and country	Date	Key events
Thailand, Asian crisis, 1997–1998	May 14	Bank of Thailand (BOT) introduces restrictions on capital account transactions.
	May 28	BOT limits outright forward transactions.
	June 2	BOT introduces additional measures to limit capital flows.
	June 10	Baht proceeds from sales of stocks required to be converted at the onshore exchange rate. Additional controls are introduced.
	June 18	The onshore–offshore interest rate differential hits a peak at 639%.
	July 2	BOT introduces a two-tier exchange rate. Thai baht is devalued.
	September 23	Additional controls on invisible and current account transactions are introduced.
	January 7, 1998	Proceeds on exports and invisible transactions and current account transfers must be surrendered after 7 days (instead of 15 days).
	January 30, 1998	BOT ends two-tier exchange rate.
	February 3, 1998	The stock market suffers its largest 1-day decline (9.5%).
Korea, Asian crisis, 1997–1998	November 17	The Bank of Korea abandons the defense of the won.
	November 24	The stock market suffers its largest 1-day decline (down 11%).
	December 22	Won plummets 12% against the dollar— its largest daily decline.
Philippines, Asian crisis, 1997–1998	June 10	The peso plummets 12% against the dollar. Its largest daily decline.
	August 27	The equity market posts its largest (9.3%) daily decline.
Malaysia, Asian crisis, 1997–1998	July 14, 1997	Interest rates peak.
	January 5, 1998	Ringgit suffers its largest daily decline (7.5%) against the dollar.
	September 1, 1998	Exchange controls introduced.
	September 2, 1998	Exchange rate is fixed.
	September 7, 1998	The stocks market suffers its largest 1-day decline (down 22%).
	February 15, 1999	Exchange controls modified. New rule introduced to replace 1-year holding period rule for portfolio capital.
Brazil, 1999 crisis	January 14	The stocks market suffers its largest 1-day decline (down 15.8%).
	February 11	The real plummets by 12% against the dollar. Controls are announced.

Table 1 (*continued*)

Episode and country	Date	Key events
Brazil, 1999 crisis	March 1	Controls become effective. * * Government ordered local investment funds to increase their holdings of government bonds. The central bank raised to 80% from 60% the minimum amount of sovereign debt that must be held in the country foreign investment fund. This lowered the share that could be held in other countries' debt.

attention to the issue of external shocks, cross-border interdependence, and volatility spillovers. We employ principal component analysis—to assess contemporaneous co-movement; block exogeneity tests in a VAR framework—to assess temporal international causality; and GARCH tests for the effects of controls on volatility spillovers—to assess changes in cross border volatility links, as in Edwards (1998).

4.1. Principal component analysis

To assess whether the degree of co-movement across countries in several financial variables is influenced by the introduction of capital controls, we applied principal component analysis to the financial time series data over the control period and contrasted those results to the subsample with no controls. A priori, one should expect a lower degree of co-movement for the country that has imposed controls during the period in which these are in place.

We focus on three daily time series, the domestic policy interest rate (described for each country in the Data Appendix), the return on equity, and the change in the exchange rate (in percent) for the five EM countries in our sample, Brazil, Malaysia, the Philippines, South Korea, and Thailand. From these series, we constructed a smaller set of series, the principal components, that explain as much of the variance of the original series as possible. The higher the degree of co-movement in the original series, the fewer the number of principal components needed to explain a large portion of the variance of the original series. In case where the original series are identical (perfectly collinear), the first principal component would explain 100% of the variation in the original series. Alternatively, if the series are orthogonal to one another, it would take as many principal components as there are series to explain all the variance in the original series. In that case, no advantage would be gained by looking at common factors, as none exist.

The procedure begins by standardizing the variables so that each series has a zero mean and a unit standard deviation. This standardization ensures that all series receive uniform treatment and the construction of the principal component

indices is not influenced disproportionately by the series exhibiting the largest variation. The correlation matrix of the standardized series, Σ, is decomposed into its Eigen-vectors (P) and the diagonal matrix of Eigen-values (Λ).

$$\Sigma = P'\Lambda P \quad (1)$$

The Eigen-vectors are the loading factors, or weights, attached to each of the original series. For a particular time-series, the higher the degree of co-movement with other series the higher (in absolute value) its loading factor. If a particular time series is uncorrelated with the remaining series included in the analysis, then its loading factor in the first principal component should be close to zero. A priori, this is what we should expect to see for the time series for the country with capital controls during the period in which these are in place.

In Table 2, we present the results for the various sample periods for interest rates; we also include the results for the two control group countries, the

Table 2
Daily interest rates: principal component analysis

Episode and time period	R^2	Factor loadings in first principal component for				
		Brazil	Malaysia	Philippines	South Korea	Thailand
Full sample	0.395	0.322	0.823	0.762	−0.456	0.867
Crises and capital control episodes						
Brazil						
Pre controls: January 1, 1995–February 28, 1999	0.359	0.312	0.833	0.801	−0.402	0.843
Controls: March 1, 1999–present	0.625*	−0.654*	0.712	0.912	−0.565	0.901
Malaysia						
Pre controls: January 1, 1995–August 31,1998	0.414	0.482	0.788	0.778	−0.571	0.827
Controls: September 1, 1998–present	0.700*	−0.774*	0.841	0.936	−0.696	0.928
Thailand						
No controls: Remainder of sample	0.437	0.079	0.931	0.624	−0.686	0.929
Controls: May 14, 1997–January 30,1998	0.533	0.773*	0.624	0.828	−0.902	0.739
Crises episodes without capital controls						
Philippines and South Korea						
Tranquil period: Remainder of sample	0.345	−0.848	0.527	0.081	0.646	0.727
Crisis: July 2, 1997–July 31, 1998	0.387	0.497*	0.620	0.669*	−0.774*	0.777

* Denotes that the difference between the two subsamples is significant at standard confidence level.

Philippines and South Korea. For each country, we report the pre-capital control results (top row) and the post-control period (bottom row). In the first column, we report the R^2 associated with the first principal component. In the remaining five columns, we report the loading factor in the first principal component for each country. An asterisk denotes that the difference between the subsamples was statistically significant at standard confidence levels.

In some instances, such as the post-control period for Malaysia and Brazil in that order, the R^2 associated with the first principal component are quite high and significantly higher than in the pre-control sample. In none of the capital control episodes do the loading factors approach zero. In the case of Brazilian interest rates, the loading factor increases (in absolute terms), as Brazil and South Korea co-move inversely with the remaining three countries. Malaysia's interest rates, after its introduction of controls on September 1, 1998 continues to exhibit a high degree of co-movement with neighboring Thailand and the Philippines. While Thailand's loading factor drops from 0.929 to 0.739 with the introduction of controls (the difference is not statistically significant), it still shows considerable co-movement with Malaysia, the Philippines, and Brazil during that period.

Table 3 summarizes the comparable results for stock returns. The extent of contemporaneous co-movement of equity returns drops significantly for both Brazil (from pre-control level of 0.328 to 0.171) and Malaysia (from 0.739 to 0.346) following the introduction of controls and moderately so for Thailand.[12] The clearest cut results, however, come from performing this exercise using daily exchange rate changes, as shown in Table 4. In both the case of Brazil after capital controls are introduced on March 1, 1999 and following Malaysia's imposition of controls on September 1, 1998, their respective loading factors drop to almost zero while the controls are in place suggesting that, at least contemporaneously, their exchange rate changes are independent from exchange rate shocks elsewhere. This is consistent with the results and interpretation of Kaplan and Rodrik (2000) that the Malaysian controls may have been successful in reviving domestic demand because these reduced uncertainty about the financial system and the exchange rate in particular.

However, this analysis only provides a partial picture of what can be a fuller dynamic cross-border interdependence. While principal component analysis reveals the extent to which there is contemporaneous co-movement across the countries in our study in interest rates, stock returns and changes in the exchange rate across the various subsamples, interdependence may have a temporal dimension as well. That is, a shock in one country may not have an immediate effect on a second country but the effects of the shock may be spread out over the course of several days. Given that our data is daily, such temporal relationships may be of

[12] Thailand continues to show a high degree of co-movement in the May 14, 1997–January 30, 1998 period with Malaysia, the Philippines, and South Korea.

Table 3
Daily stock returns: principal component analysis

Episode and time period	R^2	Factor loadings in first principal component for				
		Brazil	Malaysia	Philippines	South Korea	Thailand
Full sample	0.374	0.326	0.649	0.679	0.605	0.722
Crises and capital control episodes						
Brazil						
Pre controls: January 1, 1995–February 28, 1999	0.378	0.328	0.655	0.680	0.600	0.727
Controls: March 1, 1999–present	0.311	0.171*	0.382*	0.697	0.739	0.591
Malaysia						
Pre controls: January 1, 1995–August 31, 1998	0.394	0.378	0.739	0.690	0.559	0.704
Controls: September 1, 1998–present	0.334	0.302	0.346	0.671	0.687	0.733
Thailand						
No controls: Remainder of sample	0.363	0.302	0.591	0.677	0.598	0.746
Controls: May 14, 1997–January 30, 1998	0.403	0.377	0.742*	0.709	0.570	0.705
Crises episodes without capital controls						
Philippines and South Korea						
Tranquil period: Remainder of sample	0.330	0.270	0.518	0.667	0.611	0.699
Crisis: July 2, 1997–July 31, 1998	0.431	0.407*	0.750*	0.696	0.606	0.758

* Denotes that the difference between the two subsamples is significant at standard confidence level.

greater importance than for lower frequency data, where the synchronicity of financial market hours across different regions and other institutional aspects of trading are less important. We turn to this issue next.

4.2. Causality and interdependence: a note

To examine whether there is greater or less temporal interdependence or unidirectorial causal links among five of the countries following the introduction of capital controls, we proceed much as we in the previous exercises. For Thailand, though, divided the sample into three subperiods, the period preceding the controls which runs from January 1, 1995 to May 13, 1997, the control period, which spans May 14, 1997 to January 30 and the post-control period which ends on July 29, 1999. Similarly, for the Philippines and South Korea, we break up the

Table 4
Daily exchange rate changes: principal component analysis

Episode and time period	R^2	Factor loadings in first principal component for				
		Brazil	Malaysia	Philippines	South Korea	Thailand
Full sample	0.345	0.020	0.734	0.680	0.386	0.758
Crises and capital control episodes						
Brazil						
Pre controls: January 1, 1995–February 28, 1999	0.346	0.013	0.734	0.670	0.387	0.760
Controls: March 1, 1999–present	0.266	0.594*	−0.000*	0.472	−0.451*	0.743
Malaysia						
Pre controls: January 1, 1995–August 31, 1998	0.347	0.018	0.743	0.683	0.380	0.757
Controls: September 1, 1998–present	0.282	0.188	0.039*	0.747	0.488	0.759
Thailand						
No controls: Remainder of sample	0.380	0.044	0.814	0.711	0.207	0.828
Controls: May 14, 1997–January 30, 1998	0.328	0.109	0.694	0.671	0.406	0.728
Crises episodes without capital controls						
Philippines and South Korea						
Tranquil period: Remainder of sample	0.272	0.261	0.560	0.737	0.378	0.543
Crisis: July 2, 1997–July 31, 1998	0.351	0.087*	0.747	0.677	0.366	0.777

* Denotes that the difference between the two subsamples is significant at standard confidence level.

sample into the pre- and post-financial crisis and the crisis period, which as noted earlier spans July 2, 1997 through July 31, 1998. A priori, if the controls are insulating the country from external shocks and facilitating independent monetary policy, one should see a weakening in any pre-existing causal links.

We employ a simple vector autoregression (VAR) framework that treats all variables as potentially endogenous and include 10 lags of each of the variables in the system. Omitting time subscripts, a representative equation for domestic interest rates in Brazil (denoted by the subscript b) in this five-equation system is given by:

$$r_b = \alpha_b + A_1(L)r_b + A_2(L)r_m + A_3(L)r_p + A_4(L)r_{sk} + A_5(L)r_t + \epsilon_b. \quad (2)$$

The subscripts m, p, sk, and t refers to Malaysia, the Philippines, South Korea, and Thailand, respectively. The lag operators are the A's and ϵ's denote the random

shocks. Because the variance of the underlying fundamentals tends to increase during periods of turbulence, it is necessary to correct for heteroskedastic disturbances when estimating the parameters the system. Hubert/White robust standard errors were computed. The comparable system was estimated for daily stock returns and changes in the exchange rate (in percent). For each block of regressors, we conducted *F*- and log-likelihood ratio tests that tested the null hypothesis of no causal relationship.

In the discussion that follows, we summarize the key results of these VAR exercises; in the longer working paper version, we report these findings in detail. We found no evidence to indicate that in the cases of Brazil, Malaysia, and Thailand capital controls weakened the international interdependence of interest rates-indeed, quite the contrary. Prior to March 1, 1999, interest rates in Brazil were not influenced by interest rate changes in the other four countries. In the more recent control period, however, interest rates are significantly influenced by Korean and Thai rates. In the case of the Thai controls, a similar tendency toward greater interdependence during the period during which the controls were in place is also evident. For Malaysia, there is also no evidence of a decline in interdependence but rather a shift in which country's rates are significant. At a more general level, there is a feature of the results for the causality tests worth noting. For the earlier part of the sample, which includes the pre-Asian crisis period, most of the regressors (other than lags of the dependent variable) are not statistically significant at standard confidence levels. The more recent period (i.e., post-crisis) is quite different in that regard with a greater degree of interdependence among the countries—particularly for the countries that did not introduce controls. Philippine and South Korean interest rates are significantly influenced by interest rates in the remaining countries in the sample.

Turning to stock returns, there are several parallels to the results for interest rates. In the case of Brazil, stock market interdependence is greater during the more recent control period (South Korean and Thai stock returns are both statistically significant), while for Thailand, the introduction of controls did not alter pre-existing causal relationships. The more marked change is in Malaysia, where the number of countries whose equity market shocks have a significant on the Malay market drops from three to one. This is a contrast to South Korea, where international interdependence in equity returns seems to be on the rise during the more recent post-crisis period.

As regard daily exchange rate changes, Brazil's exchange rate is influenced more prominently by foreign exchange rate shocks during the capital control period. This result is not surprising in light of the fact that the *real* was predetermined and confined to a narrow band during most of the pre-control sample and allowed to fluctuate more freely during the control period. The same observation applies to Thailand, which has continued with a managed float up until the present time. As with equity returns, the importance of external exchange rate shocks diminishes for Malaysia during the capital control period.

Taken together, these results suggest that capital controls had little effect in reducing international interdependence among currencies, equity markets, and interest rates for both Brazil and Thailand. By contrast, Malaysia's equity market and exchange rate are more autonomously determined, following the introduction of controls. The results also suggest that interdependence among four of the five EM economies (the exception is Malaysia) has increased in the wake of the Asian financial crisis in the more recent period. Given that trade and financial linkages have not changed markedly during this recent period, one interpretation for this greater interdependence is that in the aftermath of the crisis financial market participants are more likely to lump these economies into one group than they did previously.

4.3. Volatility and capital controls

While principal component analysis sheds light on contemporaneous international links and the VARs added a temporal dimension to the analysis of international interdependence, both of these approaches have focused on first moments. Yet, there may also be important differences across regimes in second moments (i.e., variances) in the financial variables analyzed. Furthermore, our theoretical priors suggested that there should be such differences. In this subsection, we focus on how capital controls and crises affect the volatility of interest rates and stock returns.

A related issue was examined in Edwards (1998). Using weekly interest rate data for Argentine, Chile, and Mexico, Edwards (1998) analyzed the consequences of the Mexican crisis for interest rate volatility in Argentine and Chile. The "Mexican spillover" dummies were statistically significant for Argentine, irrespective of the specification used, and uniformly insignificant for Chile. One possible interpretation of these results, he concluded, is that Chile's capital controls were effective in insulating Chile from the turmoil abroad.

In what follows, we will work with a variety of generalized autoregressive conditional heteroskedasticity (GARCH) models to examine whether there was an observed change in volatility during the capital controls episodes.[13] As before, we will contrast these results to the crises episodes in the Philippines and South Korea, where no controls are imposed during the crisis. We consider the following models:

$$r_t = \sum_{t=t-i}^{t-k} \beta_i r_{t-i} + \sum_{j=1}^{4} \gamma_j r_{jt}^{*} + \epsilon_t \tag{3}$$

$$\sigma_{r_t}^2 = \omega + \text{dummy}_c + \alpha \epsilon_{t-1}^2 + \delta \sigma_{t-1}^2$$

[13] In all cases, a GARCH (1,1) model was estimated.

and

$$\Delta r_t = \sum_{t=t-i}^{t-k} \beta_i \Delta r_{t-i} + \sum_{j=1}^{4} \gamma_j \Delta r_{jt}^* + \epsilon_t \tag{4}$$

$$\sigma^2_{\Delta r_t} = \omega + \text{dummy}_c + \alpha \epsilon^2_{t-1} + \delta \sigma^2_{t-1}.$$

where the domestic nominal interest rate is denoted by r_t, in Eq. (3), the foreign interest rates for the other four countries in the study are denoted by the r_{jt}^*, and the random shock is denoted by ϵ. In the variance equation, ω is the mean of the variance; the lag of the mean squared residual from the mean equation (i.e., ϵ^2_{t-1}) is the ARCH term and last period's forecast variance (i.e., σ^2_{t-1}) is the GARCH term. The term dummy_c is a dummy variable that takes on the value of 1 during the control period for Brazil, Malaysia, and Thailand and 0 otherwise. For the Philippines and South Korea, it takes on a value of 1 during the crisis period and 0 otherwise. The number of autoregressive lags, k, is reported for the cases $k = 0$, 5, and 10. We also estimate the model in first differences (Δr_t, shown in Eq. (4)) and for the case where the r's and r^*'s refer to equity returns. As discussed earlier, periods of turbulence that are part of our sample of daily observations render the assumption of identically and independently distributed conditionally normal disturbances in the basic GARCH model inadequate. Given the presence of heteroskedastic disturbances in our sample, we use the methods described in Bollersev and Woolridge (1992) to compute the Quasi-Maximum Likelihood covariances and standard errors. To perform some sensitivity analysis and assess whether the introduction or intensification of controls might have been anticipated

Table 5
Daily interest rates variance equation: volatility spillovers with and without capital controls; Bollersev–Woolridge robust standard errors and covariance, GARCH (1,1)

Number of autoregressive lags included	ARCH (1)	GARCH (1)	Controls dummy
Brazil			
0	0.109 (0.273)	0.852 (0.000)*	−0.044 (0.598)
5	0.335 (0.003)*	0.668 (0.000)*	0.104 (0.577)
10	0.374 (0.002)*	0.708 (0.000)*	0.111 (0.597)
Malaysia			
0	0.503 (0.045)*	0.559 (0.000)*	−0.004 (0.129)
5	1.464 (0.000)*	0.117 (0.060)*	−0.005 (0.131)
10	1.442 (0.003)*	0.136 (0.037)*	−0.008 (0.021)*
Thailand			
0	0.331 (0.081)*	0.603 (0.000)*	0.073 (0.133)
5	0.342 (0.062)*	0.582 (0.000)*	0.074 (0.109)
10	0.355 (0.055)*	0.576 (0.000)*	0.072 (0.111)

* Denotes statistically significant at the 5% level.

Table 6
Daily interest rates variance equation: volatility spillovers in crisis and tranquil periods; Bollersev–Woolridge robust standard errors and covariance, GARCH (1,1)

Number of autoregressive lags included	ARCH (1)	GARCH (1)	Crisis dummy
Philippines			
0	0.099 (0.363)	0.697 (0.011)*	−0.011 (0.506)
5	2.635 (0.002)*	0.109(0.036)*	−0.045 (0.243)
10	4.295 (0.001)*	0.003 (0.489)	−0.046 (0.236)
South Korea			
0	0.347 (0.018)*	0.046 (0.000)*	0.007 (0.860)
5	0.278 (0.012)*	0.816 (0.000)*	0.001 (0.813)
10	0.275 (0.014)*	0.816 (0.000)*	0.001 (0.775)

* Denotes statistically significant at the 5% level.

by financial markets, we also allowed the controls dummy variable to assume the value of 1 four, three, two, and one week before the controls.

The results for interest rates, changes in interest rates, and stock returns, are reported in Tables 5–10. As to the specification for nominal interest rates, while both ARCH and GARCH terms are statistically significant in Brazil, Malaysia, and Thailand (Table 5), the capital control dummy variable is only significant for Malaysia—although this result is not robust across alternative lag specifications. In the case of Malaysia, the controls dummy variable has the anticipated negative sign, while in the case of Brazil and Thailand, the sign is positive, although not

Table 7
Daily interest rate changes variance equation: volatility spillovers with and without capital controls; Bollersev–Woolridge robust standard errors and covariance, GARCH (1,1)

Number of autoregressive lags included	ARCH (1)	GARCH (1)	Controls dummy
Brazil			
0	0.110 (0.272)	0.851 (0.000)*	−0.044 (0.595)
5	0.337 (0.003)*	0.734 (0.000)*	0.102 (0.598)
10	0.343 (0.048)*	0.766 (0.000)*	0.104 (0.599)
Malaysia			
0	0.465 (0.041)*	0.583 (0.000)*	−0.004 (0.119)
5	0.543 (0.050)*	0.495 (0.000)*	−0.005 (0.100)*
10	1.492 (0.001)*	0.083 (0.079)*	−0.009 (0.025)*
Thailand			
0	0.316 (0.090)*	0.601 (0.000)*	0.078 (0.136)
5	0.338 (0.067)*	0.571 (0.000)*	0.078 (0.112)
10	0.345 (0.058)*	0.577 (0.000)*	0.072 (0.111)

* Denotes statistically significant at the 5% level.

Table 8
Daily interest rates changes variance equation: volatility spillovers in crisis and tranquil periods; Bollersev–Woolridge robust standard errors and covariance, GARCH (1,1)

Number of autoregressive lags included	ARCH (1)	GARCH (1)	Crisis dummy
Philippines			
0	0.108 (0.400)	0.664 (0.078)*	−0.013 (0.529)
5	0.100 (0.419)	0.666 (0.064)*	−0.012 (0.524)
10	0.157 (0.292)	0.490 (0.073)	−0.002 (0.389)
South Korea			
0	0.350 (0.030)*	0.804 (0.000)*	−0.001 (0.944)
5	0.323 (0.029)*	0.815 (0.000)*	−0.001 (0.847)
10	0.327 (0.026)*	0.808 (0.000)*	−0.001 (0.988)

* Denotes statistically significant at the 5% level.

statistically significant.[14] For the two countries that did not introduce capital controls (Table 6), the crisis dummy variable is not statistically significant.

Turning next to the results for the first differences of interest rates (shown in Tables 7 and 8), we find the same pattern. Among the three capital control and two crises without capital controls episodes, the dummy variable is only significant for Malaysia for most of the lag profiles used.

Finally, for daily equity price returns, the control dummy is significant and positive for Thailand, indicating the control period was associated with above-average volatility in the equity market (Table 9). However, it is difficult to attribute the increased volatility exclusively to the controls. As Table 10 highlights, the crisis period in the Philippines (despite the absence of new capital account restrictions) was also associated with higher equity market volatility.

All in all, while the GARCH results do not point to across-the-board differences in volatility across capital account regimes, the three cases where the control dummies are significant (interest rates and interest rate changes in Malaysia and equity returns in Thailand) have the expected sign.

4.4. Summary of findings

While the emphasis of the previous section was on examining possible changes in the key financial variables, much of this section has been devoted to examining

[14] When the dummy variable was set at earlier dates, the dummy variable became insignificant for Malaysia—suggesting, by this measure, that the measures were not anticipated by financial markets. In the two other cases, it made no difference as the coefficients across the board were statistically insignificant.

Table 9
Daily stock returns variance equation: volatility spillovers with and without capital controls; Bollersev–Woolridge robust standard errors and covariance, GARCH (1,1)

Number of autoregressive lags included	ARCH (1)	GARCH (1)	Controls dummy
Brazil			
0	0.246 (0.001)*	0.728 (0.000)*	0.001 (0.904)
5	0.239 (0.001)*	0.735 (0.000)*	0.001 (0.870)
10	0.241 (0.000)*	0.736 (0.000)*	0.001 (0.952)
Malaysia			
0	0.131 (0.000)*	0.882 (0.000)*	0.001 (0.708)
5	0.129 (0.000)*	0.884 (0.000)*	0.001 (0.738)
10	0.146 (0.000)*	0.869 (0.000)*	0.001 (0.652)
Thailand			
0	0.140 (0.000)*	0.818 (0.000)*	0.002 (0.082)*
5	0.148 (0.067)*	0.805 (0.000)*	0.002 (0.072)*
10	0.137 (0.000)*	0.828 (0.000)*	0.002 (0.079)*

* Denotes statistically significant at the 5% level.

cross-border financial links and interdependence across policy regimes. As to the central issue of insulating the economy from external shocks and gaining greater policy autonomy, our results suggest that: there is little evidence that capital controls were effective in decoupling domestic interest rates from foreign interest rates—either contemporaneously or temporally. The closest to meeting this expectation is Malaysia. There is also little evidence that these measures were effective in decoupling domestic exchange rate changes from those changes abroad—either contemporaneously or temporally. Again, the closest to meeting this expectation is Malaysia. The evidence suggests that equity markets continue to be internationally

Table 10
Daily stock returns variance equation: volatility spillovers in crisis and tranquil periods; Bollersev–Woolridge robust standard errors and covariance, GARCH (1,1)

Number of autoregressive lags included	ARCH (1)	GARCH (1)	Crisis dummy
Philippines			
0	0.184 (0.000)*	0.781 (0.000)*	0.001 (0.071)*
5	0.198 (0.000)*	0.766 (0.000)*	0.001 (0.082)*
10	0.216 (0.000)*	0.742 (0.000)*	0.001 (0.056)*
South Korea			
0	0.086 (0.000)*	0.910 (0.000)*	0.001 (0.156)
5	0.059 (0.001)*	0.940 (0.000)*	0.001 (0.187)
10	0.061 (0.001)*	0.938 (0.000)*	0.001 (0.199)

* Denotes statistically significant at the 5% level.

Table 11
Summary of key findings

Test	Control period versus no-control period			Crisis versus tranquil period	
	Brazil	Malaysia	Thailand	Philippines	South Korea
(1) Principal components: Did its loading factor decline during the control or crisis period?					
Interest rates	No	Yes	Yes	No, increased	Yes
Stock returns	Yes	Yes	No, about the same	No, about the same	No, about the same
Changes in the exchange rate	No, increased	Yes	No, about the same	No, increased	Yes
(2) VARs: Did causality from other countries diminish during the control or crisis period?					
Interest rates	No, increased	No, the same	No, increased	Yes	No, increased
Stock returns	No, increased	Yes	No, the same	Yes	No, increased
Changes in the exchange rate	No, increased	Yes	No, increased	No, increased	No, increased
(3) GARCH: Was the control or crisis dummy significant in the variance equation?					
Interest rates	No	Yes, reduced the variance	No	No	No
Changes in interest rates	No	Yes, reduced the variance	No	No	No
Stock returns	No	No	Yes, increased the variance	Yes, increased the variance	No

linked, despite the introduction of controls. Finally, financial crises appear to be a key determinant of the timing structural changes—more so than capital controls (Table 11).

5. Final remarks

We have examined some recent experiences with capital controls during periods of market stress. In two of the three cases (Brazil and Thailand), the controls did not appear to deliver much of what was intended. Although, of course, one does not observe the counterfactual. By contrast, in the case of Malaysia, the controls did align more closely with the priors of what controls are intended to achieve—namely, greater interest rate and exchange rate stability and more policy autonomy.

Generalized policy lessons are not possible from such a scanty set of experiences. Yet it would appear that a fruitful area for future research would be to investigate the effectiveness of controls for a more comprehensive set of episodes and, particularly, as it relates to the development and international integration of

the financial sector. One could speculate that Brazil's relatively sophisticated financial markets, which are second in liquidity to Hong Kong among EMs, and Thailand's offshore banking center provided leakage and arbitrage opportunities that were absent in Malaysia. If, indeed, it were to be the case that financial sector development plays a prominent role in explaining when capital account restrictions have a bite, then the policy implications for different "tiers" of EMs would be somewhat clearer.

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