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# Dynamic Capital Mobility in Pacific Basin Developing Countries: Estimation and Policy Implications

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## Abstract

This paper estimates empirically the changing degree of capital mobility in several Pacific Basin countries that have pursued financial liberalization in recent years. Tracing the impact of the liberalization process on the capital account, the paper also examines the implications for monetary policy operating in this changing economic environment. Empirical estimates support an overall finding of increased capital mobility in the region over the past decade. However, country experiences, with the exception of Singapore, have been more episodic--oscillating between periods of high and low financial openness--rather than uniform in regards to changing capital mobility.

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1/ Department of Economics, Princeton University. Work on this paper began as part of an IMF summer internship in the Asian Department, Division C. The author would like to thank David Goldsbrough, Owen Evans, Ichiro Otani, Roger Kronenberg, and Ranjit Teja for helpful discussions and comments. Any remaining errors, however, are the author's role responsibility.

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## Summary

Developing countries in the Pacific Basin, in pursuing financial market liberalization and reform, have made significant progress over the past decade. Although individual countries have taken different measures, the overall trend in the region has been to deregulate local financial markets and introduce a greater role for market forces, domestic and foreign, in interest rate determination. This paper traces the impact over time of these developments on the degree of capital mobility and the role of monetary policy by formulating a dynamic calibration of capital mobility.

The degree of capital mobility--defined broadly as the level of financial market integration--is manifested through the extent to which local and world interest rates are interrelated. With financial liberalization, deviations from interest rate parity induce increasingly responsive market forces to narrow existing return differentials, limiting the scope for independent monetary policy. Using various econometric techniques to estimate interest rate differentials and simulate monetary shocks, the paper traces the effects of liberalization on capital mobility and the role of stabilization policy in Korea, Malaysia, Singapore, and Thailand.

Estimates support an overall finding of dampened deviations from interest rate parity and, hence, increased capital mobility in the region over the past decade. However, country experiences, with the exception of Singapore, have been episodic--oscillating between periods of low and high financial openness--rather than uniform in terms of changing capital mobility.

## I. Introduction

Recent experience among developing countries in the Pacific Basin has been, in part, a continuing process of financial market liberalization and growing financial flows over the past decade. Although particular liberalization measures have varied across countries, the region as a whole has seen a general trend toward deregulation of domestic financial markets and the removal or relaxation of many restrictions on international capital movements. Though country experiences regarding net resource flows have also differed, 1/ the trend here has been a declining proportion of external borrowing and an increasing share of private resource flows in total external liabilities among these countries.

As financial liberalization continues in the region, the empirical question remains as to the impact of these developments on the level of integration between local and world financial markets. In particular, observing the changing degree of capital mobility -- defined broadly in this context as the degree of linkage between domestic and foreign interest rates -- is of special concern to the small open economy attempting to stabilize its exchange rate, but facing ever increasing and responsive financial flows. Moreover, to the extent that monetary transmissions work through real interest rates, the ability of the authorities to independently pursue domestic stabilization objectives also becomes increasingly suspect with the opening of the capital account.

Most of the empirical work done in this area has examined capital mobility from a static perspective, estimating either an offset or an openness coefficient. For example, Edwards and Khan (1985) have developed an analytical framework for interest rate determination in developing countries wherein the prevailing interest rate represents a weighted average of open and closed economy rates that otherwise would have existed. Estimation of this weight indicates the relative importance of interest rate parity and domestic monetary factors in determining national interest rates, thus capturing the degree of financial openness. More accurately, however, this approach estimates the *average* degree of openness for a given country over the sample period. Hence, this line of research essentially eludes the question of the *changing* degree of capital mobility and, consequently, the changing roles of stabilization and exchange rate policies over time. 2/

To assess the impact of the financial liberalization process on the mobility of capital and the role of policy through time, a *dynamic* modelling

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1/ For instance, Thailand, Malaysia and Indonesia have been able to attract a growing proportion of their net resource inflows in the form of foreign direct investment (FDI) in recent years, whereas the Philippines has not. However, Malaysia - excluding FDI - had negative aggregate net resource flows towards the end of the decade. See Hussain and Jun (1991). See Tseng and Corker (1991) for an overview of financial liberalization among Asian countries in the 1980s.

2/ Glick and Hutchison (1990) attempt to address a changing degree of linkage between interest rates in the Pacific Basin and rates in the U.S. using a static model, but incorporating regime changes using time-dummy variables.

approach is needed. The technique employed in this paper involves Autoregressive Conditional Heteroschedasticity (ARCH) estimation of interest rate differentials between select Pacific Basin developing countries and Japan. 1/ Our purpose is to determine the extent to which these interest rates have become increasingly interrelated. Specifically, dampened deviations from trend in interest rate differentials reveal an increased level of capital mobility, and time series estimation of this process details the timing and magnitude of those changes. From determining the dynamics of capital mobility, we then turn to the implications for monetary policy operating in this changing economic environment.

The paper is organized as follows. Section II begins by summarizing briefly some theoretical background on interest rate parity in the presence of various adjustment costs such as capital controls and transactions costs. An appendix is included that integrates our discussion on imperfect capital mobility in section II into a dynamic model following Dornbusch (1976) to structure the econometric analysis in section III. Finally, section IV extends the time series results of section III to policy issues by simulating impulse-response functions using country parameter estimates.

## II. Theoretical Background

### 1. Interest rate parity

A central tenet in open economy macroeconomics is the theory of interest rate parity (IRP). A covered version of the theory equates the forward discount/premium with the difference between domestic and foreign interest rates. This equality can be interpreted as an arbitrage condition, indicating that covered profit opportunities have been fully exploited. Explicitly, we can express this interest parity relation in a general form by:

$$\phi = i - i^* - fd, \tag{2.1}$$

where $\phi$ represents the covered interest rate differential, $i$ and $i^*$ are the domestic and foreign interest rates for a given maturity, and $fd$ is the forward discount - equaling $(F-S)/S$, where $F$ and $S$ are the forward and spot exchange rates (expressed as home currency price of foreign currency). Time subscripts have been suppressed here for notational convenience. With risk neutral speculators and perfect substitutability of assets, the covered differential $\phi$ should be identically zero under IRP in the absence of any distortions or frictions such as capital controls or transactions costs.

In a stochastic setting, we can set an error term equal to (2.1), allowing $\phi$ to vibrate randomly around zero up to an white-noise disturbance

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1/ The methodology employed in this paper essentially follows that of Engle (1982), here applied to interest rate differentials for Korea, Malaysia, Singapore and Thailand.

term $\epsilon$. That is, the contemporaneous disturbance terms $\epsilon_t$'s are restricted to be independent and identically distributed (i.i.d.), mean zero, and unforecastable at time t. Otherwise, unexploited profit opportunities would exist, violating our basic arbitrage condition. Perfect capital mobility is often defined as (2.1) when set to zero. However, one should be careful to note that this representation also embodies assumptions on risk preference and asset substitutability.

2. Imperfect capital mobility

Adding various frictions, such as information and transactions costs, we can modify the simple case of perfect capital mobility. Rather than strict equalization of domestic and covered foreign rates of return, interest rate differentials may exist within some neutral band 1/:

$$|\phi = i - i^* - fd| < AC, \tag{2.2}$$

where AC represents the sum of the various adjustment costs, in percentage terms, involved in moving funds through domestic and foreign asset markets via the foreign exchange market. Appending the basic arbitrage condition with costs of adjustment also relaxes the white-noise constraint on the disturbance term $\epsilon$. Equation (2.2) now permits $\phi$ to systematically deviate within the band while still excluding arbitrage profit opportunities. Treating capital controls as another form of adjustment cost 2/, we can increase the band-width in (2.2) to AC' > AC, capturing the additional costs of relocating arbitrage funds in the presence of official restrictions, including such regulations as differential taxation, foreign exchange controls and so on.

3. Risk aversion, uncertainty, and imperfect asset substitutability

Relaxing our initial assumptions in the case of perfect capital mobility by allowing risk aversion in speculators, along with the non-comparability of assets, modifies (2.2) even further. For example, capital controls introduce more than just the "certainty" or direct costs associated with existing controls. Otani and Tiwari (1990) argue that their presence exerts "uncertainty costs" as well, concerning future capital restrictions. Such considerations introduce differences in underlying risk characteristics of assets, reducing the supply elasticity of capital. Using expected utility and mean-variance optimization, Otani and Tiwari (1990) show the impact of uncertainty associated with capital controls on the IRP relation as follows:

$$|\phi - \bar{\phi}| < AC'', \tag{2.3}$$

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1/ The discussion here summarizes sections of Otani and Tiwari (1990), recast in terms of our variable $\phi$.

2/ Dooley and Isard (1980) argue that implementation of capital controls acts as an explicit or implicit tax on agents. See also Otani and Tiwari (1984). Gros (1987) models quantitative capital controls explicitly using an adjustment cost function in a dynamic optimization context.

where AC''(> AC') incorporates the implicit costs associated with existing capital controls, and where $\phi$ is the risk premium indicating that the (broader) neutral band is no longer symmetric about zero. In general, capital controls are merely one aspect of political or country risk that may drive a wedge between various rates of return and reduce the responsiveness of capital to arbitrage return differentials. Note that non-comparable risk in assets in various financial markets, which places these rates of return in disparate risk classes, may remain even in the absence of any other impediments to interest rate parity. Moreover, economic liberalization measures that do not even affect financial markets directly may still impinge upon perceived differences in asset risk characteristics, affecting departures in interest rate parity.

Although not exhaustive, this list gives some sense of the many frictions and distortions that possibly preclude our original interest parity relation empirically. As for the impact of financial market liberalization, resultant changes in various adjustment costs and/or asset substitutability should directly affect the size of the neutral band wherein return differentials may systematically deviate. Specifically, liberalization measures that effectively increase financial openness will narrow the implicit band. Increasingly confined, IRP deviations will thus reflect the reduced impact of domestic monetary factors in determining domestic interest rates resulting from a heightened responsiveness of internationally mobile capital. Furthermore, the centrality of the band may also be affected by increasing financial market integration as captured by a diminishing risk premium, stemming from greater asset substitutability. Introducing imperfect capital mobility formally into a sticky-price model following Dornbusch (1976) is relegated to the appendix.

## III. Time Series Estimation

### 1. Interest rate data

Monthly data series on domestic money market interest rates were obtained for the following Pacific Basin countries: Korea, Singapore, Malaysia and Thailand. 1/ For comparison, the three-month London Interbank Offer Rate (LIBOR) on Japanese Yen deposits was chosen to represent the world rate of interest. By choosing an offshore rate as the reference point, we intended to limit the influence of liberalization measures taken in Japan in order to isolate the impact of measures taken domestically on interest rate convergence.

Series on interest rate differentials were then constructed by subtracting the Japan LIBOR from the domestic rate, or $\phi_t = (i - i^*)_t$, expressed in annual percentage terms. Assuming exchange rates versus the

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1/ For Malaysia, the particular interest rate used was the overnight interbank rate, while for Korea the daily rate on call money was obtained. Three-month interbank rates were used in the case of Singapore and Thailand.

Yen follow a random walk for our sample countries, 1/ we may relate these interest rate differentials with a suitably defined interest rate parity condition, in an attempt to calibrate deviations from the latter as a measure of capital mobility.

Initial non-parametric statistics for $\phi$ consisting of sample means and variances were computed and are given below in Table 1. The full sample period from 1978:9 to 1990:12 was also sub-divided in half with descriptive statistics for each subsample period appearing in columns 3 through 6. Note that for every country in our sample, mean interest rate differentials were smaller in absolute terms in the second half of the period than the first. The same fact holds true for sample variances as well. Also note that risk premia appear to be significant for Thailand and Korea, but relatively insignificant in the case of Singapore and Malaysia.

Table 1 - Non-Parametric Estimates:

Interest Rate Didfferentails in the Pacific Basin

| | 1978:9 - 1990:12 | | 1978:9 - 1984:10 | | 1984:10 - 1990:12 | |
|---|---|---|---|---|---|---|
| | Mean | Variance | Mean | Variance | Mean | Variance |
| Singapore | .446 | 3.723 | 1.544 | 4.226 | -.652 | .829 |
| Malaysia | -.542 | 8.518 | -.968 | 12.153 | -.116 | 4.631 |
| Thailand | 5.581 | 7.356 | 6.922 | 6.705 | 4.239 | 4.820 |
| Korea | 7.338 | 13.066 | 9.522 | 13.412 | 5.154 | 3.228 |

Data Source: IMF International Financial Statistics and IMF Staff

## 2. ARMA Estimation

To analyze deviations from interest rate parity, we must first characterize the motion of interest rate differentials by using univariate time series estimation. Here, we apply an Autoregressive Moving Average (ARMA) representation to $\phi_t$, including a constant and a non-linear time

1/ An uncovered version of interest rate parity, with perfect capital mobility and asset substitutability, has:

$$\phi_t = i_t - i^*_t - \Delta s^e_{t+k},$$

where $\Delta s^e_{t+k}$ is the expected rate of depreciation in the spot exchange rate over the length of maturity, $s$ being the log spot rate and $k$ being the length of maturity for $i$ and $i^*$. Assuming the spot exchange rate follows a random walk, we set the last term in expression to zero, equating rational with static expectations. Initial exchange rate estimates strongly support a random walk hypothesis in the data. See also Levich (1984).

trend. 1/ Introducing a constant allows for the presence of a risk premium, implying a non-zero, long-run value of $\phi$. ARMA specification with a trend permits us to separate systematic deviations about IRP, which reflect the degree of capital mobility, from movements in the IRP value itself, which reflect changes in asset substitutability. Although, these two issues are not unrelated.

As for estimation, an ARMA(p,q) model for demeaned and detrended interest rate differentials - representing IRP deviations - can be written generally as:

$$A(L)(\phi_t - \mu - \text{trend}_t) = B(L)\epsilon_t, \tag{3.1}$$

where A(L) and B(L) are respectively the AR and MA lag polynomials of orders p and q, written as $A(L) = 1 - \lambda_1 L - \ldots - \lambda_p L^p$ and $B(L) = 1 + \gamma_1 L + \ldots + \gamma_q L^q$ with L representing the lag operator, and where $\mu$ is the constant term. Using this general framework, Ordinary Least Squares (OLS) and Non-linear Least Squares (NLLS) estimates for $\phi$ -- in versions containing a constant, trend or MA errors -- were computed. Estimation results for the coefficients are reported below in Table 2.

TABLE 2. ARMA Estimation:

Interest Rate Differentials in the Pacific Basin

Model: $A(L)(\phi_t - \mu - \text{trend}_t) = B(L)\epsilon_t$

$\epsilon_t \sim$ i.i.d. $N(0,\sigma^2)$

| | $\mu$ | trend 2/ | $\phi_{t-1}$ | $\epsilon_{t-1}$ | adj $R^2$ |
|---|---|---|---|---|---|
| Singapore | --- | --- | .8684** (21.488) | --- | .748 |
| Malaysia | --- | --- | .9373** (27.500) | -.4381** (-4.982) | .658 |
| Korea | 5.424** (10.115) | 15.246** (5.287) | .8170** (16.957) | --- | .916 |
| Thailand | 5.553** (5.834) | --- | .8923** (23.850) | --- | .795 |

t statistics in parentheses    *.05 level of significance    **.01 level of significance

From Table 2, note that an AR(1) specification was chosen as the appropriate time series representation for interest rate differentials in Singapore,

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1/ In the case of time-varying risk, we approximate this process with an exponential time trend, representing smooth convergence in the risk premium to its long-run value and paralleling a process of progressive financial liberalization and integration.

2/ Exponential $\text{trend}_t = e^{(-.05t)}$.

Korea and Thailand, while an ARMA(1,1) model was selected in the case of Malaysia. So for example, from Table 2, we see that the time series behavior of interest rate differentials in Malaysia is best represented by the univariate model $\phi_t = .9373\phi_{t-1} + \epsilon_t - .4381\epsilon_{t-1}$. Selecting the particular order of the model -- that is, the number of AR and MA lags -- for each country was completed using the Schwarz Information Criterion (SIC). 1/

Constants were found statistically significant only for Thailand and Korea and elsewhere omitted. Also, a time trend was found to be significant in the case of Korean interest rate differentials. All ARMA coefficients implemented were found to be highly significant at the .01 level or better. The large estimates for the coefficient $\lambda_1$ (close to 1) on lagged interest rate differentials $\phi_{t-1}$ suggest weak mean-reverting behavior in the data and significant persistence in deviations from interest rate parity, especially in the case of Malaysia and Thailand. 2/

Plots of interest rate differentials $\phi$ and residuals from ARMA estimation are seen for each country in Charts 1 through 4. Close inspection of residuals for Singapore in Chart 1 reveals strong support for the notion that shocks to and, hence, deviations from IRP have diminished over the 1980s, suggesting increased capital mobility. Large impulses to IRP deviations typified most of the early sample period from 1979 through 1982, but disturbances have shown sustained dampening ever since.

Malaysia has seen such dampening only more recently, since 1987, as evident in Chart 2 residuals. Preceding this quiet period, a turbulent episode of large deviations existed from mid-1984 to 1987 in return differentials, although much of this volatility was attributable to a few isolated shocks. Sustained variability of disturbances to IRP, indicating limited capital mobility in Malaysia, was only evident in the beginning of the period (1979 to mid-1982) and has since subsided in accordance with increased financial integration, with the one exception occurring in the mid-1980s.

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1/ In choosing an appropriate time series model, we first estimated sample autocorrelation and partial autocorrelation functions to indicate possible candidates. Final selections, as reported in table 2, were made through computing the SIC = (RSS+log(NOBS)*SEE$^2$*K)/NOBS -- where RSS = residual sum of squares, NOBs = number of observations, SEE = standard error of estimate, and K = number of regressors -- for numerous ARMA(p,q) specifications.

2/ As the AR(1) coefficient goes 1 (unit root in A(L)), the model will exhibit non-stationarity or no mean-reverting tendencies as the effect of shocks becomes permanent. Although modelling $\phi$ as an integrated process may not be rejected statistically as an alternative representation, theoretically this specification is very unappealing for it suggests a perfectly closed capital account and no long-run equalization of returns.

As for Korea, the most dramatic development regarding financial liberalization and IRP over the 1980s has been an enormous decline in average interest rate differentials as captured by the trend in Chart 3, reflecting increased asset substitutability and a time-varying risk premium. As for capital mobility, variance of disturbances to IRP in Korea have shown a sustained decline through most of the sample period, but have more recently reverted in terms of variability since 1988.

The results for Thailand are less clear. Chart 4 portrays numerous episodes of relative tranquility and turbulence in Thai interest rate differentials. Without a clear tendency toward dampened deviations in $\phi$, evidence for increased financial market integration in Thailand appears ambiguous, in contrast with the experience elsewhere in the region.

However, one overall similarity can clearly be drawn. In each country's experience without exception, large and small residuals, respectively, have generally clustered together. And in most cases, consistent with progressive liberalization, periods of large variability in shocks have preceded periods of dampened shocks. This observation strongly suggests that an Autoregressive Conditional Heteroschedasticity (ARCH) framework -- which models an underlying pattern to the changing variance of residuals -- may be appropriate in order to improve our initial estimates and to further illustrate the systematic changes in IRP deviations and capital mobility in the Pacific Basin.

3. <u>ARCH estimation</u>

The purpose of this section is to formally test for the presence of ARCH residuals and revise our original estimates through ARCH estimation where appropriate. Following Engle (1982), we may represent errors following a *n*th order ARCH process as:

$$\epsilon_t \sim N(0,h_t); \quad h_t = h(\epsilon_{t-1},\ldots\epsilon_{t-n},\boldsymbol{\alpha}), \tag{3.2}$$

where $h_t$ is the conditional variance function at time t and $\boldsymbol{\alpha}$ is a vector of unknown parameters. Also in (3.2), we have assumed normality. In the presence of ARCH errors, it can be shown in our model that OLS estimators are consistent, but that the standard errors are not.

To correct for conditional heteroschedasticity, we employ Maximum Likelihood Estimation (MLE) to our data series. From (3.2), the log likelihood function for the *t*th observation can be written as follows:

$$\ell_t = -.5\log h_t - .5\epsilon_t^2/h_t. \tag{3.3}$$

Maximizing (3.3) with respect to the vector of parameters $\alpha,\lambda,\mu$ (constant) and $\tau$ (time trend coefficient) will then provide ARCH-corrected estimates. As discussed in Engle (1982), the MLE approach generates consistent estimation of the variance-covariance matrix and asymptotically efficient parameter estimates.

**Chart 1 - Singapore versus Japan LIBOR**
Interest Differentials, 9/1978-12/1990

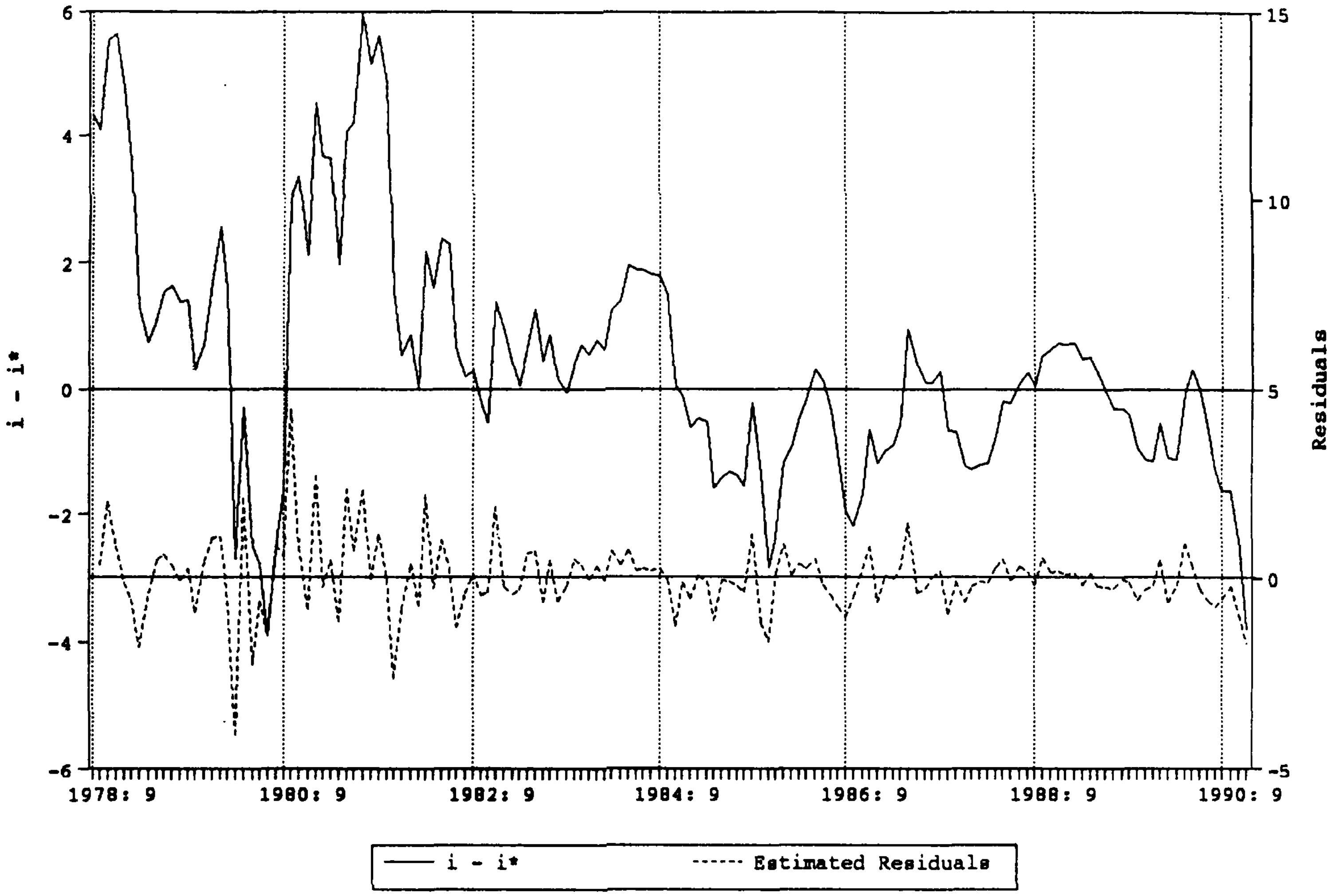


**Chart 2 - Malaysia versus Japan LIBOR**
Interest Differentials, 9/1978-12/1990

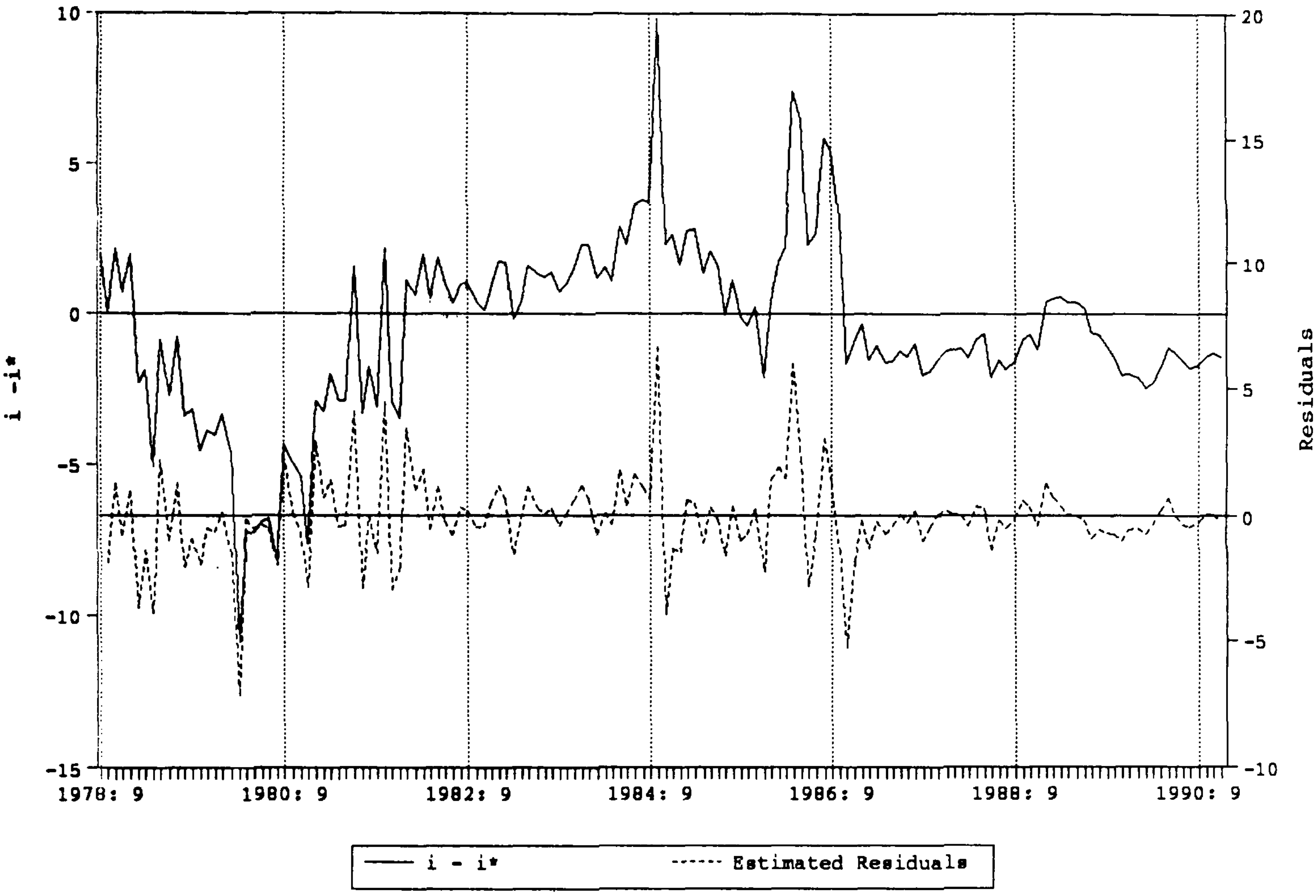


Chart 3 - Korea versus Japan LIBOR
Interest Differentials, 9/1978-12/1990

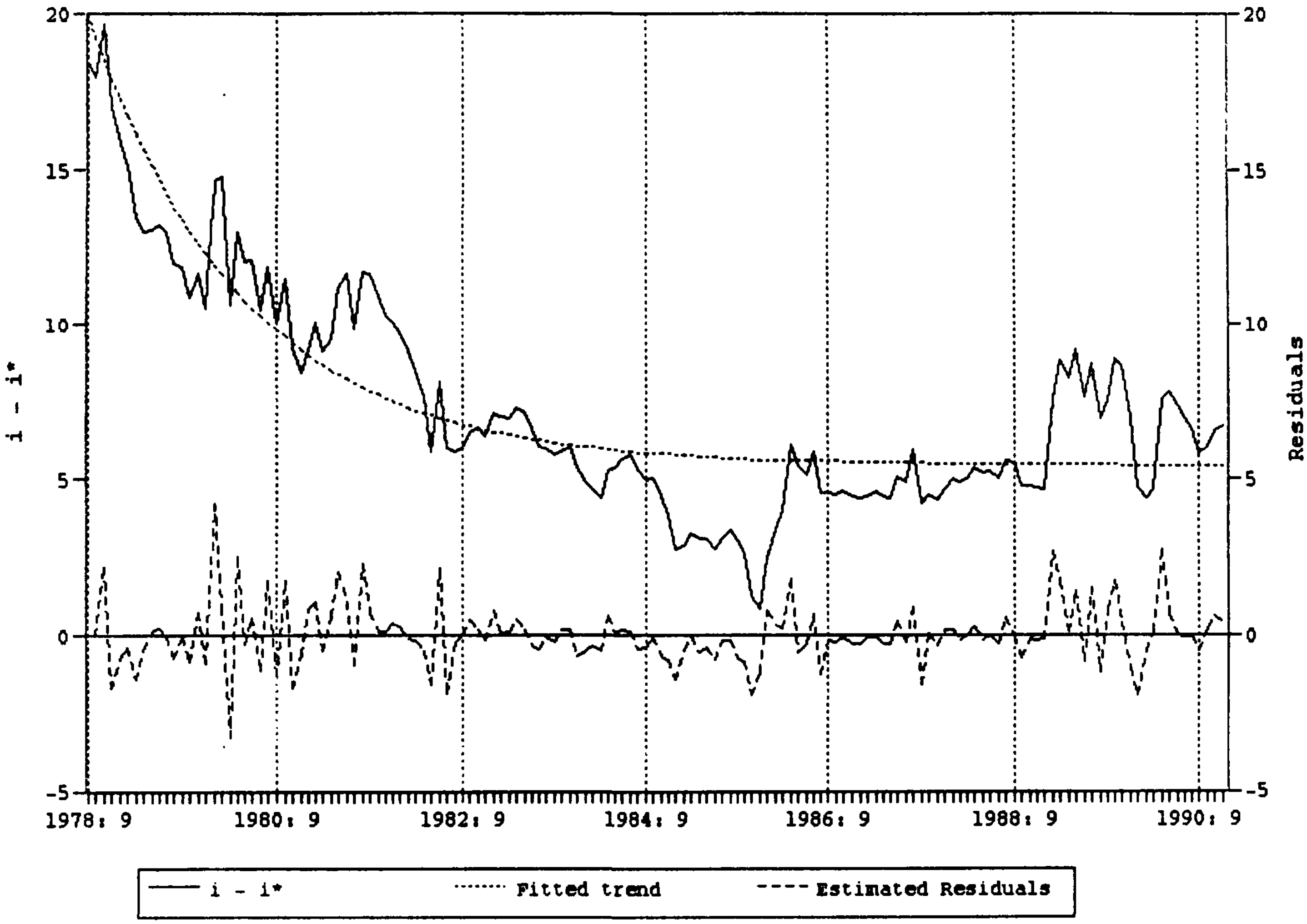
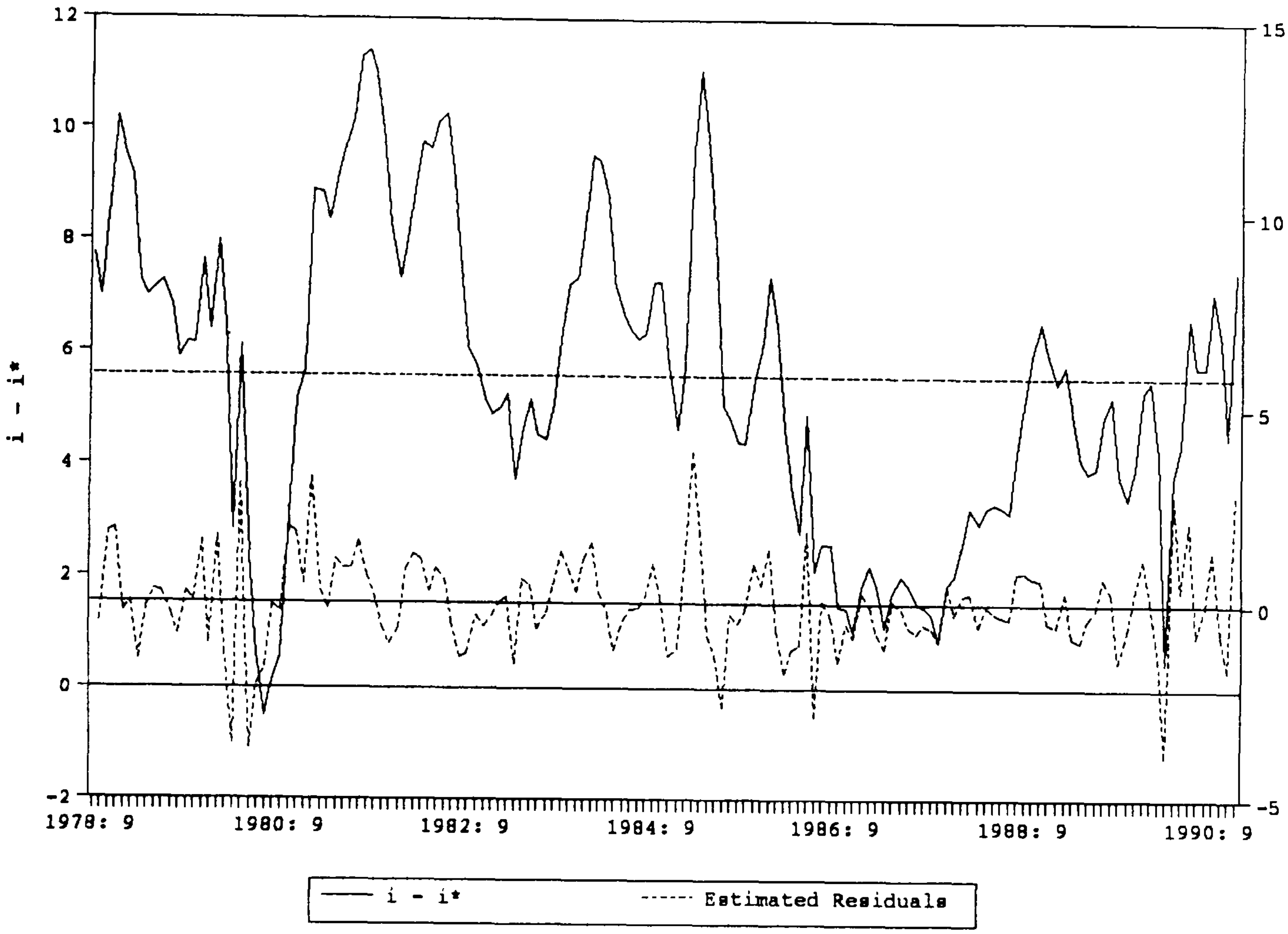


**Chart 4 - Thailand versus Japan LIBOR**
Interest Differentials, 9/1978-12/1990



To implement ARCH estimation of $\phi$, we proceed in two steps. First, using residuals obtained from our previous ARMA procedure, we apply a Lagrange Multiplier or ARCH test to check for the presence of ARCH residuals and to determine the appropriate linear specification for $h_t$, 1/ written generally as:

$$h_t = \alpha_0 + \alpha_1\epsilon^2_{t-1} + \ldots + \alpha_n\epsilon^2_{t-n}. \tag{3.4}$$

Second, once a suitable ARCH model has been selected, MLE estimates are computed through iterative search, using ARMA estimates as initial starting values. Under sufficient regularity conditions, the non-linear iterative solution will yield optimal MLE parameter values.

ARCH estimation results are given for each country in Table 3 with the exception of Malaysia. 2/

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1/ The ARCH test is conducted by regressing squared residuals on lagged values and a constant. Similar to the Breusch-Pagan LM test, the corresponding test statistic is computed by NOBS*$R^2$. The particular order of the ARCH process and form of the $h_t$ function are determined from the test regression found to be statistically significant.

2/ The presence of MA errors in the case of Malaysia prevented application of the same recursive algorithm used in ARCH estimation for the other countries. Instead, for Malaysia, we make use of the original, consistent ARMA estimates in what follows.

Table 3. ARCH Estimation:

Interest Rate Differentials in the Pactific Basin

Model: $A(L)(\phi_t - \mu - trend_t) = \epsilon_t$

$\epsilon_t \sim N(0,h_t)$ ; $\ell_t = -.5logh_t - .5\epsilon_t^2/h_t$

| | $\mu$ | trend | $\phi_{t-1}$ | $h_t$ | ARCH1/ |
|---|---|---|---|---|---|
| Singapore | --- | --- | .7645** (23.699) | $\alpha_0+\alpha_1\epsilon^2_{t-2}+\alpha_2\epsilon^2_{t-3}$ | 6.616* |
| Korea | 5.203** (7.351) | 18.964** (3.356) | .8657** (16.283) | $\alpha_0+\alpha_1\epsilon^2_{t-1}+\alpha_2\epsilon^2_{t-2}+\alpha_3\epsilon^2_{t-3}$ | 12.061** |
| Thailand | 6.190** (3.475) | --- | .9432** (23.274) | $\alpha_0+\alpha_1\epsilon^2_{t-1}$ | 16.081** |

t statistics in parentheses *.05 level of significance **.01 level of significance

From the last column in Table 3, notice that the presence of ARCH-type residuals was statistically significant in every case that the ARCH test was applied. In the previous column, the relevant conditional variance function $h_t$, corresponding to these test statistics, can be seen for each country. A first-order ARCH process was found significant in Thailand residuals, while third-order processes describe the behavior of estimated residuals in Singapore and Korea. The revised coefficient estimates and residuals from the ARCH estimation are used extensively when impulse-response functions are simulated in the next section.

But before discussing policy implications, let us reinterpret the results obtained from time series estimation of interest rate differentials in terms of dynamic capital mobility. First, note that the conditional variance function $h_t$ represents systematic changes in the variability of disturbances which underlie interest rate disparities. Departures from IRP essentially reflect the degree of linkage between interest rates by capturing the extent to which those rates of return may diverge. Consequently, the changing degree of capital mobility is characterized by the underlying pattern of conditional heteroschedasticity in disturbances effecting IRP deviations.

Chart 5 summarizes our estimates of changing capital mobility in the Pacific Basin by tracing the variation of shocks to interest rate parity.

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1/ ARCH test statistic is distributed $\chi^2(k)$ where k equals the number of lags in $h_t$.

With residuals from ARCH estimation, sample values of $h_t$ were calculated and taken as annual averages. In viewing Chart 5, note that movement down along the vertical axis toward the origin indicates increasing capital mobility.

As mentioned, Singapore appears to have experienced uniform decline (increase) in conditional variance (capital mobility) over the 1980s, leveling off around 1983. Korea's experience with increasing capital mobility was similar to Singapore's except for an apparent reversal in direction in the latter part of the decade, although that may be explained in part by the upward pressure on domestic rates in Korea due to inflation related to recent circumstances in the current account. 1/ Thailand showed several episodes of increasing and decreasing financial openness in the 1980s without a clear tendency toward either direction.

For Malaysia, graphing a moving average of ARMA residual variances would reveal a path similar to Singapore's with the notable exception of a large rise in volatility in the middle years (1984-86) similar to the concurrent experience in Thailand as seen in Chart 5. Not surprising, this volatile episode in return differentials coincides with a period of severe financial crisis in both these countries.

## IV. Policy Implications

### 1. Impulse-response simulations

Translating the variability of IRP deviations into a measure of capital mobility leaves implications for policy less readily apparent as, say, an openness or offset coefficient. To better understand policy implications based on our calibration of capital mobility, we construct impulse-response functions from the time series estimates in section III to simulate the dynamic effects of domestic monetary shocks on interest rate parity deviations. Integrating the changing variability of IRP disturbances into the estimated time series structure completes our representation of the degree of capital mobility. 2/

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1/ Our findings for Korea are quite consistent with the results in Reisen and Yèches (1991) obtained using a time-varying approach to financial openness derived in Edwards and Khan (1985), despite the fact that two different interest rates -- a domestic curb market rate for Korea and the US LIBOR -- were used.

2/ Capital mobility defines issues of *both* impulse and propagation in regard to shocks to interest rate parity. Note that although we have allowed for time variation with respect to the former as a result of dynamic capital mobility, we have kept constant the propagation mechanism over time (i.e. same AR and MA coefficients) as an approximation. It can be shown that this approximation becomes less adequate in cases where capital mobility is near zero, suggesting that allowing for time-variation in both dimensions -- the amplitude and the persistence of IRP deviations -- may sharpen the results.

For Singapore, Korea and Thailand, the estimated conditional variances summarized in Chart 5 were used to model the endogenous response of interest rate differentials with Japan's LIBOR to a "typical" economic disturbance in 1980 and in 1990. Specifically, using ARCH parameter estimates and the variance functions for each year respectively, we track the effects of a one-time, one standard deviation shock occurring in the first period. 1/ With normally distributed shocks but differing variances at each moment, we need compare the effects of an equally likely disturbance in each year -- here, the likelihood of a one-standard deviation impulse -- to measure relatively the changing impact of domestic economic factors on interest rate parity.

The impact of dynamic capital mobility is clearly evident in Figures 1-4 through comparison of the resulting IRP deviations. Deviations are given as departures from trend or long-run IRP values where amplitude is measured in annual percentage points and persistence is measured in months.

The initial impulse may represent, among other things, a negative shock to money demand or a positive disturbance to money supply in the domestic financial market, *ceteris paribus*. However, since the simulations trace the path of local market return differentials vis-à-vis a world rate, an alternative interpretation for our impulse-response experiment is that of a shock occurring abroad and effecting a response domestically.

If interpreted as a domestic monetary expansion, the impulse-response simulations in Figures 1 through 4 illustrate the empirical analog to the theoretical time-path for $\phi$ depicted in Appendix Figure A3. An open market purchase of government securities, for example, would depress domestic interest rates given some price stickiness, opening up a gap between local rates of return and the exogenous world rate. Eventually, imperfectly mobile capital responds to the return differential to close the spread, in this case, with a capital outflow from the domestic economy. With financial liberalization and increased capital mobility over time, the extent to which rates of return may diverge diminishes as return differentials induce a larger offsetting market response.

From Figure 1, we see a monetary expansion in Singapore would initially create a return differential of little more than one-half percentage point in 1990 (dashed line), but nearly a 2-percent interest rate disparity a decade ago (solid line). As for persistence, the deviation from interest rate parity essentially lasts approximately between 3 and 4 quarters in 1990, and between 4 and 5 quarters in 1980.

The changing magnitude of IRP departures over the decade is even more pronounced in the case of Malaysia as seen in Figure 2, with shocks originating disparities of one-half and greater than 2 percentage points

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1/ In the case of Malaysia, we use the ARMA estimates and a moving-average sample variance computed using the corresponding estimated residuals for the impulse-response simulation.

**Chart 5 - Regional IRP Deviations**
Conditional Variance Averages

**Figure 1 - Singapore: Impulse-Response Simulations with ARCH Estimates**

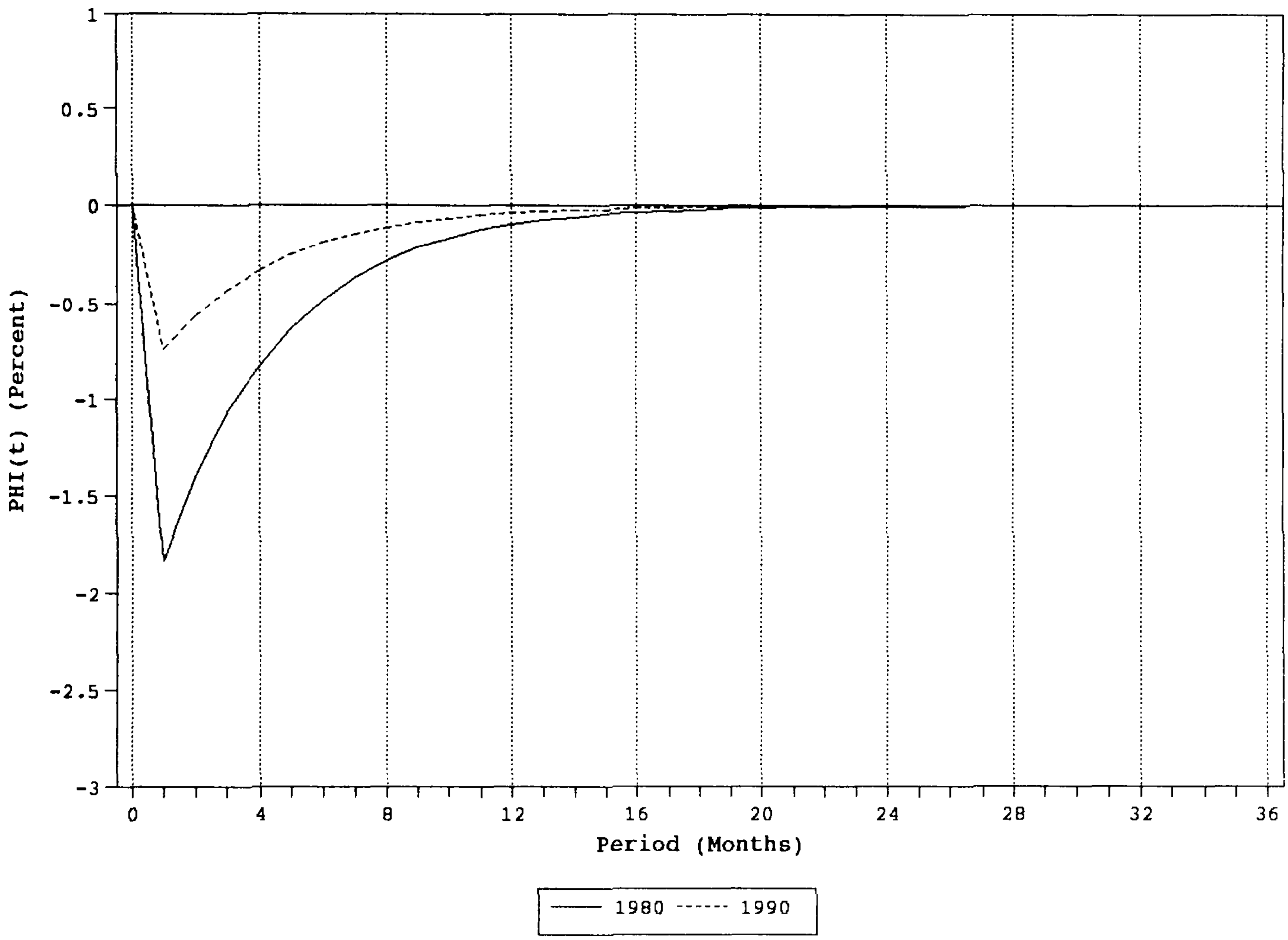


**Figure 2 - Malaysia: Impulse-Response Simulations with ARMA Estimates**

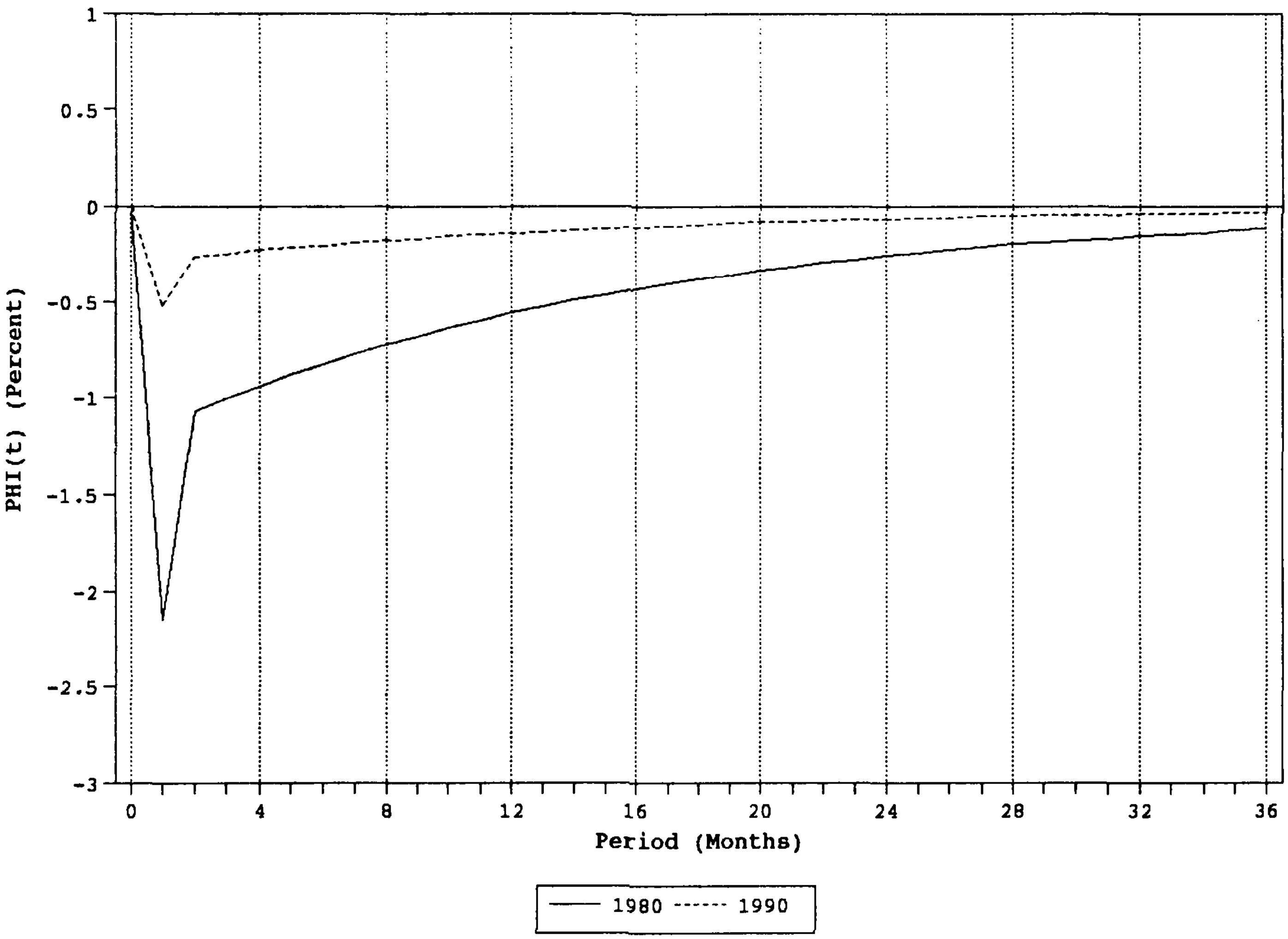


**Figure 3 - Korea: Impulse-Response Simulation with ARCH Estimates**

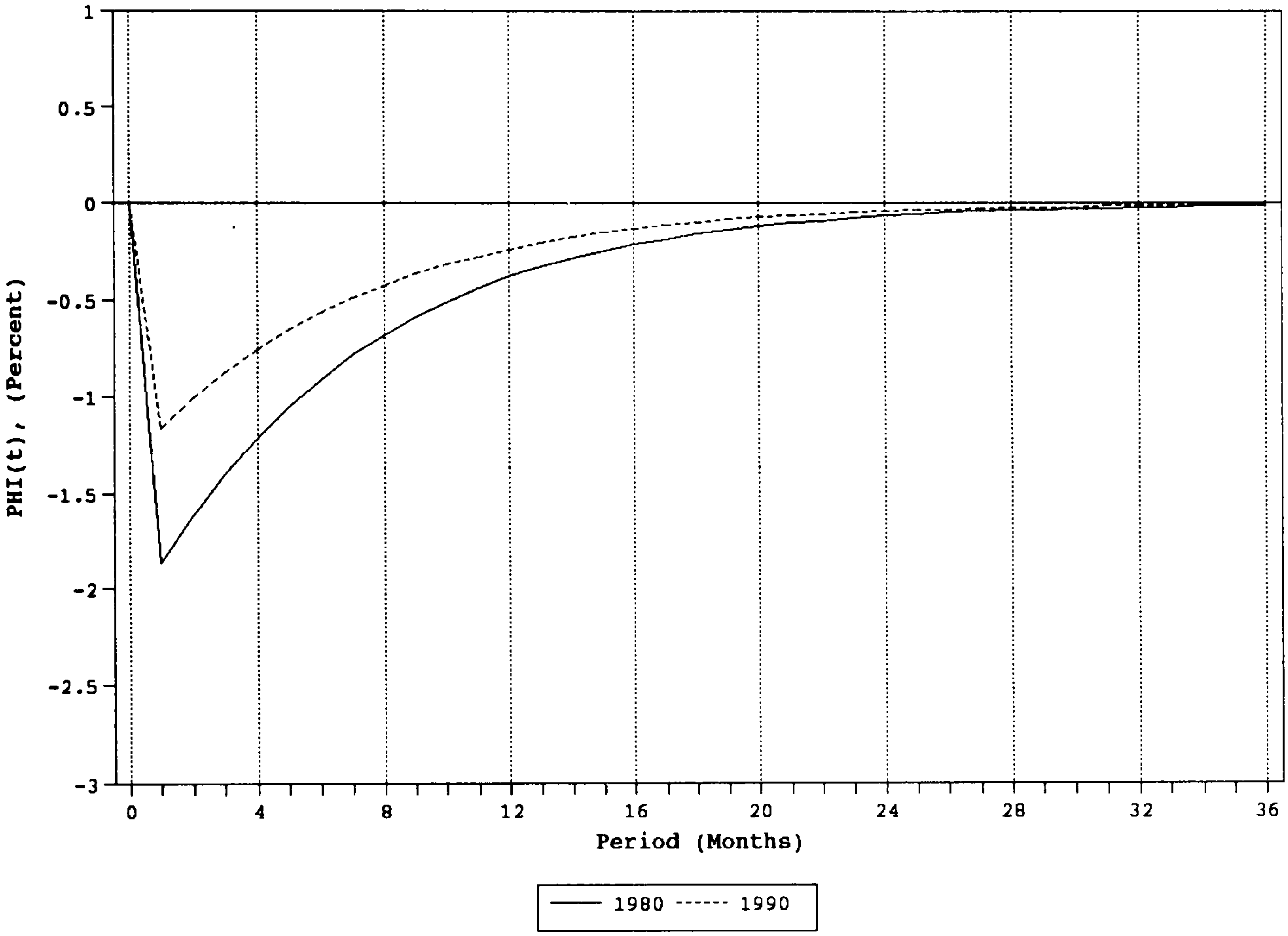
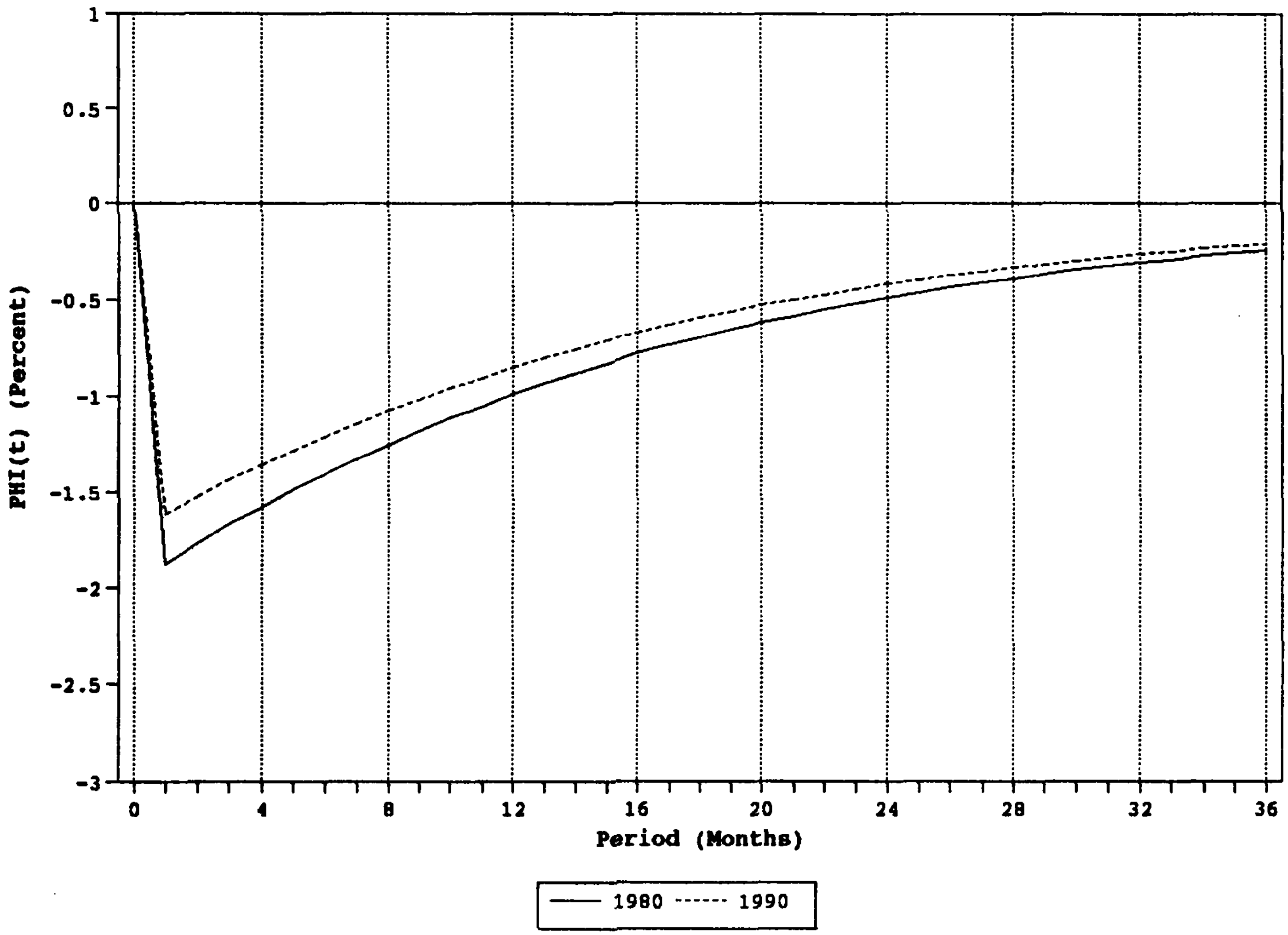


**Figure 4 - Thailand: Impulse-Response Simulations with ARCH Estimates**



respectively at each moment. 1/ The negative MA coefficient from time series estimation of $\phi$ for Malaysia is also evident in Figure 2 by the large reversal of the initial shock in the ensuing period before a very lengthy, gradual decay. In fact, convergence in rates of returns following a disturbance is much more gradual in Malaysia than in Singapore, signifying weaker mean-reverting behavior in Malaysian IRP deviations.

For Korea in Figure 3, first note that the impulse-response paths measure departures from an underlying trend similar to the one depicted in Chart 3. Thus, in this case, we have a different time path for interest rate differentials which includes the trend versus interest parity deviations which are detrended quantities. In comparing the responses of the Korean economy to a domestic monetary disturbance in 1980 and in 1990, we notice some dampening in IRP deviations indicative of increased capital mobility. This result obtains despite, as previously mentioned, the apparent increase in variability of residuals -- which translates into a decrease in financial openness -- that occurred in Korea towards the end of the decade (see Chart 5).

Like Korea, Thailand's simulated departure from interest rate parity in Figure 4 characterizes a deviation from trend, which in this case is a constant or horizontal line. Thailand shows a similar degree of persistence in the effects of monetary disturbances on return differentials as seen in Malaysia. However, in sharp contrast with the other countries, Thailand does not exhibit noticeably the dampening of shocks between 1980 and 1990 that would correspond to increased capital mobility. But, as is clear from Chart 5, this result is contingent upon which episode we draw from.

## 2. Summary and extensions

Financial market liberalization in the Pacific Basin seems to have had a significant impact on the region's economic and financial environment over the past decade. Time-varying estimation of return differentials provides strong support to the notion that liberalization measures have raised the level of integration between domestic and international financial markets. Correspondingly, increased capital mobility in the Pacific Basin has effected an increased degree of linkage between regional and world interest rates. As these rates of return have converged across markets, the ability of independent monetary policy to affect real economic activity through domestic interest rates has been reduced.

With fixed or managed exchange rates -- the predominant case in the Pacific Basin -- and responsive capital flows, changes in the domestic money supply and interest rate are reversed more swiftly, leaving monetary policy

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1/ In determining the changing size of a typical monetary disturbance in Malaysia, we were not able to use the conditional variance function $h_t$ which describes systematic changes in variance and filters out extraneous (random) noise or variation. To partially compensate, we use a 1.5 year moving average of sample variances here.

in the form of interest rate targeting as increasingly unmanageable. 1/ Consequently, heightened capital mobility requires the small, open economy to import to a greater extent its interest rate from abroad, representing international financial conditions. Also, the ability to maintain a fixed exchange rate becomes a tenuous proposition under the weight of heavier capital flows and speculation, reacting to smaller return differentials.

But even with flexible exchange rates and monetary autonomy, return differentials are still dampened resulting from increased financial integration and capital mobility. In this case, though, sensitive capital flows impact largely on the exchange rate to keep interest rates in line through the current account and inflation. Thus, monetary policy gains effectiveness through a new channel of transmission -- the exchange rate, but the tighter interrelation between local and world rates of return remains.

Although the empirical findings suggest an overall trend toward convergence in selected domestic interest rates with the Japanese offshore rate, increased interrelation among other local rates of return with foreign rates is guaranteed only to the extent that domestic financial markets are not segmented internally. That is, our discussion of increased integration between local and world markets presupposed financial integration within the domestic market itself. If there exists signifcant financial segmentation within the home country, estimation of interest rate differentials as a measure capital mobility will be sensitive to the choice of domestic interest rate. 2/

To test for robustness of the findings presented here, a natural follow up would be to include a wider menu of domestic financial assets and repeat the econometric techniques outlined in section III. Choice of a different

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1/ Although our sample countries float vis-à-vis the Yen, one should think of the Japanese offshore interest rate more generally as a proxy for the rate of return and financial conditions in the world market. Thus, given a fixed exchange rate at some margin and the small-country assumption, the domestic money supply and domestic rate of return are fixed in the long run, ceteris paribus.

2/ As for policy implications, domestic financial segmentation may leave some scope for monetary autonomy over some sections of the economy despite convergence in return differentials in other segments of the financial market. See Goldsbrough and Teja (1991).

foreign rate like the U.S. LIBOR 1/ is another empirical alteration of interest. A second type of modification that could possibly sharpen our results would be to incorporate exchange-rate risk explicitly into the time series data, using either the forward or spot rate. If efficiency in the foreign exchange market has significantly changed in conjunction with other asset markets, adding that extra information will strengthen the conclusions. With any of these extension, the same general econometric approach to measurement of dynamic capital mobility that we have developed here would readily apply.

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1/ Preliminary time-series estimates were calculated using the US LIBOR as the international rate of return, and strongly support the findings presented here. ARMA estimation of interest-rate differentials along with ARCH tests and visual inspection of the resulting residuals reveal essentially the same systematic pattern of dampened deviations from IRP shown in the paper, not surprising given the close interrelation between the US and Japan LIBORs in practice. Using the US offshore rate is perhaps the more natural choice as a reference point given that, in our sample countries, exchange rates versus the dollar are closely managed and essentially fixed. Thus, with the US interest rate, we can drop our random-walk assumption on the spot exchange rate and follow the theoretical model found in the appendix more closely.

## Simple Model of Imperfect Capital Mobility

### 1. Imperfect capital mobility

Extending the results in Section II into a dynamic context, we develop a fixed-exchange rate version of the Dornbusch overshooting model 1/ with imperfect capital mobility to provide some intuition for the econometric framework that follows in section III. Consider a small, open economy that credibly pegs its exchange rate so that the expected rate of depreciation can be set to zero. Imperfect capital mobility, for reasons already seen, ensures the equalization of expected returns only in the long run. Thus, we can modify the interest parity relation as follows:

$$\phi = i - i^*, \qquad (A.1)$$

where $i^*$ is the given world rate of interest and $i$ is the domestic rate of interest. Again, with imperfectly mobile capital, the interest rate differential $\phi$ may be nonzero in the short run and may systematically wander within some neutral band. Explicitly, suppose $\phi$ adjusts only gradually to its long-run value:

$$\dot{\phi} = -\theta(\phi - \bar{\phi}); \quad \theta > 0, \qquad (A.2)$$

where dot variables represent time derivatives and bar variables represent long-run values. To simplify things, we assume no risk premium and set the long-run (IRP) value $\bar{\phi}$ to zero, which then equates nonzero interest rate differentials $\phi$ with actual deviations from interest rate parity. Finally, the coefficient of adjustment $\theta$ represents the actual degree of capital mobility, 2/ measuring the speed at which interests rate differentials and, thus, deviations from interest rate parity are eliminated (i.e. when $\phi$=0). As stated, (A.2) may also be interpreted as a long-run stability condition assuring the eventual equalization of interest rates in local and world financial markets.

### 2. The money market

Using a conventional demand for money specification, we can represent equilibrium in the domestic money market as:

$$m - p = \eta\bar{y} - \sigma i, \qquad (A.3)$$

where $m$, $p$, and $y$ denote the logs of the nominal money supply, price level and real income. In equation (A.3), $\eta$ is the income elasticity and $\sigma$ the interest semi-elasticity of money demand. Output is taken as fixed

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1/ See Dornbusch (1976). See also Dornbusch (1988), chapters 4,12.

2/ In this simple model, which postulates rather than derives these dynamics, $\theta$ is assumed constant. However, our basic claim is that this parameter is *not* fixed. Rather, $\theta$ is influenced by, among other things, the entire financial liberalization process. Indeed, the fundamental objective of the paper is to allow and test for a changing $\theta$.

throughout the analysis at its long-run equilibrium level $\bar{y}$, although the model could easily be appended to allow for movement in output as well as prices.

Using equations (A.1), (A.2), and (A.3), we can solve for the long-run equilibrium price level:

$$\bar{p} = m - \eta\bar{y} + \sigma i^*. \quad \text{(A.4)}$$

Equation (A.4) shows $\bar{p}$ to be a function of the domestic nominal money supply, the long-run level of national output or potential GNP, and the world interest rate. Note that since $\bar{y}$ and $i^*$ are taken as given, changes in the long-run equilibrium price level must equal any changes in nominal money or $d\bar{p} = dm$. However, given some degree of capital mobility ($\theta$>0) and commitment to a fixed exchange rate, a specie-flow mechanism must operate in the long run, leaving $dm = 0$. In other words, $m$ must eventually equal its long-run equilibrium level $\bar{m}$, which is itself predetermined by balance of payments constraints, leaving $dm = d\bar{m} = 0$.

Now combining equations (A.3) and (A.4), and using our definition of $\phi$ from (A.1), we can also relate deviations in price from its long-run level with departures from interest rate parity:

$$\phi = 1/\sigma \; (p - \bar{p}). \quad \text{(A.5)}$$

Moreover, substituting this latest expression directly into equation (A.2) yields the first of our two dynamic equations:

$$\dot{\phi} = - \theta/\sigma \; (p - \bar{p}), \quad \text{(A.6)}$$

stating that adjustment in deviations from IRP correspond to deviations in price from its given long-run equilibrium value. We will make use of equation (A.6) more extensively when discussing steady-state equilibrium and the dynamics of the model shortly.

3. The goods market

As for the goods market, we characterize demand for domestic output as a function of real income, the real interest rate, and the real exchange rate seen by:

$$y^d = \gamma y - \rho r + \delta(\bar{e} - p), \quad \text{(A.7)}$$

where all variables are expressed in logs, except for the real interest rate. 1/ The last term in this expression is the real exchange rate, equaling the (fixed) nominal exchange $\bar{e}$ minus the domestic price level $p$, taking the world price as given and normalized to zero (in logs). From equation (A.7), we see that demand for domestic output depends positively on this real exchange rate term, asserting that a decreasing relative price increases demand for domestic output.

The second dynamic equation in this system describes the rate of domestic inflation as a function of excess demand in the goods market:

$$\dot{p} = \underline{\pi}(y^d - y) \tag{A.8}$$

$$= \frac{\pi}{1-\rho}((1-\underline{\gamma})y - \underline{\rho}(\underline{\phi}+i^*) + \underline{\delta}(\bar{e} - p)).$$

4. Equilibrium and dynamics

Having presented the essential elements of the model, we can now characterize steady-state equilibrium and some dynamics. First, note that the $\underline{\dot{\phi}}$=0 locus given by (A.6) represents a modified LM-type relation 2/ in the model. Drawn in $\underline{\phi}$-$p$ space, this locus is a vertical line positioned at $\bar{p}$ as seen in Figure A1, and steady-state equilibrium in the money market can only be achieved along this locus. Specifically, long-run equilibrium in the money market constrains the price level and the money stock to equal their long-run values, which in turn requires equilibrium in the capital account, corresponding to interest rate parity (where $\phi$=0). Hence, steady-state equilibrium in the asset markets is found at the intersection of the $\underline{\dot{\phi}}$=0 and the $\phi$=0 lines.

Equilibrium in the goods market occurs only along the $\dot{p}=0$ locus, representing an IS curve in the model. From equation (A.8), one can show this locus to be a downward sloping line in $\underline{\phi}$-$p$ space, where points above the line indicate excess supply and falling prices, and where points below correspond to excess demand and rising prices in the goods market. The overall dynamics of the system are presented by the arrows in Figure 1, and steady-state equilibrium is found at point $E_0$. At that point, we have equilibria in both the money and goods markets as well as interest rate parity. The dynamics governing the system exhibit a unique stable

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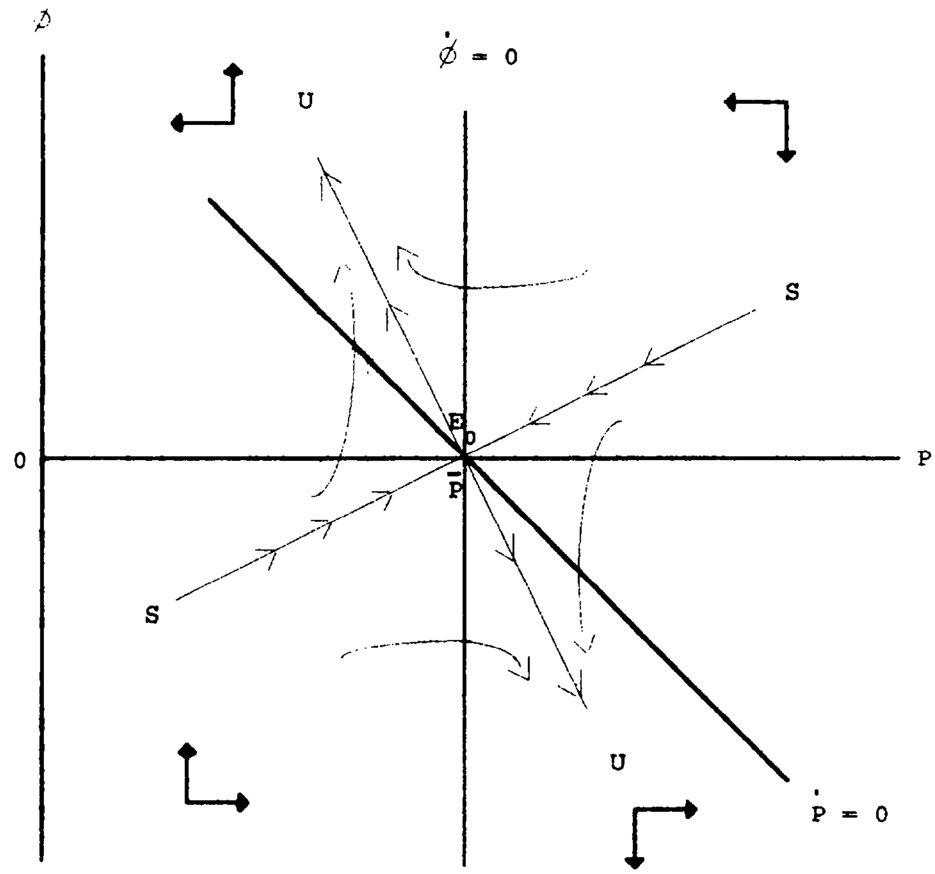
1/ Using the Fisher equation and perfect foresight in this non-stochastic, rational expectations framework, we set the real interest rate $r = i - \dot{p}$, equating expected with actual inflation. Adding purchasing power parity, long-run price stability (zero inflation) is assured which translates equalization in nominal rates of returns to convergence in real returns as well.

2/ The standard Mundell-Fleming LM relation derives from equilibrium in the money market seen by $M/P = L(i,Y)$. Here, we have inverted this relation as $i = i(M/P,Y)$ and defined $\phi = i(M/P,Y) - i^*$. By solving for $i(M/P,Y), i^*$ and using money market equilibrium we reduce this equation for $\phi$ to (3.9).

Figure A1 - Phase-Space Diagram: Interest Rate Deviations and Price Dynamics



trajectory or saddle path and an unstable counterpart labeled as SS and UU, respectively in Figure A1.

5. Policy experiment

We are now ready to conduct policy experiments on the model and determine the dynamic responses of prices and interest rate differentials. In particular, consider the effects of an unanticipated, transitory monetary shock on the system as follows. At $t_0$, we begin at steady state $E_0$. At that instant, the central bank expands the domestic money supply ($m'>m$), which shifts the $\dot{\phi}=0$ locus outward to $\dot{\phi}'=0$, reflecting a higher long-run equilibrium price level $\bar{p}'$ shown in Figure A2. The corresponding new steady-state equilibrium can be found at E'. However, given the central bank's commitment to fix the exchange rate, agents realize that the increase in domestic money cannot be sustained indefinitely in the face of imminent capital outflows and declining reserves.

Assuming the Central Bank sterilizes its ensuing loss of finite reserves only until some lower-bound level is reached, 1/ we can treat this monetary expansion as strictly transitory. With price-stickiness, $\phi$ instantly jumps down from $E_0$ to a point A to assure money market equilibrium. 2/ Interest rate differentials and prices in the longer run then adjust gradually according to the dynamics corresponding with steady-state E' until some time T when reserves cross their threshold level and the monetary expansion is finally undone. At that point, the dynamics governing the system return to its original configuration corresponding to $E_0$. Therefore to satisfy long-run stability, the economy must intersect along the old saddle path SS just at time T (point D in Figure A2) to track back to the old steady-state when the money supply is restored to its original level. The complete time path for the economy is displayed in Figure A2, while the individual time paths for the interest rate differential and the price level can be seen in Figures A3 and A4.

The degree of capital mobility enters by determining the rate at which Central Bank's reserve holdings are depleted as a consequence of the monetary disturbance and the resulting departure from interest parity. Hence,

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1/ To formally close the model, we need to specify an adjustment process for $m$ to endogenize the domestic money supply. The initial expansion in Central Bank credit would then be gradually offset by the continuous outflow of foreign exchange reserves. Instead, to simplify things, we assume the monetary expansion is maintained temporarily through sterilization and then undone all at once. Qualitatively, however, the dynamic effects are unchanged.

2/ With differential rates of adjustment in goods prices versus asset prices, to assure money market equilibrium -- $M/P = L(i,Y)$ -- the interest rate must jump initially in response to an increase in $M$ given that $P$ and $Y$ are fixed in the immediate short run.

the degree of financial market integration of this small, open economy with world financial markets establishes the time required for reserves to reach their threshold value signaling a contraction in $m$. As this time T approaches 0, the case of perfect capital mobility, the economy would simply remain at its initial point $E_0$ with incipient capital outflows effecting an immediate portfolio substitution of bonds for international reserves in the Central Bank's asset holdings. As $T \to \infty$, the case of no capital mobility, the monetary expansion approaches permanence, and the economy would jump down below point A toward the new stable arm S'S' in Figure A2. In between these limiting cases, the economy must initially move down a certain distance - contingent upon the mobility of capital - to some intermediate point before gradually returning to steady-state equilibrium and IRP over the longer run.

As for the time path of interest rate differentials, increasing capital mobility essentially diminishes the impact of domestic monetary shocks that lead to IRP deviations and, hence, reduces the magnitude of those deviations. If financial liberalization measures have effectively changed the degree of capital mobility in the Pacific Basin, those developments should be manifested by a dampening in the deviations of regional interest rate differentials from their respective trend or long-run levels. In terms of our earlier discussion, the neutral band within which departures from IRP may wander should narrow, indicating an increased degree of linkage between domestic and world rates of return. Also, the risk premium -- if one exists -- may also gradually diminish with steadily increasing financial openness, reflecting an increased substitutability between investment opportunities in local and world financial markets. Section III makes use of this basic intuition to estimate over time the level of financial integration in certain Pacific Basin countries, considering issues of both capital mobility and asset substitutability.

Figure A2 - Transitory Monetary Expansion

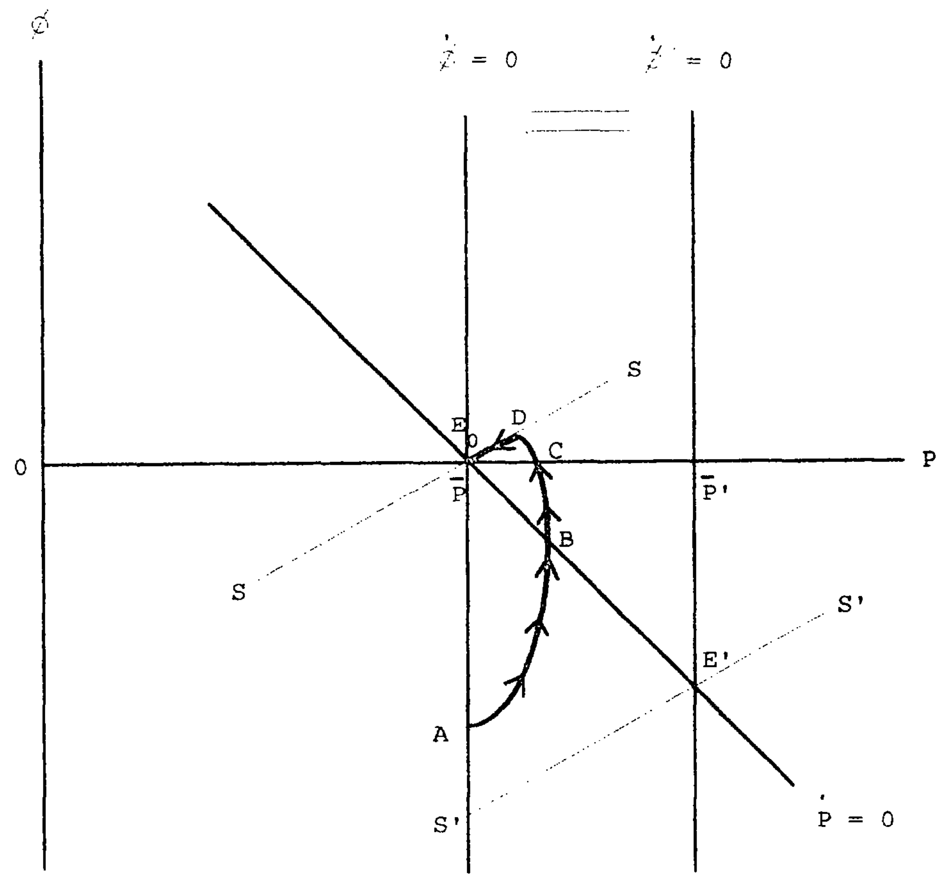


Figure A3 - Deviation from Interest Parity:
Transitory Monetary Shock

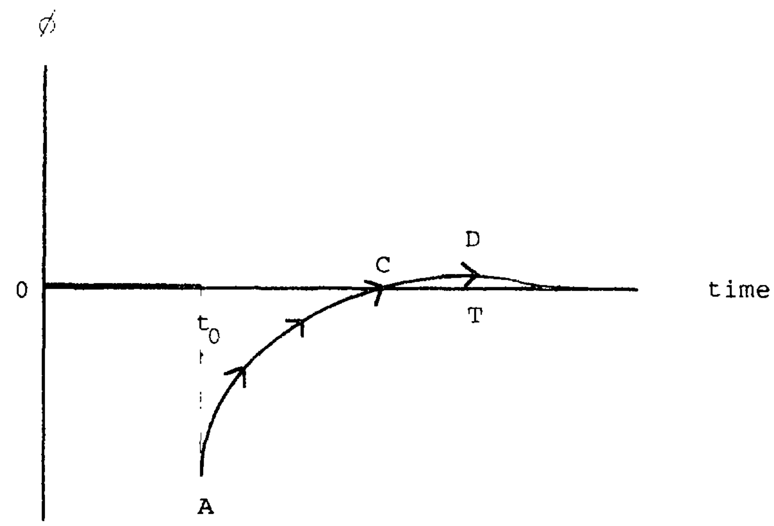
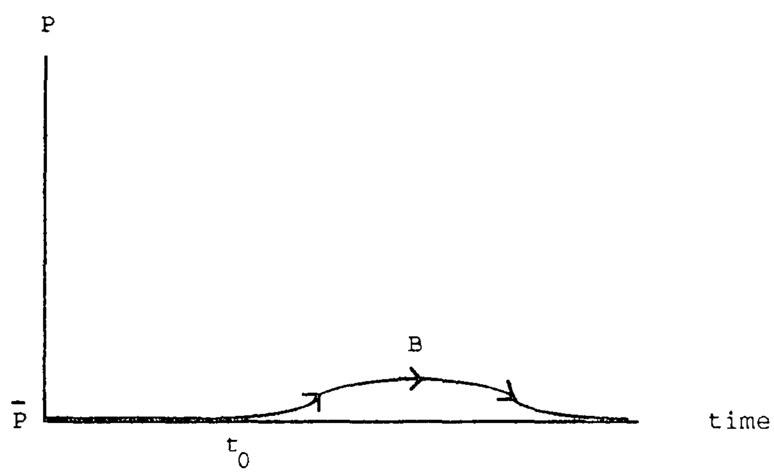



Figure A4 - Price Level Time Path:
Transitory Monetary Shock



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