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Misalignment and Managed Exchange Rates: An Application to the Thai Baht

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Abstract

This paper proposes a methodology for analyzing dynamic misalignment in managed exchange rate systems that combines the estimation approach to modeling the real exchange rate with the calibration approach to generating the equilibrium real exchange rate. The methodology is applied to the Thai baht and the model is estimated using only pre-July 1997 data. An analysis of the difference between the evolution of the actual real exchange rate and the generated equilibrium rate - the misalignment gap - reveals the extent to which the market was persistently factoring in an expected depreciation of the Thai baht.

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I. Introduction

Misalignment – the deviation of the actual real exchange rate from its equilibrium value – has been a topic of research that has occupied exchange rate analysts for many years. While the desirability of a policy which keeps the exchange rate on its equilibrium path has broad consensus (especially when the costs,[2] as evident in the recent Asian currency crisis, are considered) there remains a number of issues to be confronted. There is the conceptual issue of the definition of the equilibrium real exchange rate, the empirical issue of the estimation of the determinants of the rate and the policy issue of the evaluation of the misalignment.

These issues are well canvassed in Hinkle and Montiel (1998) – a collection of papers on estimating equilibrium exchange rates in developing countries. Included are discussions by: Ahlers and Hinkle (1998) on the more traditional purchasing power and trade equation approaches; Devarajan (1998) and Haque and Montiel (1998) on the general equilibrium and simulation approaches; and Baffes, Elbadawi and O'Connell (1998) on the single-equation reduced-form approaches. While each of these approaches has much to offer, Hinkle and Montiel (1998) in their summary and evaluation of the methodologies suggest that the single-equation reduced-form approach based on time-series methods of unit root and cointegration may on balance provide the framework "to significantly advance our ability to generate credible empirical estimates" of the equilibrium real exchange rate.

The methodology proposed in this paper for analyzing misalignment is in the single-equation reduced-form class of approaches. It further develops the analysis in Baffes, Elbadawi and O'Connell (1998) by exploiting the properties inherent in the estimation of the reduced-form equation to derive, interpret and operationalize the calculation of dynamic misalignment. The methodology is an extension of the Clark and MacDonald (1999) distinction between the fundamental equilibrium exchange rate (*FEER*) and the behavioral equilibrium exchange rate (*BEER*).

To highlight these issues, consider an example where the equilibrium real exchange rate (in log form)[3], q^e is a function (assume linear, for convenience) of determinants which can be classified into exogenous[4] economic variables x_1 and policy variables x_2:

[2] Two recent theoretical studies of the cost of misalignment are: Huizinga (1997) on the political economy of import subsidies and Balwin and Lyons (1994) on the welfare cost of industrial dislocation.

[3] The equilibrium rate has been variously described as the fundamental or the long run rate. For this study superscripts would be used to denote the various definitions – equilibrium (*e*); fundamental (f); long-run (*l*). Also, in keeping with the literature, the log form shall be used throughout.

$$q^e = \alpha_1 x_1^e + \alpha_2 x_2^e \tag{1}$$

Abstracting for now, complicated dynamics of adjustment, let actual q reflect actual x_1 and x_2 and a disturbance term e:

$$q = \alpha_1 x_1 + \alpha_2 x_2 + e \tag{2}$$

Misalignment, which is the difference between actual q and equilibrium q^e can then be written as:

$$q - q^e = \alpha_1 (x_1 - x_1^e) + \alpha_2 (x_2 - x_2^e) + e \tag{3}$$

Equation (3) has the advantage of providing a simple conceptual framework, which shows that misalignment reflects adjustments of the economic variables x_1, deviations of the policy variables x_2 and the behavior of the disturbance term e. Three steps are hence essential in single-equation empirical analysis of misalignment. They are: the identification of the determinants (x_1, x_2); the determination of their equilibrium values (x_1^e, x_2^e); and the analysis of the dynamic properties of the misalignment gap with reference to the nature of the behavior of (x_1, x_2) relative to their equilibrium values (x_1^e, x_2^e).

The first two issues have been extensively discussed in the literature. For a review of the determinants of the real exchange rates, see for example, Faruqee (1995), Stein and Allen (1995) and MacDonald and Stein (1999).[5] For an understanding of the difficulties associated with the calibration of determinants at equilibrium values commensurate with some concept of "sustainability", see Williamson (1994), Clark, Bartolini, Bayoumi and Symansky (1994), Clark (1994), Edwards (1994) and Elbadawi (1994).[6] What has been less well discussed in the literature, is the exploitation of the time-series framework to derive an analysis of the dynamics of misalignment. The aim of this paper is to suggest one such analysis.

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[4] This is an important requirement for efficient single-equation estimation and especially if the equation is to be used to generate counter-factual simulations.

[5] Taken together, these references review various models of the real exchange rate from purchasing power parity, to more elaborate models which allows for determinants such as productivity, the terms of trade and net foreign assets.

[6] In particular, these references discuss the related concepts of Fundamental Equilibrium Exchange Rate (*FEER*), Desirable Equilibrium Exchange Rate (*DEER*) and Equilibrium Real Exchange Rates (*ERER*).

The methodology proposed may be viewed as a development of the *FEER-BEER* distinction and exploits the best feature of both. With respect to the equations above, the *FEER* approach may be viewed as focussing on equation (1). Interpreting equation (1) as the reduced-form equation of a structural model of the economy, the *FEER* approach determines the fundamental values of the determinants x_1^f and x_2^f according to sustainability criteria (such as internal and external balance), and then computes the q^f consistently as:

$$q^f = \alpha_1 x_1^f + \alpha_2 x_2^f \tag{4}$$

Actual q is assumed to correspondingly behave as described in equation (2) so that the components of the misalignment gap are:

$$q - q^f = \alpha_1(x_1 - x_1^f) + \alpha_2(x_2 - x_2^f) + e \tag{5}$$

By drawing attention to the gaps $(x_1 - x_1^f)$ or $(x_2 - x_2^f)$, the *FEER* approach has the advantage of allowing a richer analysis of misalignment because it can identify the cause of the misalignment and relate them to views on sustainability.[7] Moreover, ex ante, the approach allows for a range of misalignment possibilities from short-run temporary to long-term chronic types. However, since equation (4) is not estimated, the choice of x_1 and x_2 are determined by theory according to views on sustainability, this approach has been criticized on the grounds that the variables selected for calibration may not be the relevant empirical determinants of the real exchange rate.

In contrast, the *BEER* approach focuses on estimating equation (2) to ensure that the determinants are empirically significant. Indeed if a cointegrated relationship exist, the estimated long run equation represents the equilibrium relationship. However, the problem with this approach lies with the practice of defining the equilibrium value as the estimated long run value set at actual values of x_1, x_2. This definition of the equilibrium rate limits the usefulness of this approach for analyzing misalignment, because if the estimated long run value of q^l is:

$$q^l = \hat{\alpha}_1 x_1 + \hat{\alpha}_2 x_2 \tag{6}$$

[7] Identification of the nature of the misalignment is particularly important for informed policy response because different reactions are required depending on whether the misalignment reflect the adjustment process of economic variables, policy variables or the disturbance term. For more discussion of types of policy reactions see Isard and Faruqee (1998) and references therein.

then the resultant misalignment gap is just the estimated disturbance term (for simplicity of exposition only, assume $\alpha = \hat{\alpha}$ and $\beta = \hat{\beta}$):

$$q - q^l = \hat{e} \tag{7}$$

Consequently, misalignment in this framework is only about short-term deviations.[8] Thus, while *BEER* may be empirically more appropriate, it does not generate the classification inherent in the *FEER* approach that is helpful for evaluating the cause of the misalignment.

It is clear from this discussion that the analysis of misalignment can be enriched in a number of ways. The first general point is that misalignment is more useful when treated in a dynamic, not a static, framework. While knowledge about the size of the gap is useful, the extra knowledge that the misalignment gap would dissipate over time, is even more useful because it suggests that there are inherent self-correcting mechanisms in the economy and so policy reactions, if any, need only be temporary. Similarly the knowledge that a misalignment gap has persisted for some time is also useful because it suggests the possibility of a forthcoming structural realignment. For these reasons, the analysis of the misalignment gap in this paper is dynamic.[9]

Another way to enhance the computation of misalignment is to exploit the best features of the estimation and calibration approaches. In the following sections, a model of the real exchange rate is proposed which utilizes estimation techniques (to ensure that the determinants are empirically valid) and calibration techniques (to ensure that the equilibrium values of the determinants are defined relative to some meaningful concept of "sustainability"). The framework suggested permits the analysis of a broader class of dynamic misalignment ranging from temporary to permanent. The methodology is applied to a case study of the Thai baht. The paper is structured as follows.

Section II presents the theoretical framework for the analysis of dynamic misalignment for managed exchange rate regimes. The term "managed" is used here to describe systems where the monetary authorities, and not the market, determines the exchange rate and where official intervention is practiced to maintain the exchange rate within a narrow band around the official rate. This includes the fixed and pegged rate systems. This section contains three subsections. Section II.A shows how the time-series approach to misalignment can be naturally expanded from a static to a dynamic framework. Its focus is on the interpretation of the dynamics of misalignment with reference to the

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[8] The limitation applies even in a dynamic setting. This is because, put simply, deviations in a cointegrated regression are, by construction, restricted only to short-run terms.

[9] For an example using fractional integration to analyze the dynamics of misalignment see Lim and Wilkins (1998).

components in an error-correction specification. In particular, it shows how an estimated model may be recast into a model of misalignment, which allows for the full range of misalignment outcomes from temporary to permanent.

The aim of Section II.B is to identify a variable such that its dynamic properties relative to its calibrated value (set with reference to a defined concept of "sustainability") is informative about whether misalignment is temporary or permanent. For this study, misalignment is viewed in terms of whether the official exchange rate can be maintained. The misalignment gap considered here is the difference between the evolution of the real actual exchange rate with the evolution of a hypothetical generated rate derived from a scenario where the monetary authorities' and the markets' views of the exchange rate coincide. If the gap between actual and generated hypothetical real exchange rates diverge with no evidence of mean-reversion, then it suggests that the monetary authorities "managed" official exchange rate is severely misaligned relative to the market's perception of what it should be. In such situations, the rate is likely to be subjected to speculative attacks which then increases the probability of it not being maintained. This sub-section discusses how to use the information inherent in interest differentials to generate the hypothetical scenario.[10]

Section II.C draws together the analysis relating dynamic misalignment, fundamentals, interest differentials and the market's perception of the maintenance of the exchange rate into a long run model of the real exchange rate for managed regimes. It shows how to calibrate the model to generate the rate that describes the evolution of the **M**anaged **E**quilibrium **E**xchange **R**ate –*MEER* (the hypothetical case where market participants behave as if the policy-managed exchange rate is maintainable). By comparing the generated path of *MEER* to the actual situation (the case which incorporates the market's true view about the maintenance of the managed spot rate), an assessment can be made about the extent to which the managed exchange rate is different from the market's expected exchange rate.

Section III applies the model to the case study of the Thai baht and in particular it uses only information prior to the July 1997 crash to infer the extent of dynamic misalignment, if any. This section estimates a reduced form equation of the real exchange rate, calibrates the model to generate the *MEER*, compares the generated series with the actual rate and then examines the dynamic path of the misalignment gap to assess the extent to which the managed Thai baht rate could or could not be maintained. The final Section IV concludes by drawing attention to the broader applicability of the proposed methodology.

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[10] A point worth noting at the outset is that the target zone literature is also concerned with the relationship between interest differentials and realignment. This paper is about these relationships in a different context – that of long run and equilibrium relationships.

II. Theoretical Framework

A. Dynamic Misalignment and Fundamentals

Although structural models of the real exchange rate exist and may be used to analyze misalignment, such an approach may not be feasible for small developing economies. The appeal of the reduced-form cointegration approach to modeling the real exchange rate is that it is less demanding of resources than a full-scale structural model. This is particularly useful for smaller developing countries where data may be somewhat scarce. This section discusses dynamic misalignment using the single-equation reduced-form estimation approach for the case of economies with managed exchange rates.

The simplest model of the real exchange rate is that proposed by purchasing power parity:

$$q = s - p + p^* \tag{8}$$

where s is the log of the nominal exchange rate, here defined as the number of domestic currency per *U.S. dollar* (+ indicates depreciation), and $p(p^*)$ are the logs of the domestic and foreign prices respectively. According to the purchasing power parity theory, nominal exchange rates adjust to offset changes in relative prices to maintain the real exchange rate q at a constant value. This proposition has been shown not to hold for numerous currencies and a number of alternative theories of the real exchange rate have been proposed.[11]

In general then, q would be determined by a vector of variables z, say, $q = \beta z + u$. Since the data are usually non-stationary time-series, estimation is by cointegration methods. Let the estimated error-correction equation excluding other short run dynamic terms be:

$$q_t - q_{t-1} = -\hat{\delta}(q - \hat{\beta}z)_{t-1} + \hat{u}_t \tag{9}$$

At this juncture, it is worth noting again the advantages and disadvantages for analyzing misalignment when the equilibrium rate is defined as the long run value of the real exchange rate q_t^l set at current values of z_t:

$$q_t^l = \hat{\beta}z_t \tag{10}$$

[11] In the case of Thailand, the time-paths of q, s and $(p - p^*)$ show clearly that purchasing power parity does not hold. Also unit root tests of the real exchange rate show that it is an I (1) variable. For a survey of purchasing power parity, see Rogoff (1995).

Dynamic misalignment, according to this definition of the equilibrium (subtract (10) from (9) and rearrange) is:

$$q_t - q_t^l = (1-\hat{\delta})(q-\hat{\beta}z)_{t-1} - \hat{\beta}\Delta z_t + \hat{u}_t \tag{11}$$

where $\Delta z_t = (z_t - z_{t-1})$. As can be seen from equation (11) the size of the misalignment gap comprises the lagged error-correction effect, the current change in the explanatory variables and the size of the disturbance – by construction, since this is a cointegrated system, all I (0) terms. The dynamics of misalignment reflect the error-correction speed of adjustment $(\hat{\delta})$ and the dynamic behavior of z and u. But since the behaviors of all these terms are aspects of the mean-reverting behavior of the real exchange rate, this implies that dynamic misalignment according to this definition is only about short-run temporary behavior.[12] Restricting the scope of misalignment possibilities severely limits the range of the analysis unless one can argue that only this class of behavior is relevant and worthy of attention.

In other words, while the estimated reduced form approach facilitates the identification of the underlying relationship between q and its determinants z, its use as a model of misalignment is somewhat restricted to the analysis of stationary dynamics, if the long run relationship is determined using current values. This restriction does not apply to the calibrated approach. To illustrate, suppose that it is possible to calibrate, by whatever benchmark, the equilibrium value of the real exchange rate based on the estimated determinants as:

$$q_t^c = \hat{\beta}z_t^c \tag{12}$$

where the superscript c denotes that the real exchange rate is calibrated on a set of variables z^c according to some concept of sustainability. It follows that the dynamics of misalignment based on (12) and using (9) can now be written as equation (13) below:

$$q_t - q_t^c = (1-\hat{\delta})(q-\hat{\beta}z)_{t-1} - \hat{\beta}(z_t^c - z_{t-1}) + \hat{u}_t \tag{13}$$

Equation (13) shows the extent to which deviations of actual z from z^c determine the dynamics of misalignment and since apriori, this deviation can follow any dynamic path (i.e., it may be any order of integration) it also implies that misalignment can encompass a broad range of behavior. Thus, if a measure of this deviation which relates to some concept of "sustainability" of the exchange rate can be found, it would serve to broaden the analysis of

[12] Techniques of fractional integration and its associated impulse response functions may be used for this class of models, to understand better the nature of the dynamic path to equilibrium.

the misalignment gap whilst taking advantage of the estimated approach. In the next section, one such measure based on interest differentials is proposed.

B. Interest Differentials and Managed Exchange Rates

Two parity relationships dominate the study of exchange rate analysis – purchasing power parity and interest parity. This section discusses how to exploit the information about maintenance of the managed exchange rate embodied in the interest parity relationships. Briefly, the discussion will show how interest differentials are informative about the gap between the managed spot rate and the market's expected exchange rate. The following discussion is in three parts covering, firstly the nominal interest parity relationship, secondly the real parity relationship and thirdly the conversion from changes to levels of the real exchange rate.

First, consider the standard uncovered interest parity relationship:

$$i_t - i_t^* = E_t s_{t+1} - s_t + rp_t \tag{14}$$

where i_t, i_t^* represent domestic and foreign rates respectively, $E_t s_{t+1}$ is the expected one-period ahead exchange rate and rp_t is a time-varying risk premium. In general $E_t s_{t+1}$ is unknown, and it may not be equal to the managed spot rate.

In a managed exchange rate system, the policy determined rate is generally known. Consider then a hypothetical situation where the market knows the managed rate and believes that it is "sustainable" (i.e., can be maintained); the condition describing this scenario is then:

$$E_t^m s_{t+1} = s_{t+1} \tag{15}$$

where E_t^m is the expectation under this hypothetical scenario.[13] Assuming no risk premium in this scenario, yields the implied uncovered interest parity relationship as:

$$i_t^m - i_t^* = E_t^m s_{t+1} - s_t = s_{t+1} - s_t \tag{16}$$

[13] An alternative scenario is to assume a fixed exchange rate regime so that the assumed $E_t^m s_{t+1} = \bar{s}$ and so $i_t^m - i_t^* = \bar{s} - s_t$.

where i_t^m represents the domestic interest rate that would have satisfied the interest parity relationship in the hypothetical scenario where market participants know the policy managed exchange rate and believe that it can be maintained.

To reiterate a point here: equation (14) describes an actual situation where actual interest differentials are related to expected spot rates which may or may not be equal to the managed rates; equation (16) describes a hypothetical situation where the hypothetical interest differentials are consistent with the observed spot rates because the expected spot rates are hypothesized to be equal to the managed rates.

Subtracting (16) (hypothetical scenario) from (14) (actual situation) gives:

$$i_t - i_t^m = E_t s_{t+1} - E_t^m s_{t+1} + rp_t = (i_t - i_t^*) - (s_{t+1} - s_t) \tag{17}$$

Hence $(i_t - i_t^m)$ captures the extent to which the market actually expects the future exchange rate $E_t s_{t+1}$ to be different from the current policy managed rate s_{t+1} plus the risk premium. Briefly, it summarizes the market's assessment of the state of the economy and its perception of the "sustainability" (i.e., maintenance) of the prevailing regime-managed rate.[14] Using (14), $(i_t - i_t^m)$ can also be shown to be equal to the actual interest differential less the actual future change in the exchange rates.

Second, to derive the real counterpart of equations (14)-(17) first write the actual uncovered interest parity relationship in real terms as:[15]

$$(i_t - i_t^*) - E_t(\pi_{t+1} - \pi_{t+1}^*) = E_t q_{t+1} - q_t + rp_t \tag{18}$$

where $(E_t\pi_{t+1} = E_t p_{t+1} - p_t)$ and $(E_t\pi_{t+1}^* = E_t p_{t+1}^* - p_t^*)$. As before, in general $E_t q_{t+1}$ is an unknown and it may not be equal to the actual real exchange rate. Again, in a managed economy, in keeping with the earlier scenario, it is interesting to consider the hypothetical case where market participants behave as if the managed nominal exchange rate is known and will be maintained given the prevailing current and known inflation rates. The assumed hypothetical scenario is:

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[14] The relationship between interest differentials, exchange rate variability and the credibility and reputation of policy makers is explored in Agenor and Masson (1999). See also, Caramazza (1993), Knot, Sturm and de Haan(1998) and Ros and Svensson (1994).

[15] Recall: $Eq_{t+1} = E(s_{t+1} - p_{t+1} + p_{t+1}^*)$ and $q_t = (s_t - p_t + p_t^*)$.

$$E_t^m q_{t+1} = (s_{t+1} - p_t + p_t^*) \tag{19}$$

which yields the hypothetical interest parity relation in real terms as:

$$i_t^m - i_t^* = E_t^m q_{t+1} - q_t = s_{t+1} - s_t \tag{20}$$

Subtracting (20) from (18) gives the real equivalent of (17) as:

$$(i_t - i_t^m) - E_t(\pi_{t+1} - \pi_{t+1}^*) = E_t q_{t+1} - E_t^m q_{t+1} + rp_t = (i_t - i_t^*) - (s_{t+1} - s_t) \tag{21}$$

and after more manipulations (21) can be shown to differ from (17) by the inflation differential - a consequence of the assumed scenario which is that in the nominal case, $s_{t+1} - E_t^m s_{t+1} = 0$, while in the real case, $q_{t+1} - E_t^m q_{t+1} = -(\pi_{t+1} - \pi_{t+1}^*)$.

Third, to relate this discussion to the dynamics of the real exchange rate q, it is necessary to transform these parity relationships which describe the change in q into an expression about the level of q. By backward substitution, of equation (18) the expected level of the real exchange rate based solely on the real interest differentials and risk premia is:

$$E_t q_{t+1} = q_0 + \sum_{k=0}^{t} \Phi_k - \sum_{k=0}^{t} rp_k \tag{22}$$

where $\Phi_k = (i - i^*)_k - E_t(\pi - \pi^*)_{k+1}$, and q_0 is an arbitrary starting point. To derive the equivalent expression for the hypothetical scenario which assumes that the market behaves as if the managed real exchange rate would be maintained, use (20) and again by backward substitution:

$$E_t^m q_{t+1} = q_0 + \sum_{k=0}^{t} \Phi_k^m \tag{23}$$

where $\Phi_k^m = (i^m - i^*)_k = (s_{k+1} - s_k)$. This then gives the difference between the level of expected real exchange rate $E_t q_{t+1}$ (unknown) and the managed rate under the assumed hypothetical scenario $E_t^m q_{t+1}$ as:

$$E_t q_{t+1} - E_t^m q_{t+1} = \sum_{k=0}^{t} [(E_t s - s)_{k+1} - E_t(\pi - \pi^*)_{k+1}] \tag{24}$$

that is, it is the cumulative sum of exchange rate expectation errors less cumulative inflation differentials.

This difference has a particular interpretation in managed exchange rate system. Consider the case where the cumulated terms are random. In this case, fluctuations in $(E_t q_{t+1} - E_t^m q_{t+1})$ would be correspondingly random or at least stationary, and one may infer that managed and expected exchange rates are only "temporarily misaligned" with each other. However, if fluctuations in $(E_t q_{t+1} - E_t^m q_{t+1})$ display nonrandom, nonstationary behavior it suggest that either the market is persistently expecting the exchange rate to be different from actual and/or the inflation differentials are persisting over time. Whatever the reason, the managed and the expected exchange rates are "seriously misaligned." Thus, the nature of the time-path of this gap is informative about the degree of misalignment, i.e., it reveals the market's perception of the maintenance of the managed exchange rate.

Note that the analysis depends on the difference between i_t and i_t^m and in general this difference can be computed. However, what is important here is whether in the long run, when expected becomes actual, that cumulative differentials play a significant role in determining the exchange rate. In the next section a model of the real exchange rate, which includes a role for the cumulative information, described in (22) and (23) is proposed.

C. A Model of the Real Exchange Rate and the Managed Equilibrium Exchange Rate (*MEER*)

Following the framework in Section II.A, a reduced form equation for the long run real exchange rate which includes current account and capital account factors (ignoring the constant term) can be written generally as:

$$q = \beta_1 z + \beta_2 \Lambda \tag{25}$$

where $\Lambda = \sum_{k=0}^{t} \Phi_k$ are the cumulative actual real interest differentials defined in (22), and z are the vector of fundamental determinants (such as the terms of trade and relative productivity) which may or may not have an effect on the time-varying risk premium. The advantage of this model is that it is an estimable model, which isolates the effect of cumulative real interest differentials, Λ, from the effect of other nonstationary variables, z.

For the purpose of this paper with its focus on single equation estimation, the estimated error-correction model is:

$$q_t - q_{t-1} = -\hat{\delta}(q - \hat{\beta}_1 z - \hat{\beta}_2 \Lambda)_{t-1} + \hat{u}_t \tag{26}$$

Based on the estimated model, the underlying long run q is:

$$\hat{q}_t = \hat{\beta}_1 z_t + \hat{\beta}_2 \Lambda_t \tag{27}$$

which is to say that it incorporates the market's expectations of the real exchange rate as described in the real interest parity equation (18).

The question now is what is the counter-factual long run real exchange rate predicated on the hypothetical case that market participants believe the managed spot exchange rates at prevailing inflation rates can be maintained - in other words, they act according to equation (20). To generate the equilibrium (i.e., long run) model under this hypothetical scenario, replace the actual real interest differential Λ_t with the hypothetical implied differential $\Lambda_t^m = \sum_{k=0}^{t} \Phi_k^m$ defined in (23) to give a calibrated managed equilibrium exchange rate (*MEER*) as:

$$MEER_t = \hat{\beta}_1 z_t + \hat{\beta}_2 \Lambda_t^m \tag{28}$$

This is the hypothetical case where the real exchange rate evolves according to the dynamics of fundamental variables *z* but where the managed spot exchange rates are believed (by assumption) to be maintainable. The difference between actual and hypothetical i.e., the difference between (27) and (28) is:

$$\hat{q}_t - MEER_t = \hat{\beta}_2 (\Lambda_t - \Lambda_t^m) \tag{29}$$

which is as described in (24). For this scenario, the dynamics of misalignment can be derived by subtracting (28) from (26) and rearranging to give equation (30) below (where $\Delta z_t = z_t - z_{t-1}$):

$$q_t - MEER_t = (1-\hat{\delta})(q - \hat{\alpha}_1 z - \hat{\alpha}_2 \Lambda)_{t-1} - \hat{\alpha}_1 \Delta z_t - \hat{\alpha}_2 (\Lambda_t^m - \Lambda_{t-1}) + \hat{u}_t \tag{30}$$

Writing the misalignment gap this way shows the extent to which the gap will display dynamics associated with error-correction, deviations of z (which by definition are $I(0)$ variables) and the extent to which the discrepancy between interest differentials which reflect the hypothetical "maintained" scenario and the actual "expected" situation affects the path of misalignment. The more $(\Lambda_t^m - \Lambda_{t-1})$ diverge, the more serious the misalignment.

Thus, the advantage of the framework is twofold. First, the gap between the two cumulative interest differentials has a particular economic meaning. It shows the extent to which market expectations of the exchange rate differed from the managed rates over time. Second, isolating the interest differential term based on a calibrated series, allows for a richer analysis of misalignment, since apriori, this term can display a wide range of dynamic behavior including persistent behavior. The later is particularly informative for managed regimes, as evidence of non-stationary behavior signals permanent or chronic misalignment and potential future realignment.

III. An Application to the Thai Baht

Since March 8, 1978 the Thai baht had been pegged to a weighted basket of currencies and the Bank of Thailand had managed to keep the exchange rate as close as possible to the middle official rate through the process of foreign exchange intervention.[16] Following a series of attacks on the baht, especially from May 1997, the Bank of Thailand reached the point when it could no longer defend the rate and the Thai baht was floated on July 2 1997.[17] With hindsight it is clear that the Thai baht was not sustainable (i.e., could not be maintained) at the exchange rate prevailing then; in other words, it was seriously misaligned.

This paper is concerned with the application of the framework set out in Section II to the Thai baht to see if it is possible to uncover evidence of the underlying misalignment. The quantitative analysis is based solely on pre-crash data as the intention is to unearth information about the nonsustainability of the exchange rate before the crash. Based on the methodology given above, the first step in the analysis is to determine whether the behavior of the real Thai baht could be related to cumulative real interest differentials and other fundamental variables (such as terms of trade, relative productivity, measure of fiscal policy).

The model is estimated on monthly data based on the precrash sample period 1988:01 to 1996:12. Following typical studies of the equilibrium real exchange rate, a number of variables were considered[18] and the significant ones are listed in Table 1.

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[16] Based on information in the International Monetary Fund's report on exchange arrangements for Thailand. Details about the extent of forward intervention by the Bank of Thailand in the months prior to the July crash can be found in the IMF's September 1998 International Capital Markets Report, especially in Box 2.11.

[17] Much has been written about the Asian currency crises, both on the lead-up to the crisis and the aftermath of the crisis, see for example the reviews by Corsetti, Pesenti and Roubini (1998 a, b) and the discussion in the International Monetary Fund, World Economic Outlook (1998) and references therein.

[18] Other variables considered include: the log of the terms of trade defined as log (export price/import price); a log measure of the relative price of nontraded to traded goods defined as log (consumer price index/wholesale price index); a term to capture the influence of fiscal policy defined as (total government debt/nominal GDP). None of these variables were significant in the cointegrating equation.

Table 1. Definition of Variables

$$R = \log\left(\frac{bhat\_usd * cpi\_usa}{cpi\_thai}\right)$$

$$F = -\left(\frac{net\_foreign\_assets}{nominal\_GDP}\right)$$

$$X = \sum_{k=0}^{t}\left[(i - i^*)_k - (\pi - \pi^*)_{k+1}\right]$$

The variable R is the log of the real exchange rate; F captures the role of foreign debt and X is the cumulative sum of real interest differentials based on observable inflation rates. Note that the empirical measure of cumulative interest differentials is based on available past information (since expectation is at time t) except for when $k = 0$, where it is assumed that $E_t\pi_{t+1} = \pi_{t+1}$. The base period is 1988:05 at the point where the data showed that the interest parity relationship held, that is, $(i_t - i_t^*) = (s_{t+1} - s_t)$.[19] All data were extracted from the International Financial Statistics compiled by the International Monetary Fund.

Figure 1 presents the data for our sample period. As can be seen, the spot rate (in logs) has varied within a very narrow band (1a), but the log of the real exchange rate has been declining (1b) due to the increasing inflation differential (1c). The interest differentials have also been above zero through most of the sample period (1d), resulting in a cumulative value that has been increasing over time (1e). Finally, over the sample period, the ratio of foreign debt to nominal gross domestic product initially declined but since 1993 it has been steadily rising (1f).

Table 2 presents the unit root tests. The results reported are based on the Phillips-Perron (1988) test statistics for the three cases: $PP(o)$ (no intercept), $PP(u)$ (with intercept) and $PP(t)$ (with intercept and time trend). As shown, all series are $I(1)$ and hence potentially cointegrated. However, to test for structural change, the Table also reports the Zivot-Andrews (1992) tests with a null of a unit root in the univariate time series against the alternative of stationarity with a structural change in the deterministic component. There are two tests: $ZA(u)$ (mean shift) and $ZA(t)$ (trend shift). These tests show that all series reject

[19] This is the point where $i_t = i_t^m$, that is the point when there is no misalignment between expected and managed exchange rate.

the null, with the minimum t-test for all series, except the F variable, occurring in late 1995. The minimum t-test for the F series occurred in late 1992. The data reflects the timing of capital flows – the huge inflows in the early 1990's and then the reversals in late 1995. The cointegration results are discussed next.

Table 2. Unit Root Tests

	Phillips-Perron			Zivot-Andrews	
	PP(o)	*PP(u)*	*PP(t)*	*ZA(u)*	*ZA(t)*
R	-1.318	-0.131	-3.240	-9.083	-2.713
F	-0.635	0.472	-1.202	-4.067	-2.525
X	3.272	-1.162	-0.909	-15.241	-2.039
5% c.v.	-1.943	-2.888	-3.451	-4.80	-4.42
10% c.v.	-1.617	-2.581	-3.151	-4.58	-4.11

Figure 1. Times-series of the Data

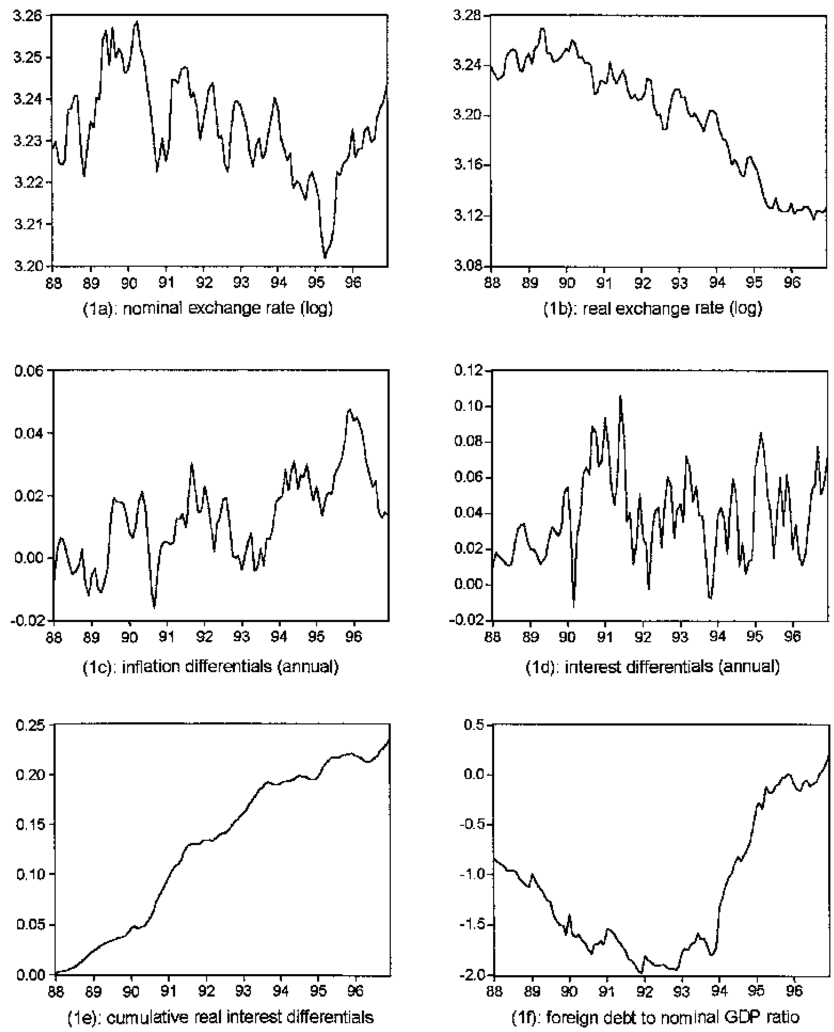


Table 3. Cointegration Tests

Engle-Granger Test:

$$R = 3.219 - 0.031F - 0.411X$$

$R^2 =$	0.947	
$ADF(\hat{u}) =$	-4.308	(5% c.v. = -3.27)
$GH(1) =$	-6.633	(5% c.v. = -4.92)
$GH(2) =$	-6.908	(5% c.v. = -5.29)
$GH(3) =$	-7.040	(5% c.v. = -5.50)

Johansen Test:

$$R = 3.227 - 0.030F - 0.466X$$

$LR(0) =$	37.243	(5% c.v. = 29.68)
$LR(\leq 1) =$	14.020	(5% c.v. = 15.41)
$LR(\leq 2) =$	0.548	(5% c.v. = 3.76)

Phillips-Loreton Test:

$$R = \underset{(0.000)}{3.224} - \underset{(0.000)}{0.028F} - \underset{(0.000)}{0.416X} + \underset{(0.000)}{0.691\hat{u}(-1)} + \underset{(0.026)}{0.218\Delta R(-1)}$$

$R^2 =$	0.976	
$ADF(\hat{u}) =$	-4.198	
$Q(1) =$	0.022	(0.881)
$Q^2(1) =$	3.000	(0.083)
$BJ =$	0.228	(0.892)

* p-values in parenthesis
BJ is the Bera-Jarque (1980) test for normality
LR(x) is the likelihood ratio test of the number of cointegrating vectors denoted by *x*.

Table 3 presents the tests for cointegration. It includes the single-equation Engle-Granger (1987) 2-step OLS test for cointegration, the multivariate Johansen test (1988) and the Phillips-Loreton (1991) single-equation cointegration estimator. The main reason for the Engle-Granger test is that, although the t-tests are non-standard, the OLS estimates are super-consistent. Consequently, the estimates serve as a consistency check for robustness against other cointegration results reported later. Moreover, unit root test of the residuals, $ADF(\hat{u})$, serves as a simple check for the presence of cointegration, and according to this test, the result here shows that the variables are cointegrated. Also in view of the structural change present in the data, the Gregory Hansen (1996) residual based test for regime shifts in the cointegration relationship was performed. The null is no cointegration against the alternative of cointegration with a one-time regime shift of unknown timing. Three types of regime shifts were considered: the level shift test in test $GH(1)$, the level shift with trend in test $GH(2)$ and the intercept and slope shifts in test $GH(3)$. These three test statistics are also reported in Table 3 and they reject the null of no cointegration.

The existence of one cointegrating vector for the set of variables - R, F, X - is corroborated by the Johansen (1991) test of the number of cointegrating vector. Note too that the normalised coefficients are consistent with the OLS results.

The Phillips-Loreton estimator is a single-equation approach, which generates consistent and efficient results under certain conditions, one of which is that the determinants be exogenous.[20] Hence, the system vector error correction results reported next in Table 4 are to test for the causal relationship amongst the trivariate. As revealed by the error correction terms, both cumulative interest differentials and foreign debt are exogenous with respect to the trivariate system analysed.[21] Note, that there is some evidence of persistence in the dynamics of X.

Since the determinants are exogenous, the final set of cointegrating coefficients reported in Table 3 are estimated by the single equation procedure of Phillips-Loreton (1991). Since the residuals are white noise, the procedure has generated appropriate standard errors and the p-values reported indicate that all the terms are significant. An important point to note here is that the cointegration results are robust across all estimation techniques.

[20] See, Lim and Martin (1995) for an analysis of the relationships between regression-based cointegration estimators.

[21] For more information on testing erogeneity in error-correction systems see, Boswijk (1992), Urbain (1993) and Ericson and Irons (1994).

Table 4. Vector Error Correction*

Cointegration:	$R = 3.227 - 0.030F - 0.466X$					
Error Correction:	ΔR		ΔF		ΔX	
$\hat{u}(-1)$	-0.315	(0.000)	0.698	(0.008)	-0.008	(0.296)
$\Delta R(-1)$	0.215	(0.010)	0.154	(0.444)	0.009	(0.340)
$\Delta F(-1)$	-0.003	(0.385)	0.133	(0.103)	0.001	(0.326)
$\Delta X(-1)$	-0.148	(0.441)	-2.134	(0.268)	0.749	(0.000)
Constant	-0.000	(0.318)	0.014	(0.103)	0.001	(0.003)
$Q(1)$	0.007	(0.932)	0.098	(0.754)	0.817	(0.366)
$Q^2(1)$	1.560	(0.212)	0.188	(0.665)	2.216	(0.137)

* p-values in parenthesis

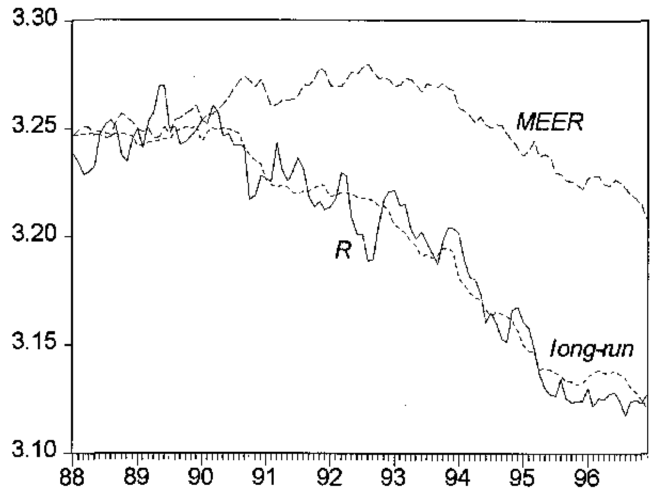
The results show that in the long run, both a higher level of X (cumulative real interest differentials) and F (ratio of foreign debt to nominal GDP) are associated with a lower level of the real exchange rate R (appreciation). In the context of cointegration and mean-reverting behavior, these directional results may be viewed as depicting (net reduced-form) behavior amongst the three variables R, F and X as they shift from one equilibrium position to another. A possible mechanism could be as follows: following a shock which generates an increase in the exogenous variable X and which results in a higher domestic interest rates, inflows of capital are encouraged, leading to exchange rate appreciations. The new equilibrium associated with an increase in X is at a lower R, given F. Alternatively, a positive shock to F which could be driven by exogenously determined capital inflows,[22] causes R to appreciate, given exogenous X. Thus the new equilibrium at the higher F is associated with a lower R.

Figure 2 plots actual real exchange rate (R) and the estimated long run cointegrated equation based on actual values of the ratio of foreign debt to nominal gross domestic product (F) and the cumulative real interest differentials (X). As can be seen, from Figure 2, the estimated long run tracks the actual real exchange rate very well. The residuals

[22] It has been argued that increases in net foreign debt are caused by current account deficits, and hence the real exchange rate should depreciate for equilibrium (positive relationship). In floating exchange rate regimes, this is probably true, but in managed regimes, capital flows can be the cause of an increase in foreign debt. For an analysis of the role of capital flows and currency crisis see, Milesi-Ferretti and Razin (1998).

from the cointegrating equation (actual less estimated long-run) have a unit root test value of -4.198, which confirms that we have a cointegrated system. But, to reiterate a previous point, note that if misalignment had been defined as actual less estimated long-run, then one would infer that there was no serious misalignment since the deviations will mean-correct to zero.

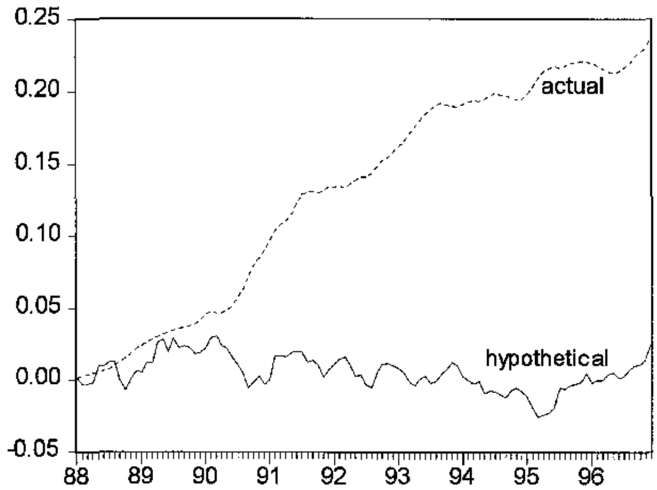
Figure 2. Real Exchange Rates



Actual (solid line), estimated long run (dotted line) and *MEER* (dashed line)

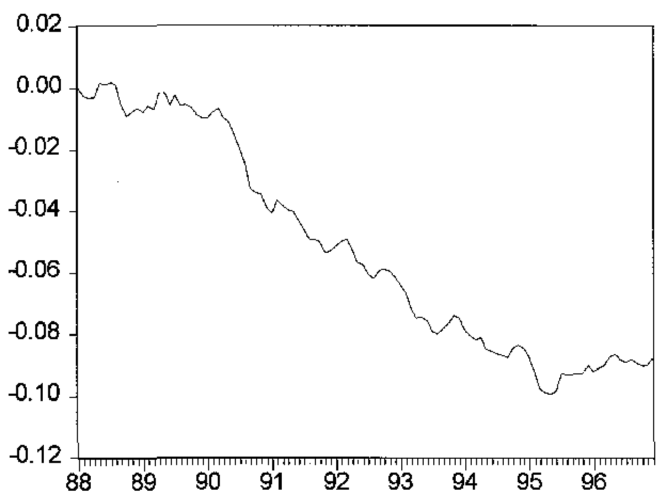
However, the aim of assessing misalignment is to provide policy makers with information about pending realignment and this requires an analysis based on readily available data capable of identifying the range of deviations from temporary to chronic. Consequently, a counterfactual simulation is conducted to generate the managed equilibrium exchange rate, *MEER*, also shown in Figure 2. To generate this series, actual interest differentials were replaced with hypothetical "sustainable" interest differentials which described the scenario that the market supports the policy determined spot rate at the given inflation rates. Recall from discussion above that while the actual interest differentials were associated with expected spot rates that were not necessarily equal to the managed rates, the hypothesised interest differentials were associated with expected spot rates that were, by assumption, equal to the managed rates. Hence these hypothetical interest differentials can be computed according to equation (23) because, by design, they are consistent with the actual exchange rate changes. Figure 3 shows the actual cumulative interest differentials (which determined the evolution of the actual real exchange rate) and the hypothetical cumulative interest differentials (which determined the *MEER* described in equation (28)). The divergence between the actual and hypothetical series is clearly shown in Figure 3.

Figure 3. Actual and Hypothetical Cumulative Interest Differentials



Note that, by construction, *MEER* and the estimated long run have the same base value set at the point when the interest parity held exactly. Since the simulation is deterministic (mainly to focus on the underlying relationship and because the noise terms average to zero) the misalignment gap is computed as the difference between the estimated long run and *MEER*. The estimated misalignment gap is shown in Figure 4.

Figure 4. Estimated Misalignment (Estimated Long-Run less *MEER*)



As noted from discussion in previous section, these deviations are informative not only about the extent of any misalignment, but also about the nature of the dynamics of misalignment. The gap here has a unit-root test value of -0.159, which suggests that it is a nonstationary variable. This implies that the markets expected exchange rate and the managed exchange rate were diverging persistently, i.e., they were severely misaligned relative to each other.

The implication of this result can be stated as follows. If in 1996, the *MEER* (which described the hypothetical scenario assuming that the market supports the managed exchange rate at the prevailing inflation rates) had been computed and had then been compared with the actual situation, an indication that there was a growing divergence between the evolution of actual real exchange rate and our assumed situation would have been revealed. In other words, the market was factoring in an expected rate, which was increasing with time – the exchange rate system was primed for a realignment.[23]

Table 5. Rolling Regressions

	1988-1992	1989-1993	1990-1994
F	-0.006 (0.708)	0.004 (0.716)	-0.018 (0.010)
X	-0.298 (0.009)	-0.337 (0.000)	-0.414 (0.000)
constant	3.248 (0.000)	3.270 (0.000)	3.241 (0.000)
$ADF(\hat{u})$	-3.363	-3.900	-3.464
	1991-1995	1992-1996	1990-1996
F	-0.025 (0.000)	-0.023 (0.009)	-0.026 (0.000)
X	-0.473 (0.003)	-0.569 (0.026)	-0.443 (0.000)
Constant	3.240 (0.000)	3.260 (0.000)	3.231 (0.000)
$ADF(\hat{u})$	-3.220	-3.407	-3.966

An interesting point to note here, as indicated in Figure 2, is that the divergence between the managed and expected rate began in the early 1990's, roughly at the time when the current account deficit as a percentage of GDP began to exceed 5 percent. Why the realignment did not occur till mid-1997 and why it did then is the subject of future research; the focus of this paper is to propose a framework to detect misalignment defined as the gap between the managed and the expected real exchange rate.

[23] Which is to say that the system was inherently self-correcting – as suggested by the cointegration relationship. However, that the inevitable realignment of the currency took the form of a dramatic crash was just one form of mean-reversion. If information about the misalignment had been discerned earlier, it may have been possible to engineer a series of progressive devaluations.

Finally, since structural change is noted in the data, the robustness of the results across different sample periods is examined. A 5-year rolling regression is conducted and Table 5 presents the Phillip-Loreton estimates for the model reported in Table 3. As shown, F is not a significant variable in the earlier years, but since 1990, the results are robust across different sample periods.

IV. Concluding Remarks

This paper has been concerned with the computation of misalignment in the context of managed exchange rate regimes, that is systems where the monetary authorities, and not the market, determines the exchange rate and where official intervention is practiced to maintain the exchange rate within a narrow band around the official rate. The framework proposed for analyzing dynamic misalignment combines the estimation approach (to ensure that the explanatory variables are empirically valid) with the calibration approach (to ensure that misalignment is assessed relative to some economic concept of sustainability). The particular misalignment gap analyzed is based on a comparison of the evolution of the actual real exchange rate (the path which reflects the market's true expectations of the future exchange rate including their perceptions of whether the managed system can be maintained) with the generated managed equilibrium exchange rate –*MEER* (the hypothetical scenario that assumes that the market believes that the managed real exchange rate can be maintained at the prevailing inflation rates). The dynamics of this gap is indicative of the divergence or convergence of the market's expected rate with the policy-managed exchange rate.

The methodology is applied to the case study of the Thai baht. A long run model of the real Thai exchange rate as a function of cumulative real interest differentials and the ratio of foreign debt to nominal GDP was estimated using pre July 1997 data. The estimated model was then calibrated to generate the implied *MEER*. The divergence between actual and generated *MEER* provided an indication of the extent to which the market was factoring in an expected depreciation. The results show the persistent expectation of a depreciation, suggesting strongly that the Thai baht exchange rate was not maintainable.

To conclude, the framework is suitable for situations when economy-wide system estimation and simulation approaches are unfeasible. This paper has opted to calibrate on information from the capital side of the balance of payments on the assumption that it is behavior on the capital account that is relatively more critical for the maintenance of the exchange rate. In particular, it utilizes current available information contained in the cumulative interest and inflation differentials to assess the degree of misalignment between expected and managed exchange rates. In a world of high-speed capital flows, such an analysis may serve to alert policy makers in managed exchange rate regimes of pending realignments. However, the framework has broader applicability – it may be used to design a misalignment model for floating regimes and be calibrated to test other concepts of sustainability.

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