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The Dynamics of Real Interest Rates, Real Exchange Rates and the Balance of Payments in China: 1980–2002

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The Dynamics of Real Interest Rates, Real Exchange Rates and the Balance of Payments in China: 1980–2002

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Abstract

Based on China's experience between 1980 and 2002, a cointegrated vector autoregression model was established to explore the relationships among real interest rates, real exchange rates and balance of payments in China. Taking into account institutional changes, the empirical study shows that significant and usually non-monotonic interactions exist between these three variables. The paper discusses theoretical and policy implications of the empirical result.

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Contents

I. Introduction

The rapid development of the Chinese economy since the early 1980s has been an important force in reshaping the world economic structure. During the Asian financial crisis in 1997, China's decision to maintain a stable exchange rate policy revealed a growing influence of the Chinese economy in its neighboring region. With China as a WTO member since 2001 and its growing share in world trade and capital flows, analysis of the dynamics of China's exchange rate, interest rate, and balance of payments has become increasingly relevant to the rest of the world.

The relationship between the real exchange rate and real interest rate differential has long been a focal point in international economics. This is not only because of their prominent theoretical importance demonstrated by, among others, interest rate parity theory (Keynes, 1923: Levich and Frenkel, 1975) and the M-F-D model (Mundell 1963, Fleming 1962, Dornbusch 1976), but also because of their potential application in real business and policymaking. Empirical evidence, however, has not always been consistent with theoretical analysis. For example, a prediction of the M-F-D model that an increase in real interest rate differential will correlate with an appreciation in real exchange rate cannot be securely verified by empirical studies. Many, if not all, out-of-sample predictions based on the M-F-D model have not been able to outperform a random walk model(see, among others, Meese and Rogoff, 1983; Meese 1990).

This empirical puzzle has propelled advances in empirical methods. An important direction of advance has been the use of time varying parameters (Wolff 1987, Schinasi and Swamy 1989). More recently, Wu and Chen (2001) applied a model that allows for time-varying-coefficient and Markov-switching heteroskedasticity.

The puzzle has also stimulated rethinking of the underlying assumptions of the original theoretical models.

One element in the M-F-D model that deserves scrutiny is the assumption of a constant equilibrium real exchange rate. Research shows that the equilibrium real exchange rate may be determined by real fundamentals and is subject to change (Sebastian Edwards, 1988; Williamson, 1991; and Hinkle and Montiel, 1999). This also relates to the issue of whether the movement of the real exchange rate is stationary or nonstationary. It seems that debate on this issue has been continuing unabated (see, among others, Engel, 2000; Imbs, Mumtaz, Ravn and Rey, 2002).

To tie the real exchange rate with its fundamental determinants, Edison and Pauls (1991) introduced an important third variable--cumulative current account--into their empirical study of the relationship between the real interest rate differential and real exchange rate. The choice of the cumulative current account, however, may not be the most appropriate one. The single-equation approach in this study also failed to capture interactions among different variables. In a model developed by Montiel (1999) that synthesizes previous models of the equilibrium real exchange rate, factors such as productivity growth, composition of government spending, changes in the international environment (including changes in terms of trade, flows of external transfer, etc.) and changes in commercial policy (such as reductions of export subsidies) were identified as major fundamentals. Based on Montiel's model, the analysis in the following section will use foreign exchange reserves as the representative fundamental variable. This new variable has the capacity to incorporate the effect of all the factors identified by Montiel and thus may be more appropriate than the cumulative current account as representative fundamental underlying the equilibrium real exchange rate.

Another element in the M-F-D model that deserves scrutiny is the assumption that adjustments in the real exchange rate take a monotonic path. Obstfeld and Rogoff (1996) have already shown that this assumption can be dropped in deriving a dynamic model for exchange rate determination with a solid microeconomic foundation. In more recent debate on the relation between the nominal interest rate and nominal exchange rate in the aftermath of the Asian financial crisis, the monotonic issue has also been analyzed. Some economists like Stanley Fischer (1998) regard a stable currency supported by appropriate interest rate policy (usually higher interest rates) as one of the key factors for a successful financial and macroeconomic stabilization program. On the other hand, other economists, like Jeffrey Sachs (1997) and Joseph Stiglitz (2000), argue that higher interest rates might lead to a depreciation, rather than appreciation, of the currency. Based on a simple monetary model and multicountry empirical studies, Amartya Lahiri and Carlos A. Vegh (2002) tried to solve this puzzle by showing that the relationship between the nominal interest rate and nominal exchange rate is non-monotonic. Specifically, with an increase in the nominal interest rate, the currencies of most of the *developed* countries in a sample tend to appreciate while the currencies of most of the *developing* countries in a sample tend to depreciate in the short run and may appreciate thereafter.

The third element in the M-F-D model deserving of scrutiny is the assertion that the real interest rate differential is correlated with the *level* of the real exchange rate. Krugman and Obstfeld (1997) have shown that when relative PPP and interest rate parity hold, the expected real interest rate differential is equal to the expected depreciation of the real exchange rate.

Compared with the enormous numbers of articles on major international currencies and related interest rates, the literature on exchange rates of the Chinese currency renminbi, RMB, has been scant. Hoe Ee Khor (1994) analyzed China's foreign currency swap market and Lardy (1996) documented the evolution of China's trade liberalization and associated evolution of the foreign exchange regulation system. Jin (1996) analyzed the determination of China's equilibrium exchange rate during the transition period. Mehran, Nordman, and Laurens studied monetary and exchange system reforms in China (1996), and Chou and Shih (1998) estimated the equilibrium exchange rate using a PPP approach and the shadow price of the foreign exchange model. Xiaopu Zhang (2000) and Zhichao Zhang (2000) estimated real exchange rate misalignment with different methodologies. Nicolars Blancher (2003) discussed exchange rate policy in China.

Drawing from the experience of the previous research, the following part of this paper will establish and estimate an empirical model that has the following features.

First, it will incorporate the real exchange rate, real interest rate differential, and foreign exchange reserves (which represents overall changes in the balance of payments position) into a vector autoregressive (VAR) model that allows feedback between all of the three variables.

Second, the model will identify the cointegration relationship between the real exchange rate and foreign exchange reserves to reflect the role of fundamentals in determining the long-run equilibrium real exchange rate.

Third, based on unit-root tests on the three variables, the model will include the real interest rate differential, log difference of real exchange rate, and log difference of foreign exchange reserves. It will also include the cointegration relationship between real exchange rate and foreign exchange reserves as an error-correction term to reflect the adjustment process to correct deviations from the long-run equilibrium.

For ease of visual interpretation, the real exchange rate in the following sections of the paper is basically defined as the ratio of the price of nontradable goods over the price of trade-weighted tradable goods; therefore an upward movement of real exchange rate index represents a real appreciation.

With this model, we are particularly interested in (1) whether there exists a cointegration between the real exchange rate and its deterministic fundamental--foreign exchange reserves, (2) whether the real interest rate differential should be correlated with the *level* or *change* (log difference) of the real exchange rate, (3) whether the relationship between the real interest rate differential and the *change* (if this is the case) in the real exchange rate is monotonic, and (4) in the case of a non-monotonic relationship, what is the real exchange rate effect caused by changes in the real interest rate differential and vice versa?

II. Setup and Estimation of an Empirical Model

A. Setup of the Model

A three-equation system with three variables can be set up as the following:

$$\text{RateGap}_t = \sum_{i=1}^{12}\alpha_{1i}\text{RateGap}_{t-i} + \sum_{i=1}^{12}\beta_{1i}\text{DLREER}_{t-i} + \sum_{i=1}^{12}\gamma_{1i}\text{DLReserve}_{t-i} + \lambda_1\text{CI}_{t-1} + \mu_{1t} \quad (1\text{-}1)$$

$$\text{DLREER}_t = \sum_{i=1}^{12}\alpha_{2i}\text{RateGap}_{t-i} + \sum_{i=1}^{12}\beta_{2i}\text{DLREER}_{t-i} + \sum_{i=1}^{12}\gamma_{2i}\text{DLReserve}_{t-i} + \lambda_2\text{CI}_{t-1} + \mu_{2t} \quad (1\text{-}2)$$

$$\text{DLReserve}_t = \sum_{i=1}^{12}\alpha_{3i}\text{RateGap}_{t-i} + \sum_{i=1}^{12}\beta_{3i}\text{DLREER}_{t-i} + \sum_{i=1}^{12}\gamma_{3i}\text{DLReserve}_{t-i} + \lambda_3\text{CI}_{t-1} + \mu_{3t} \quad (1\text{-}3)$$

This setup of the model is supported by tests on stationarity on all three variables. RateGap is the short-term real interest rate differential between China and the United States.

DLREER is the log difference of the real effective exchange rate of the Chinese RMB. DLReserve is the log difference of China's foreign exchange reserves. CI is the error correction item representing the cointegration relationship between the log of real exchange rate, LREER, and the log of foreign exchange reserves, LReserve, and can be expressed as:

$$CI_t = LREER_t + \rho LReserve_t$$

ρ is the standardized cointegration parameter.

B. The Data

The real interest rate differential, RateGap, is the real one-year deposit rate in China minus the real one-year yield on treasury securities in the United States. China's real one-year deposit rate is equal to the nominal one-year deposit rate minus 12-month changes in the CPI in China. The U.S. real yield on constant maturity one-year treasury securities is the nominal yield minus 12-month changes in the CPI in the United States. The U.S. nominal yield on constant maturity one-year treasury securities is obtained from the Federal Reserve System and the others are based on the IFS of the IMF.

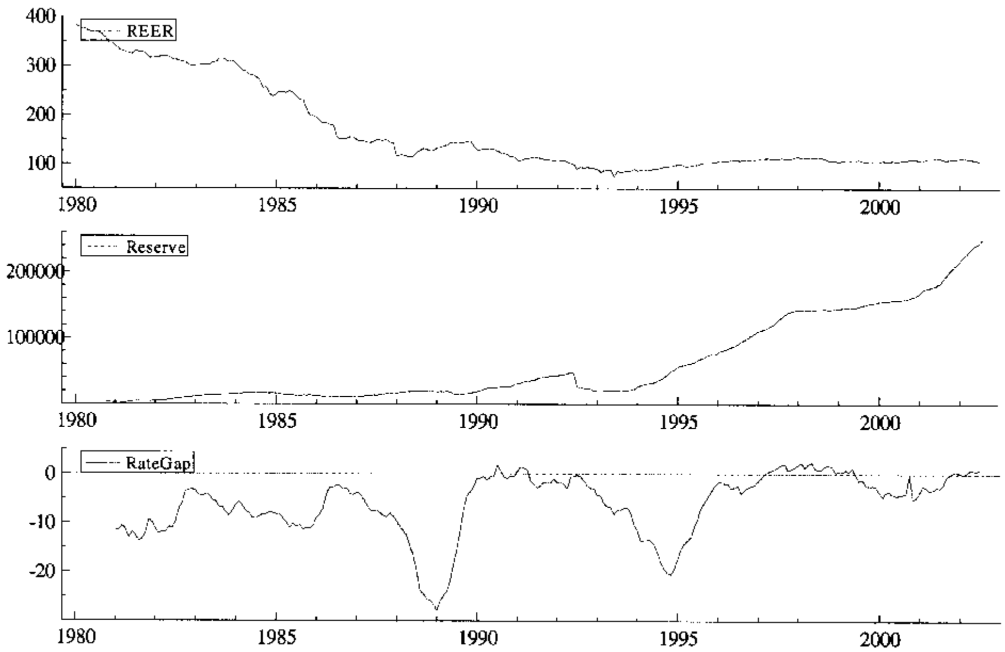
The REER is the trade-weighted real effective exchange rate for the Chinese RMB vis-a-vis its major trading partners composed by the IMF. Foreign exchange reserves are official statistics. Both of them are sourced from the IFS of the IMF.

The sample range is between January 1980 and July 2002.

C. Stylized Facts

A graphic demonstration of the movement of the three variables can be seen in Figure1.

Figure 1. China's Real Effective Exchange Rate, Foreign Exchange Reserves, and Real Interest Rate Differential: Jan. 1980- July 2002



The first graph shows the movement of REER. In the prereform era in the late 1970s, foreign trade was totally monopolized by the state, and the official exchange rate was largely fixed according to principles related to purchasing power parity. In the1980s, the government gradually devalued the RMB by introducing a parallel exchange rate for nontrade transactions and granting retained foreign exchange earnings to foreign-trade activities in selected regions and sectors. A swap market was established for retained foreign exchange holdings in the mid-1980s and the share of retained foreign exchange was gradually increased. Because of overvaluation in the prereform era and rising inflation induced by price liberalization and occasional deficit financing by the central bank, the official exchange rate was gradually devalued, often with the guidance of depreciation in swap market rate. The coexistence of the official rate and the swap rate continued until January 1994, when the official exchange rate and the swap market rate were unified. Since 1994, the nominal exchange rate has been officially a managed float, often within a very narrow band, and the real effective exchange rate has been on a general trend of slight appreciation (Jin, 1996, Zhang, 2001).

It can be observed that the evolution of REER during the above sampling period can be roughly separated into two periods, with January 1994 as the point of division. The period before January 1994 is characterized by a dual exchange rate system. The parallel market rate had made the nominal effective exchange rate, *de facto*, flexible. This fact supports findings made by Reinhart and Rogoff (2002) in their reinterpretation of the modern history of exchange rate arrangements. The period after January 1994 is characterized by a single exchange rate regime. The exchange rate is determined in an interbank foreign exchange market in which commercial banks and the central bank are major players in influencing supply and demand. This has been a exchange rate system that, in effect, lies somewhere between a managed float and a *de facto* peg--in the initial period it is closer to the former while in the more recent period it is closer to the latter. To account for this difference, a step dummy--d1994p1-- will be used in the following empirical estimation. Its value will be zero before January 1994 and one thereafter.

The second graph shows that foreign exchange reserves increased slowly during most of the 1980s. Since the early 1990s, the growth of foreign exchange reserves has sped up, partly owing to significantly increased foreign capital inflows. The break point in July 1992 was caused by a change in the definition of foreign exchange reserves in China, which excluded the foreign exchange reserves held by the state-owned commercial bank—the Bank of China. During 1994–98 and after 2001, foreign exchange reserves witnessed a rapid increase. Two dummies will be used in the empirical estimation. The first is a step dummy--d1992p7--that reflects the downward shift of the curve after July 1992. The value of this dummy is zero before July 1992 and one thereafter. The second is an impulse dummy--i1992p7--that represents the one-time change in the growth rate of foreign exchange reserves. The value of this impulse dummy is one in July 1992 and zero in the rest of the sampling period.

The third graph shows that during the entire 1980s, China's real short-term interest rate was lower than that in the United States and the gap reached its peak level in 1988-89, when price liberalization induced high inflation. In most portions of the sampling period, nominal interest rates were fixed in China and adjustment occurred occasionally, depending on the authorities' judgment on the trend of the macroeconomic development. In periods of high inflation, such as the late 1980s and early 1990s, the nominal deposit rate was indexed to inflation to maintain people's confidence in the value of their savings. With the development of an interbank money market in the second half of 1990s, a market-determined interbank rate has formed gradually and has been used as a reference in setting the level of nominal lending and deposit rates for banking system. Since 1997, nominal rate adjustment has been used more frequently in response to changes in the macro economy. It can be observed that since the early 1990s, real interest rate differential has been narrowed significantly and has been relatively close to zero in most portions of this period except for 1994–96, when the overheated economy induced high inflation.

D. Unit-Root Tests

In order to determine whether the three variables (namely RateGap, LREER and LReserve) should be estimated in the model in level form or in first order difference form, we implement standard unit root tests based on regression of the following general form:

$$\Delta y_t = \alpha + (\beta - 1)y_{t-1} + \sum_{i=1}^{s} \gamma_i \Delta y_{t-i} + \varepsilon_t \qquad (1\text{-}4)$$

The null hypothesis is that of a unit root, which means $\hat{\beta} = 1$. The alternative hypothesis is that $\hat{\beta} < 1$.

Table 1.Tests for Unit Roots in RateGap, LREER and LReserve[a]

Dependent Variable	$\hat{\alpha}$	$\hat{\beta}$	ADF t-Ratio for $\hat{\beta}$	The highest *s* with a significant last $\hat{\gamma}_s$	t-Ratio for the significant last $\hat{\gamma}_s$ with the highest *s*	t-Prob for the significant last $\hat{\gamma}_s$ with the highest *s*
RateGap	None	0.98299	-2.285*	2	3.413	0.0007
LREER	Yes	0.98994	-2.409	0	None	None
LReserve	None	1.0012	3.122	1	2.785	0.0057

[a]Monthly observations, May 1981 through July 2002 for RateGap and November 1980 through July 2002 for LREER and LReserve.

*Significant at 5% level.

In the equation for RateGap, the critical values of ADF t-ratio for $\hat{\beta}$ are -1.94 and -2.57 at significant level of 5% and 1% respectively. In the equation for LREER, the corresponding critical values of the ADF t-ratio for $\hat{\beta}$ are -2.87 and -3.46. In the equation for LReserve, the corresponding critical values of the ADF t-ratio for $\hat{\beta}$ are -1.94 and -2.57. The distribution of $\hat{\gamma}_s$ is the conventional student-t distribution.

In regressions for RateGap and LReserve, the constant $\hat{\alpha}$ is not significant and therefore has been excluded.

E. Cointegration Tests

Since both LREER and LReserve are I(1), it is necessary to carry out a cointegration test with these two variables. The general VAR used for the cointegration test is:

$$y_t = \sum_{i=1}^{m} \pi_i y_{t-i} + v_t \quad \text{where } v_t \sim IN_n[0, \Omega]. \qquad (1\text{-}5)$$

In this case, y_t is $n \times 1$. $n = 2$. When the data $\{y_t\}$ are I(1), a useful reformulation of the system is the equilibrium-correction form (see Engle and Granger, 1987; Johansen, 1988; Banerjee, Dolado, Galbraith, and Hendry, 1993):

$$\Delta y_t = \sum_{i=1}^{m-1} \delta_i \Delta y_{t-i} + P_0 y_{t-1} + v_t \qquad (1\text{-}6)$$

No restrictions are imposed by the transformation in (2-6). However, when y_t is I(1), then Δy_t is I(0) and the system specification is balanced only if $P_0 y_{t-1}$ is I(0). P_0 cannot be full rank in such a state of nature since that would contradict the assumption that y_t was I(1), so let $\text{rank}(P_0) = p<n$. Then $P_0 = \alpha\beta'$ where α and β are $n\times p$ matrices of rank p, and $\beta' y_t$ must comprise p cointegrating I(0) relations inducing the restricted I(0) representation:

$$\Delta y_t = \sum_{i=1}^{m-1} \delta_i \Delta y_{t-i} + \alpha(\beta' y_{t-1}) + v_t \tag{1-7}$$

The statistical hypothesis of cointegration is H_p: $\text{rank}(P_0) \leq p$.

The approach in this research to determine the cointegration rank, and the associated cointegration vectors, is based on Johansen (1988). The common *trace statistic* η_p for H_p is used to determine the cointegration rank. The distribution of the η_p is a functional of n-p dimensional Brownian motion. Testing proceeds by the sequence $\eta_0, \eta_1, \ldots, \eta_{n-1}$. Then p is selected as the first insignificant statistic η_p, or zero if η_0 is not significant.

In the unit root test for LREER, a constant term is found significant and that means the LREER is a random walk process with a drift. This in turn means the expected value of LREER is linearly dependent on time t. Therefore a variable *Trend* is restricted into the cointegration space together with LREER and LReserve. Equation (2-7) can be revised as:

$$\Delta y_t = \sum_{i=1}^{m-1} \delta_i \Delta y_{t-i} + \alpha(\beta'_0\, y_{t-1}) + \phi_0 + \phi_1 t + v_t,\ \ \phi_1 = \alpha\beta'_1, \tag{1-8}$$

which can be rewritten as:

$$\Delta y_t = \alpha(\beta'_0, \beta'_1)\binom{y_{t-1}}{t} + \sum_{i=1}^{m-1} \delta_i \Delta y_{t-1} + \phi_o + v_t \tag{1-8'}$$

Table 2 summarizes the results of identifying the cointegration rank and the associated cointegration vector.

Table 2: Test for Cointegration Rank and the Corresponding Cointegration Vectors

Test of Cointegration Rank		
Null Hypothesis: rank ≤	Trace Test η	Probability of η
0	39.981	0.000
1	2.6529	0.902
Cointegration Vectors		
LREER	Lreserve	Trend
1.0000	-1.8634	0.029555
-3.1439	1.0000	-0.028766

The asymptotic p-values are based on regression with a constant and two step-dummies--d1994p1 and d1992p7--being included unrestrictedly. The first dummy, d1992p7, is used to account for the change in the definition of foreign exchange reserves in China that excluded the reserves held by a state-owned commercial bank—the Bank of China--from the aggregate official foreign exchange reserves. The second dummy, d1994p7, is used to account for the unification of the official exchange rate and the swap market exchange rate. The number of lags used in the analysis is 12.

The identified cointegration relation is:

$$CI_t = LREER_t - 1.8634 LReserve_t + 0.029555 Trend .$$

F. Model Estimation

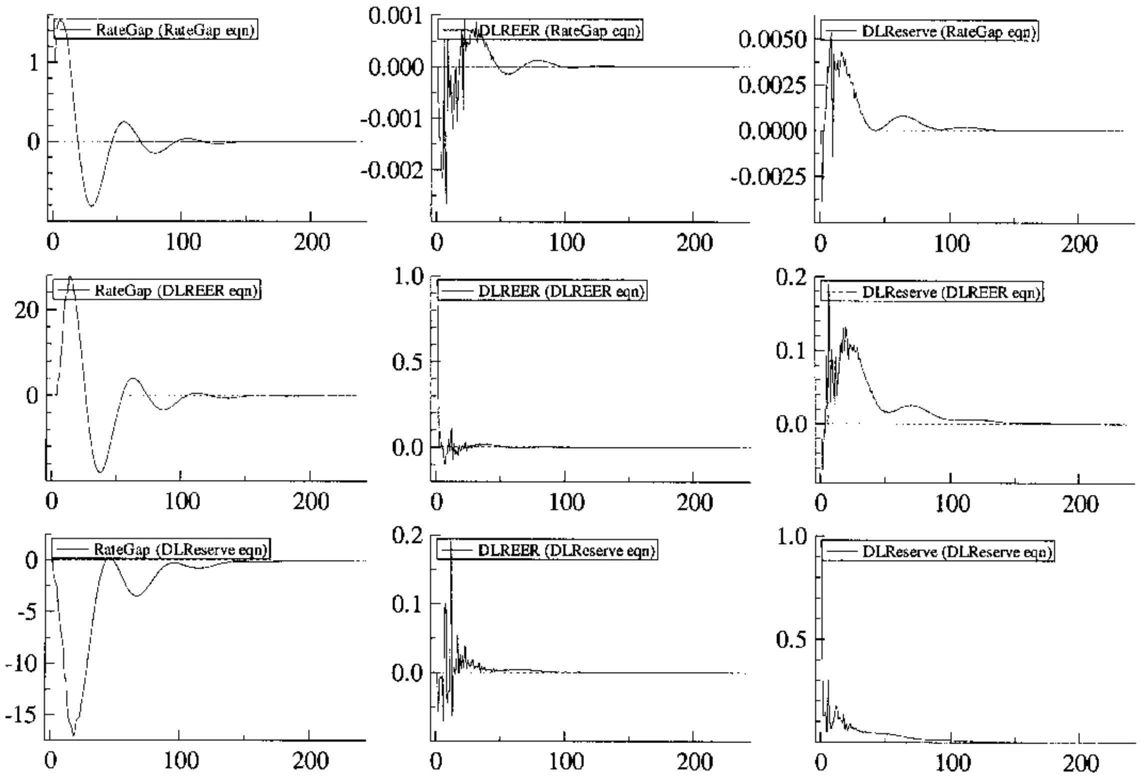
Having identified the unit root of the three variables and the cointegration relationship between the real exchange rate and foreign exchange reserves, a model can be established with the level of RateGap, the first-order difference of LREER and LReserve, the cointegration relation CI, and a constant and dummies.

The PcGive 10 (Doornik and Hendry 2001) was used for the modeling. The modeling starts with a three-equation system, equation (1-1), (1-2) and (1-3), comprising RateGap, DLREER (first-order difference of LREER) and DLReserve (first-order difference of LReserve) with 12 lags, and a constant and two dummies, all entered restrictively. Initially the system was estimated with Ordinary Least Squares. System reduction was implemented by deleting the same lags of the three variables that were judged system-wide insignificant sequentially. An F-test was used to determine the acceptability of reductions. The system reduction ended when all the right-hand variables were judged systemwide significant. Then the system was reduced into a model that was estimated using Full Information Maximum Likelihood methodology, which allows each equation having different lags of variables. The constant and dummies could also be deleted in a specific equation if they were not significant. The model reduction ended with all the remaining estimated parameters being significant at a probability level of 30% or lower. Appendix I summarizes the estimation results of the final model.

G. Dynamic Impulse Response Analysis

An impulse response analysis presents an intuitive illustration of how the interaction of the three variables evolves over time.

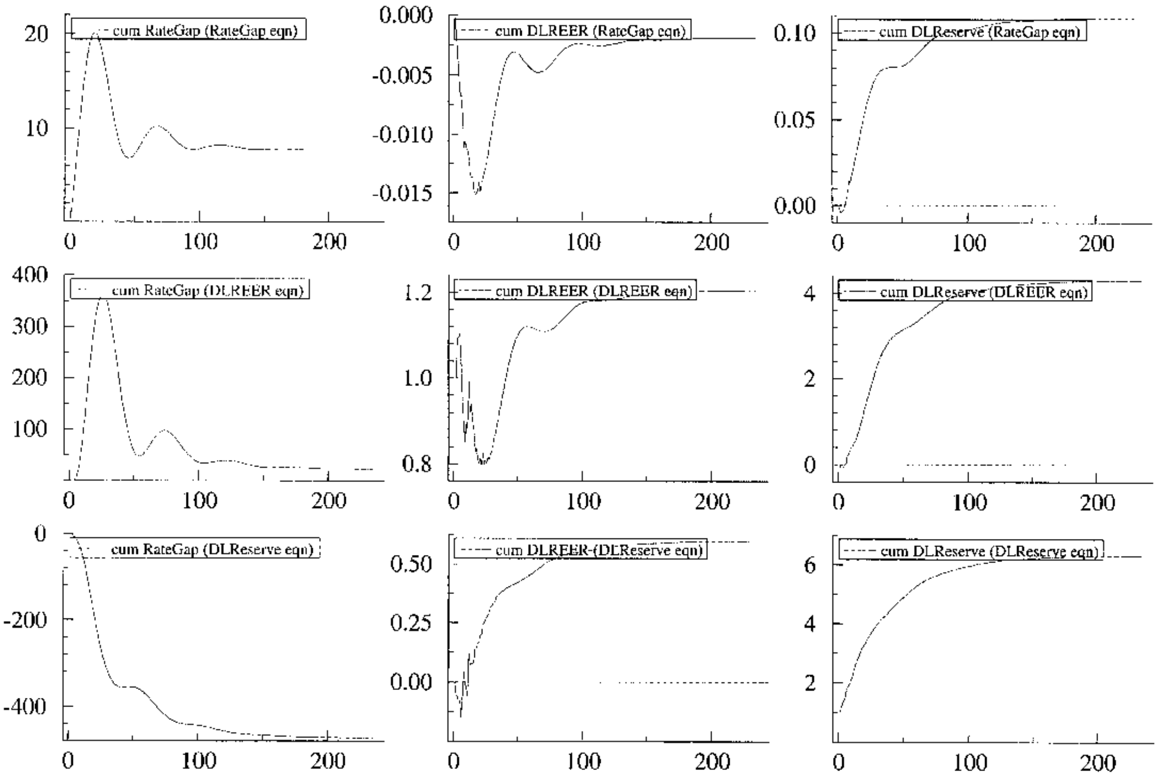
Figure 2. Impulse Response Analysis



The first row shows how an impulse of one standard error in RateGap (left) will affect DLREER (middle) and DLReserve (right). It can be seen that the responses of both DLREER and DLReserve are not monotonic. The second row above shows how an impulse of one standard error in DLREER (middle) will affect RateGap (left) and DLReserve (Right). The responses of both RateGap and DLReserve are not monotonic. The third row shows how an impulse of one standard error in DLReserve(right) will affect RateGap (left) and DLREER (middle). Again, the responses of both RateGap and DLREER are not monotonic.

The net result of impulse response can be shown in the cumulated impulse response graphics in Figure 3.

Figure 3. Cumulative Impulse Response



The first row shows that, over time, an increase in the real interest rate differential (RateGap) will induce a real depreciation (a negative DLREER) and a higher growth rate of foreign exchange reserves (a positive DLReserve). Intuitively, an increase in the real interest rate differential may be induced by an increase in nominal interest rate. The dampen effect of a higher rate on domestic demand tends to offset its potential stimulating effect channeled by capital inflow, and that will in turn depress domestic inflation. Or, the increased real interest rate differential may be caused by lower domestic inflation relative to foreign inflation. In either case, the lower domestic inflation means a rise of the tradable goods price relative to the non-tradable goods price, and that, by definition, is a real depreciation. A real depreciation will stimulate export and increase foreign exchange reserves.

The second row shows that a real appreciation will induce an increase in the real interest rate differential and a higher growth rate of foreign exchange reserves. An intuitive explanation is that the real exchange rate appreciation may increase the supply of nontradable goods and reduce the supply of tradable goods (the possible supply-side effect can be observed from the long lags of DLREER in the first estimated equation). This may dampen domestic inflation and increase domestic real interest rate. Although real appreciation tends to discourage exports, the induced increase in real interest rate may squeeze domestic demand. As a result, the exports could continue to grow, and foreign exchange reserves will increase.

The third row shows that a higher growth rate in foreign exchange reserves will induce a lower real interest rate differential and a real appreciation. An increase in foreign exchange reserves will increase money supply and induce higher domestic inflation. This will in turn reduce the real interest rate differential. Higher domestic inflation will also mean higher prices for non-tradable goods, which, by definition, is a real appreciation.

III. Theoretical Implications of the Empirical Results

How relevant is this study to mainstream international economics? At first glance, economists may have good reasons to cast doubt on the appropriateness of using the case of a transition economy to discuss issues raised in mainstream international economic theories. The argument is that mainstream economic theory like the M-F-D model usually assumes an open economy with a flexible exchange rate and free capital flows, while in the past two decades the Chinese economy has been characterized by capital control and officially managed exchange rates, interest rates and prices of many commodities.

Nevertheless, there are several factors that may help us to rethink the above perception. First, the real exchange rate and real interest rate differential are by definition relative concepts. Their value cannot be controlled by domestic authorities because of the flexibility of exchange rates and interest rates of China's many trading partners. Second, China's nominal effective exchange rate and domestic price level have been quasi-flexible even during the early transition period because of the introduction of a dual exchange rate and dual price system. Third, although the authorities have officially maintained capital controls, China has experienced increasingly large capital flows. As a matter of fact, foreign capital has entered and exited China in the forms of FDI, foreign borrowing, equity investment and various kinds of capital smuggling and flight under the current account. The scale of China's FDI inflow is now larger than most developed countries with capital account convertibility. Fourth, beyond the short term, changes in China's balance of payments have to be determined by market forces, in order to accommodate changes in the real exchange rate and real interest rate differential. An inverse argument is also true. In medium and long term, it is practically impossible, fiscally unsustainable and ultimately undesirable for the authorities to manipulate changes in the balance of payments, real exchange rates and real interest rates.

It may be fair to argue that although it may not be appropriate to use mainstream theory as a strict guide to carry out an empirical study of China, it could be helpful to use mainstream theory as a suggestion to identify the specific relationship between relevant economic variables in China. Furthermore, we cannot preclude the possibility that in our studies of China, we may find some generalized theoretical implication that can help us to better understand and even modify the existing mainstream theory that, sometimes, may be too simplified to encompass the complexity of the real world.

All this being said said, the following findings in this empirical study may have important theoretical meanings.

- First, the fact that an increase in the real interest rate differential will cause a depreciation rather than an appreciation and the non-monotonic relationship between the real exchange rate, real interest rate, and foreign exchange reserves have provided further support on similar empirical findings (in the case of negative correlation and non-monotonic adjustment, see Amartya Lahiri and Carlos A. Vegh, 2002) and arguments (see Rogoff, 1996 for non-monotonic assumption). This may suggest that the capital flows are not sensitive to short term interest rate changes in China. A deeper understanding on this phenomenon may shed some light on the hope of finding more pragmatic solutions in preventing and resolving financial crises in the future.

- Second, the way in which the real exchange rate and real interest rate differential are correlated in the empirical study may suggest a possible reinterpretation of the related expression in the M-F-D model and associated empirical puzzle. The M-F-D model predicts that there exists a positive correlation between the real interest rate differential and the *level* (rather than the *change*) of the real exchange rate. The underlying assumption is a constant (or stationary) equilibrium real exchange rate. If the equilibrium real exchange rate is nonstationary, a more appropriate expression should be a correlation between the change of the real exchange rate and the real interest rate differential. This may provide a useful clue in explaining some empirical works (see, among others, Mease and Rogoff, 1983) that failed to confirm the prediction in the M-F-D model. The detailed reasoning can be found in Appendix II. Although Krugman and Obstfeld have also derived an equation of correlation between real interest rate differential and changes in real exchange rate, the relative PPP must hold as a precondition in their work.

- Third, the empirical study also shows that a single equation (linking real exchange rates and real interest rates like those in the M-F-D model and K-O model) may not be sufficient to capture the complex interaction between these two variables. An increase in the real interest rate differential may cause a real depreciation, while a real depreciation may cause a decrease, rather than an increase, in the real interest rate differential.

- Fourth, the cointegration between the real exchange rate and foreign exchange reserves could lend support to theories that have identified relevant real fundamentals determining the equilibrium real exchange rate (see, among others, Montiel, 1999). If properly interpreted, this cointegration relationship can also be used to estimate the equilibrium real exchange rate and potential real exchange rate misalignment in China.

IV. CONCLUSIONS

China's real interest rates, real exchange rates and balance of payments have shown significant interaction during the past two decades during which market-oriented reform has been carried out in an unprecedented scale. The authorities have been able to influence this interaction by setting and adjusting nominal interest rate, nominal exchange rate and selected control on capital flows. However, the authorities' influence has not gone beyond recognizing and reflecting the requirement of market rule that takes effect in China's specific environment.

In addition to the significant general interactions among the three variables, the empirical result suggests specifically that (1) in China where capital flows may be insensitive to short term interest rate changes, an increase in the real interest rate differential may cause depreciation in the real exchange rate, and (2) a real exchange rate appreciation may stimulate supply of nontradable goods, discourage supply of tradable goods and cause downward pressure on inflation. This will in turn increase real interest rates, dampen domestic demand, and may go hand-in-hand with a growing surplus in the balance of payments.

The complex nature of these interactions, moreover, suggests that several key assumptions and predictions in mainstream international economics should be interpreted cautiously and, when necessary, modified appropriately. It also highlights the importance of policy interdependency and coordination across countries in an era of economic globalization.

Appendix I. Model Estimation and Evaluation

A. Model Estimation

Estimating the Model by FIML
The estimation sample is: 1983 (1) to 2002 (7)

Equation for: RateGap

	Coefficient	Std.Error	t-value	t-prob
Constant	-2.83652	2.003	-1.42	0.158
RateGap_1	1.23533	0.06590	18.7	0.000
RateGap_2	-0.100199	0.1053	-0.951	0.343
RateGap_3	-0.145033	0.07111	-2.04	0.043
RateGap_10	-0.0375014	0.01601	-2.34	0.020
DLREER_4	3.65051	2.199	1.66	0.099
DLREER_6	3.01401	2.227	1.35	0.178
DLREER_7	2.85529	2.145	1.33	0.185
DLREER_8	4.48052	2.159	2.08	0.039
DLREER_9	2.09916	2.171	0.967	0.335
DLREER_12	4.33123	2.183	1.98	0.049
DLReserve_1	-1.36536	1.266	-1.08	0.282
DLReserve_5	-1.54631	1.281	-1.21	0.229
DLReserve_10	-2.07523	1.338	-1.55	0.122
DLReserve_11	1.34668	1.333	1.01	0.314
DLReserve_12	-1.85041	1.353	-1.37	0.173
CI_1	-0.263411	0.1910	-1.38	0.169

Equation for: DLREER

	Coefficient	Std.Error	t-value	t-prob
RateGap_1	-0.00134629	0.0006655	-2.02	0.044
RateGap_5	0.00288270	0.002049	1.41	0.161
RateGap_6	-0.00354685	0.002345	-1.51	0.132
RateGap_8	0.00385398	0.002344	1.64	0.102
RateGap_9	-0.00256709	0.001727	-1.49	0.139
DLREER_2	0.0907272	0.05985	1.52	0.131
DLREER_5	-0.0555066	0.06127	-0.906	0.366
DLREER_6	-0.102537	0.06309	-1.63	0.106
DLREER_9	0.0782767	0.05901	1.33	0.186
DLREER_11	0.114518	0.06025	1.90	0.059
DLREER_12	-0.0651940	0.06068	-1.07	0.284
DLReserve_1	-0.0572567	0.03459	-1.66	0.099
DLReserve_5	-0.0708203	0.03502	-2.02	0.045
DLReserve_6	0.114363	0.03640	3.14	0.002
DLReserve_7	0.0932890	0.03514	2.65	0.009
DLReserve_8	-0.0793523	0.03489	-2.27	0.024

DLReserve_9	-0.0537655	0.03379	-1.59	0.113
DLReserve_11	0.175217	0.03501	5.01	0.000
DLReserve_12	-0.0869756	0.03540	-2.46	0.015
CI_1	0.00135049	0.0003850	3.51	0.001
d1994p1	0.0124080	0.004268	2.91	0.004
i1992p7	-0.0770231	0.02643	-2.91	0.004

Equation for: DLReserve

	Coefficient	Std.Error	t-value	t-prob
Constant	0.424594	0.06239	6.81	0.000
RateGap_1	-0.00389069	0.001985	-1.96	0.051
RateGap_2	0.00516963	0.002452	2.11	0.036
RateGap_5	0.00145693	0.001404	1.04	0.301
RateGap_9	-0.00717234	0.002343	-3.06	0.003
RateGap_10	0.00795450	0.003169	2.51	0.013
RateGap_11	-0.00220767	0.001957	-1.13	0.261
DLREER_1	-0.0626061	0.06932	-0.903	0.368
DLREER_4	0.101845	0.06685	1.52	0.129
DLREER_6	0.184105	0.06755	2.73	0.007
DLREER_8	0.0650177	0.06663	0.976	0.330
DLReserve_1	0.132543	0.03947	3.36	0.001
DLReserve_2	0.0996811	0.04068	2.45	0.015
DLReserve_3	0.115775	0.03929	2.95	0.004
DLReserve_5	0.272745	0.03908	6.98	0.000
DLReserve_9	0.0836055	0.03890	2.15	0.033
DLReserve_11	0.110653	0.04051	2.73	0.007
DLReserve_12	0.0975909	0.04355	2.24	0.026
CI_1	0.0398103	0.005970	6.67	0.000
i1992p7	-0.567603	0.03047	-18.6	0.000

Correlation of structural residuals (standard deviations on diagonal)

	RateGap	DLREER	DLReserve
RateGap	0.98629	-0.13725	-0.078099
DLREER	-0.13725	0.026257	0.011824
DLReserve	-0.078099	0.011824	0.029987

1. The equation for RateGap shows that real exchange rate appreciation tends to cause an increase in the real interest rate differential. The strongest real exchange rate effect comes with a lag of 4, 8 and 12 months, respectively. This equation also shows that the real interest rate differential has been highly persistent. The changes in foreign exchange reserves and the cointegration relation do not have a significant effect on real interest rate differential.

2. The equation for DLREER shows that a change in the real interest rate differential will have a non-monotonic effect on the real exchange rate. The initial effect is negative and the parameter is statistically significant. This means that an increase in the real interest rate

differential will cause a real depreciation, rather than real appreciation. However, as can be seen in the equation, the real exchange rate effect is not monotonic, but the parameters for RateGaps with lags longer than one are less significant.

The two dummy variables, i1992p7 and d1994p1 are highly significant, suggesting the usefulness of introducing them to account for regime changes in July 1992 and January 1994.

The autoregression of DLREER is not significant for most lags. Only the lag of 11 months is relatively significant.

DLReserve, the changes in foreign exchange reserves, will generate significant positive effects on DLREER, changes in real exchange rate. The most significant effect comes with lags of 5–8 months.

The parameter on cointegration relation CI is highly significant. Although it confirms that the deviation of the real exchange rate from its long-run equilibrium has an important effect on the short-term behavior of itself, the positive sign of this parameter seems to suggest that the deviation from equilibrium is self-enhancing. This result seems to be in-consistent with intuition. But the first equation has shown that an increase in DLREER will cause a higher RateGap which will dampen the increase in DREER. In addition, it can be seen that the adjustment caused by CI is quite slow, much lower than the adjustment of foreign exchange reserves in response to CI as indicated in the equation for DLReserve.

3. Equation for DLReserve shows that RateGap, the real interest rate differential, will have a significant effect on DLReserve, the change of foreign exchange reserves, with lags of 1–2 months and 9–10 months. It also shows that this effect is not monotonic, either. The initial effect of a rise in RateGap is negative, followed then by a positive effect. But in general the positive effect will dominate.

The effect of DLREER is also non-monotonic. Initially, the change in DLREER will have the first wave of a (insignificant) negative effect on DLReserve. After 6 months, however, the second wave of a (significant) positive effect will come.

The DLReserve is also highly persistent. This is indicated by its strong tendency of autoregression.

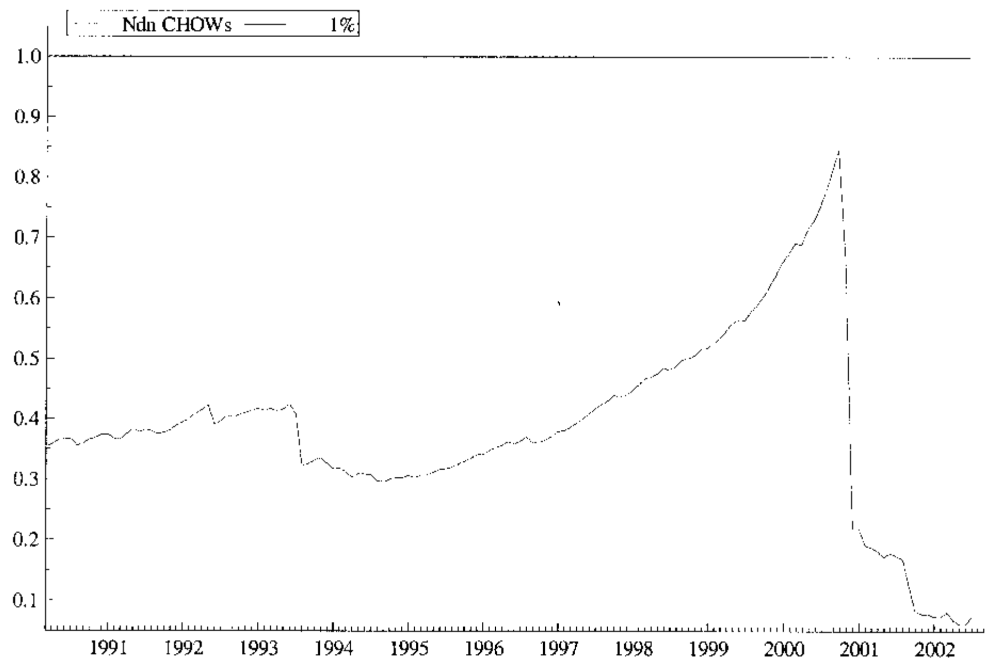
The cointegration relation CI has a highly significant positive effect on DLReserve and the speed of adjustment seems to be much faster than that in the equation for DLREER. Unlike the equation for DLREER, the deviation from the long-run equilibrium is self-correcting in this equation.

The impulse dummy, i1992p7, is highly significant.

B. Parameter Constancy and Model Evaluation

The parameter constancy and model evaluation have been monitored throughout the modeling process. Based on recursive regressions, break-point Chow tests were used to check the parameter constancy at the system level. The result of break-point Chow tests indicate that in spite of the structural reforms carried out in the 1990s and 1980s, the introduction of dummy variables has helped to maintain parameter constancy in the model. In the system level, the parameter constancy cannot be rejected at the 1% significance level. The result of break-point Chow tests are shown in Figure A.1 below.

Figure A.1. Test of Parameter Constancy:Break Point Chow Test at 1% Significance Level



The model evaluation shows that at the system level, vector autocorrelation and vector heteroscedasticity have been kept under control. But the vector normality has been rejected. This may be caused by the smallness of the sample and may only be solved with an enlarged sample in the future. The result of the vector autocorrelation test, vector normality test and vector heteroscedasticity test for residuals are shown in Table A1.

Table A1: Model Evaluation Diagnostics

Diagnostics (multivariate)			
Vector AR 1-7 test:	F(63,576) =	0.56794	[0.9970]
Vector Normality test:	Chi^2(6) =	368.71	[0.0000]**
Vector hetero test:	F(456,811)=	1.1218	[0.0803]

Figures in brackets are P values. F(63, 576) means that the test has an F-distribution with 63 degrees of freedom in the numerator and 576 degrees of freedom in the denominator. Chi^2(6) refers to the χ^2 test with 6 degrees of freedom.

** suggest significant at 1% significance level.

APPENDIX II: A REINTERPRETATION OF THE M-F-D MODEL

A. Traditional Expression of the M-F-D Model

A famous prediction of the traditional M-F-D model is that there exists a negative correlation between the real interest rate differential and the level of the real exchange rate (defined as the ratio of tradable goods to nontradable goods[2]). It has attracted numerous economists in this field to test the validity of this prediction. The up-to-date empirical findings have, in general, failed to confirm this prediction.

A traditional interpretation of the M-F-D model on the relationship between the real interest rate differential and the real exchange rate are based on the following:

First, we assume there is a monotonic adjustment process that will gradually correct for the deviation of the real exchange rate from its equilibrium level.

$$E_t(q_{t+k} - \bar{q}_{t+k}) = \theta^k (q_t - \bar{q}_t), \quad 0 < \theta < 1 \tag{A-1}$$

Assume:

$$E_t \bar{q}_{t+k} = \bar{q}_t, \tag{A-2 }$$

Then:

$$E_t q_{t+k} - E_t \bar{q}_{t+k} = \theta^k q_t - \theta^k \bar{q}_t$$

$$E_t q_{t+k} - \bar{q}_t = \theta^k q_t - \theta^k \bar{q}_t$$

$$q_t = \alpha(E_t q_{t+k} - q_t) + \bar{q}_t \text{ in which } \alpha = \frac{1}{\theta^k - 1} \tag{A-3}$$

Second, we assume uncovered interest rate parity holds:

$$E_t s_{t+k} - s_t = {}_k r_t - {}_k r_t^* \tag{A-4}$$

which means the expected nominal depreciation is equal to the nominal interest rate gap.

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[2] The definition of the real exchange rate in this Appendix is the inverse of that in the main text of this paper.

By definition, the relation between the nominal exchange rate s_t and the real exchange rate q_t is:

$$s_{t+k} = q_{t+k} - P^*_{t+k} + P_{t+k}, \quad s_t = q_t - P^*_t + P_t;$$

Also by definition, the relationship between the nominal interest rate and the real interest rate is:

$${}_k r_t = {}_k R_t + (E_t P_{t+k} - P_t), \quad {}_k r^*_t = {}_k R^*_t + (E_t P^*_{t+k} - P^*_t).$$

Substitute the above expressions for the real exchange rate and the real interest rate into (A-4) and get:

$$E_t q_{t+k} - q_t = R_t - R^*_t \qquad \text{(A-5)}$$

Substitute (1-5) into (1-3):

$$q_t = \alpha({}_k R_t - {}_k R^*_t) + \bar{q}_t \qquad \text{(A-6)}$$

Equation (A-6) means that, given constant equilibrium $\bar{q}_t$, the level of the real exchange rate is negatively correlated with the real interest rate differential. That is to say, an increase in the real interest rate differential will tend to correlate with a real appreciation in the real exchange rate.

In empirical study, this relationship was expected to be found when both q_t and ${}_k R_t - {}_k R^*_t$ are I(1) (when there is a co integration) or I(0) (which is less likely). Since Meese and Rogoff published their famous article challenging the existence of such a relationship as illustrated in equation (A-8) in 1983, it has become well known that many empirical results have failed to find cointegration relationship between (long-run) real interest rate differentials and the level of real exchange rates (Edison and Pauls, 1991), and that has constituted a puzzle (Obstfeld and Rogoff, 2000).

B. Reinterpretation

There have been some important exceptions or clues, however. First, although some studies have found that most long-term real interest differentials exhibit the property of I(1), it is still quite often found that a short-term real interest rate differential is I(0) (Meese and Rogoff, 1988). Second, the fact that the nonstationarity of long-term real interest rate differentials has been a puzzle, by itself, suggests that it may not be appropriate to jump and do a cointegration analysis before we really understand the puzzle in the first place. Third, the stationarity of a short-term real interest rate differential is consistent with economic intuition and this, in turn, suggests that we may need to pay more attention to the relationship between short-term real interest rates and real exchange rates.

Based on the above reasoning, I tend to assume that the assumption of a constant equilibrium real exchange rate may be a crucial element for the failure of empirical studies on the relationship between q_t and ${}_kR_t - {}_kR_t^*$.

Theoretically, if q_t is indeed I(1), the assumption of a constant $\bar{q}_t$ will become problematic because it is hard to imagine that the actual q_t can depart from its equilibrium forever. A $\bar{q}_t$ of I(1) will make the statistical inference of the estimated parameter of the real interest rate differential invalid. In fact, equation (1-2) already assumes $\bar{q}_t$ follows a random walk with no drift.

Research on the determination of equilibrium real exchange rates has also suggested that the equilibrium real exchange rates are determined by real fundamentals and are subject to changes (Sebastian Edwards, 1988; Williamson, 1991; and Hinkle and Montiel, 1999).

A further examination of the M-F-D model suggests that the relationship that deserves careful empirical study may be that between the first order difference of real exchange rate q_t and the real interest rate differential ${}_kR_t - {}_kR_t^*$. This can be shown as the following:

Equation (A-2) implies that:

$$\bar{q}_t = \bar{q}_{t-1} + \mu_t, \qquad \text{(A-2')}$$

where μ_t is IIN(0, σ). Substituting (A-2') into (A-6), we get:

$$q_t - \bar{q}_{t-1} = \alpha({}_kR_t - {}_kR_t^*) + \mu_t$$

Next we want to find the relationship between q_{t-1} and $\bar{q}_{t-1}$. Equation (A-1) implies that in the long run, there could be a cointegration relationship between the actual real exchange rate and the equilibrium real exchange rate.

$$\bar{q}_t = q_t + \varepsilon_t \qquad \text{(A-7)}$$

in which ε_t follows a IIN(0, δ). We also assume the cointegration parameter of q_t is unit one.

Using equation (1-7) to substitute $\bar{q}_{t-1}$ with q_{t-1}, we get:

$$q_t - q_{t-1} = \alpha({}_kR_t - {}_kR_t^*) + \mu_t + \varepsilon_{t-1} \qquad \text{(A-8)}$$

Due to the lack of a feedback channel between $q_t - q_{t-1}$ and ${}_kR_t - {}_kR^*_t$, the relationship between the two, as shown in equation (A-8) can be interpreted in both direction. In the empirical study, however, we can find the direction of causality is important.

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