The Undisclosed Renminbi Basket: Are the Markets Telling us something about where the Renminbi – US Dollar Exchange Rate is Going?

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Abstract

On 21 July 2005 China adopted an undisclosed basket exchange rate regime. We formally assess and envisage the gradual evolution of the renminbi over time. We utilize nonlinear dependencies in the renminbi exchange rate and describe the smooth transition of the renminbi/U.S. dollar (RMB/USD) exchange rate using the family of time-varying autoregressive (TV-AR) models. Specifically, the nonlinear models allow for a smooth transition from one optimal level to another. Our estimation results imply that the RMB/USD exchange rate will likely be about 7.10 RMB/USD in summer/autumn 2009.

JEL Code: C22, F31, F37.

Keywords: China, renminbi, de facto exchange rate regime, TV-AR model, TV-AR-GARCH model.

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"An Economist … is an expert who will know tomorrow why the things he predicted yesterday did not happen today. This is especially true of currency forecasting."

The Economist, February 25th 1995, p. 19

1. Introduction

One issue which has been the subject of intensive debate among academic economists and politicians alike is the Renminbi (RMB) exchange rate. On July 21, 2005, after more than a decade of pegging the renminbi to the U.S. dollar (USD) at an exchange rate of 8.277, the People´s Bank of China (PBoC) announced a revaluation of the currency, together with a reform of the exchange rate regime.[1] In the new regime, the PBoC manages the RMB against an undisclosed basket of currencies of the main trading partners.[2] Although critics were not impressed with the initial 2.1 percent appreciation of the RMB to 8.11 per USD, much initial excitement surrounded the Chinese pledge to link the RMB to a group of major currencies. Many economists have argued that the modest RMB revaluation merely marks the beginning of a more significant evolution of the currency regime which could translate into a major upward revaluation if the RMB in accordance with market forces.

Concerns about China´s competitive threat as a global production place are widespread in both advanced and emerging economies. For a start, the large bilateral U.S.-China trade deficit has led to American pressure to revalue the RMB. Above and beyond this pressure, the U.S. has been joined by the international community, including the G-8 and the IMF, in encouraging China to implement greater exchange rate flexibility, which would most likely be associated with a larger RMB appreciation. Greater flexibility in China's exchange rate is viewed as an essential element of a global response to the large macroeconomic imbalances in the world economy.

In East Asia there are concerns that China´s industrialisation - underpinned by cheap labour - devalues manufacturing assets outside China. This concern stems from the fact that the current hollowing out of their low-end manufacturing trade in third markets, as well as their trade with China, may soon extend to more complex production processes. Gaulier et al. (2007) have demonstrated that, since the emergence of China, Asian trade has become increasingly centred on China – a development largely driven by the international segmentation of production processes. Lall and Albaladejo (2004) have analysed exports disaggregated according to technological content in order to gain a deeper understanding of China´s changing competitive edge vis à vis its

[1] The terms "renminbi" and "yuan" are generally used interchangeably to refer to China´s currency. The renminbi is the currency, while the yuan is the unit of account.

[2] This poses a problem in that the announcement and subsequent clarifications leave the Chinese central bank with considerable discretion over its renminbi target. Funke and Rahn (2005) have estimated that the equilibrium renminbi exchange rate against the U.S. dollar is undervalued by 10-15 percent, while Cheung et

neighbours. Their work has yielded the well-documented insight that China has boosted intra-regional trade. Furthermore they have shown that the Asian countries differ greatly in their industrial capabilities and that the competitive threat facing each country therefore differs greatly. With appropriate restructuring, most countries will be able to match China´s export surge and maintain high rates of export growth. The real threat is to the less technologically advanced Tigers that have much higher wages than China but lack the domestic capabilities to climb up the quality ladder.[3]

A substantial literature has emerged examining the *de facto* currency regimes which are currently in operation [see Calvo and Reinhart (2002)]. Given this literature, our paper seeks to address questions such as (i) what is the nature of the current RMB exchange rate regime? (ii) Is a basket in operation and if yes, what are the weights of the various currencies? (iii) How can we envisage the gradual evolution of the *de facto* currency regime towards a new equilibrium?

The reminder of the paper is organized as follows. Section 2 briefly outlines the new RMB basket peg. Section 3 discusses the *de facto* currency regime in operation using a rule-of-thumb framework. In Section 4 we exploit the time-varying TV-AR family of models which is suitable for describing the evolution of regimes with a smooth transition. Section 5 summarizes the findings and concludes with some general remarks.

2. How Does the New Renminbi Peg Work?

The Chinese basket peg replaces the obligation to hold the RMB exchange rate within a fixed margin of the USD with an obligation to hold the RMB within a fixed margin of a constant nominal value of a basket of currencies. On 10 August 2005, three weeks after China abandoned its decade-old peg to the USD, the PBoC revealed the mix of this basket.[4] However, the weights attached to each currency were not revealed.[5] According to the PBoC, the US dollar (USD), the Japanese yen (JPY), the euro (EUR) and the South Korean won (KRW) have the largest weights, but the basket also includes the currencies of Australia (AUD), Canada (CAD), Great Britain (GBP), Malaysia (MYR), Russia (RUB), Singapore (SQD), and Thailand (THB). Given the political problems this might pose, the Hong Kong and Taiwanese dollars are absent. The choice of currencies (and hence presumably the weights), depends not only on the pattern of China's trade but also on the sources of its foreign direct investment and the currency composition of its reserves.

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al. (2007) have found that once serial correlation and uncertainty is accounted for, there is little statistical evidence that the renminbi is undervalued. A survey of the literature is provided by Dunaway et al. (2006).

[3] A theoretical variety expansion growth model allowing for industrial hollowing-out has recently been presented by Kim (2007). According to the model, due to China´s increasing "experience capital" the Asian countries will experience an industrial hollowing-out unless they are able to switch to more technology-intensive products and exports.

[4] Singapore, which has operated a similar system since the 1980s, has never taken such a step.

[5] The obvious disadvantage of the undisclosed basket peg therefore is a lack of transparency. Markets may become flustered about what may happen next.

The operation of the new system involves the daily calculation of a new central parity ("medium value" in the gap/band).[6] Initially the trading range was monitored and controlled at ± 0.15% around this medium value for the USD, with different ranges for other currencies (perhaps 0.5-1% for EUR and JPY).[7] On 18 May 2007, the PBoC eventually widened the RMB´s daily trading band against the USD from 0.30% to 0.50%.[8]

There are several similarities between the Chinese system and Singapore´s basket system. Singapore adopted its basket approach in 1981 and it was seen as a halfway house between fixed and flexible currencies. Notable similarities between the two systems include the following: (i) Both countries link their currency to a basket of major currencies; (ii) both have a central parity and a moving band, and finally (iii) Singapore does not reveal exactly how its basket of currencies is constructed, an approach China appears to be emulating. The motivation is to ward off speculators. On the other hand, there is no capital control in Singapore and therefore no need to publish the official central parity. The band for Singapore is announced semi-annually. Singapore's Monetary Authority intervene at their own discretion to maintain the central parity and the band. The PBoC publishes the central parity every evening (necessitated by the fact that they have capital control and RMB is not freely tradable).

The basket is likely to be heavily dominated by the USD. Using China's trade weights, a four currency basket would have the following weights: USD (50%), JPY (20%), EUR (15%), and KRW (10%). The hard dollar pegs (USD and HKD) therefore account for close to 50% of the basket. If one considers the JPY as a soft USD peg, the weight on the dollar could be as high as 80%. This means that the RMB/USD will still be very "compliant", with the index being "sticky" relative to the USD.

The development of the RMB/USD exchange rate since July 2005 is plotted in Figure 1. Since departing from its USD peg at 21 July 2005, the RMB has gradually appreciated – albeit by incremental margins – moving from its original parity of 8.11 RMB/USD to about 7.6 RMB/USD as of late June 2007.

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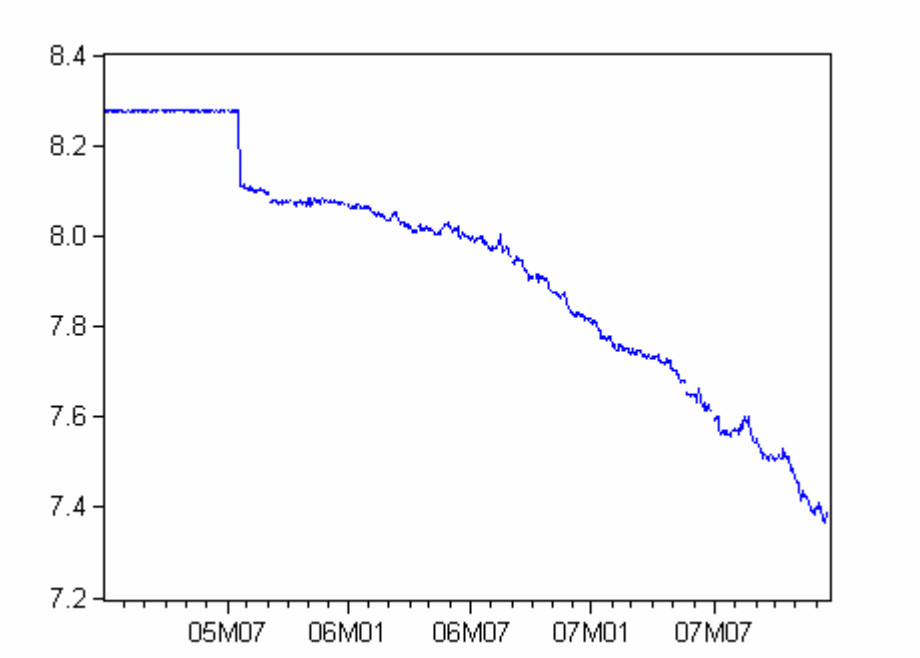
[6] Consider a simple example: Assume that the basket just contains the USD and the EUR with weights of 70% and 30%, respectively. On July 22 (as announced on July 21 evening), the rate is 1 USD = 8.11 RMB and 1 EUR = 9.81 RMB (because 1 EUR = 1.21 USD), to get 8.11 RMB you need USD 0.70 and EUR 0.30/1.21. During the day RMB/USD is allowed to trade at 8.11 ± 0.012. When recalculating the exchange rate, the PBoC will take the spot price of USD and EUR. If, for example, the EUR/USD = 1.19, then the new central parity for USD/RMB will become [8.11×0.70 + 9.81×(1/1.19)×0.30] = 8.15. The corresponding new EUR/RMB central parity is then 8.15×1.19 = 9.70. During day trade, PBoC will defend the exchange rate for the USD within the ± 0.015% band.

[7] PBoC have also stressed that they only "reference" a basket formula and that they have the discretion to not follow the formula strictly.

[8] The widening of the band may be a token gesture and may not indicate a policy change leading to a faster appreciation of the Renminbi. The reason is that the renminbi never hit its previous trading limits, so even within the tighter band it could have appreciated faster.

Figure 1: Daily China – U.S. Foreign Exchange Rate (RMB/USD)



Note: All daily exchange rates were obtained from the Pacific Exchange Rate Service (see http://fx.sauder.ubc.ca/).

The conventional wisdom is that the Renminbi has not moved much since the PBoC adopted the new regime in July 2005. This may be interpreted as a gradual policy approach trying to avoid slashing the RMB value of central bank reserves. In the next section we therefore track the (time-varying) weightings of the currencies in the basket.

3. A Standard Monitoring Procedure

We begin by calculating the *de facto* RMB currency regime that has been in place since July 2005 using a linear regression model that measures the relationship between daily changes in cross-currency rates. In order to monitor the new RMB basket peg system, we first employ the easy-to-use Haldane and Hall (1991) and Frankel and Wei (2007) methodology which has been used extensively in the exchange rate literature. Formally, the estimated model can be expressed as follows:

$$\begin{aligned}\Delta E_{RMB/k,t} = {} & \delta_0 + \delta_1 \Delta E_{USD/k,t} + \delta_2 \Delta E_{JPY/k,t} + \delta_3 \Delta E_{EUR/k,t} + \delta_4 \Delta E_{KRW/k,t} \\ & + \delta_5 \Delta E_{AUD/k,t} + \delta_6 \Delta E_{CAD/k,t} + \delta_7 \Delta E_{GBP/k,t} + \delta_8 \Delta E_{MYR/k,t} \\ & + \delta_9 \Delta E_{RUB/k,t} + \delta_{10} \Delta E_{SQD/k,t} + \delta_{11} \Delta E_{THB/k,t} + \varepsilon_t \ , \end{aligned} \tag{1}$$

where the exchange rate data consists of the log-level daily spot prices ($E_{i/k,t}$) and Δ is the first-difference operator.[9] The numeraire currency *k* used here is the Swiss Franc because the Swiss Franc is known to be a clean floating exchange rate. The OLS estimation results with robust standard errors are given in Table 1 below. The error term appears to have a fat-tailed distribution relative to the normal distribution, i.e. large changes tend to be followed by large changes, and small changes tend to follow small changes.[10] Therefore, we have also estimated a conditional GARCH-in-mean model specification where the conditional variance takes the form

$$(2) \qquad h_t = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 h_{t-1}.$$

The two cases of interest are:

(i) Peg to the USD: When the RMB is still pegged to the USD, then δ_1 is close to 1 and $\delta_2 = \delta_3 = ... = \delta_{11} = 0$.

(ii) Basket peg: If instead a basket peg is in operation, then the coefficients $\delta_1 = \delta_2 = ... = \delta_{11}$ would turn out to be positive and significant.

The estimation results using high-frequency daily data for the period 26 July 2005 to 19 December 2007 are given in Table 1. As shocks to the mean equation are the main actors in the multivariate framework, it is important that the mean equation is not misspecified. The final specification of the mean equation and the lag structure has been chosen using information criteria. The diagnostic tests fail to detect any autocorrelation, thereby suggesting that there is little unexplained dependence in the data. The ARCH tests performed on the squared residuals turn out insignificant, which indicates that the GARCH(1,1) model does a good job of tracking the strong temporal dependence in the variance.

[9] The daily series represent changes between business days with no adjustment for holidays.

[10] Conditional heteroscedasticity in nominal exchange rate residuals is a well-known feature of daily exchange rate data that tends to vanish at lower frquencies due to time aggregation. With heteroscedasticity, the OLS estimator is still unbiased and consistent but it is not BLUE or asymptotically efficient. When heteroscedasticity is mild, OLS standard errors behave quite well [Long and Ervin 2000)]. However, when heteroscedasticity is severe, ignoring it may bias the standard errors. The direction of the bias depends on the pattern of heteroscedasticity: standard errors may be too large or too small. Usually, heteroscedasticity is a nuisance that cannot be modeled because its source is not well understood. In this case, a classic correction for heteroscedasticity is the HC0 estimator proposed by White (1980). But although this estimator is correct in large samples, it is no better than OLS in small samples. MacKinnon and White (1985) discussed three improvements, HC1, HC2, and HC3. The evaluation by Long and Ervin (2000) suggests that HC3 is the best, especially in small samples.

Table 1: Estimating the Implicit Basket Weights

	OLS		GARCH(1,1)	
	Estimates	Prob-values	Estimates	Prob-values
USD	0.911	0.0001	0.910	0.0001
EUR	-0.043	0.0761	-0.027	0.1603
JPY	0.006	0.4618	0.012	0.1351
KRW	0.031	0.0032	0.025	0.0046
SQD	-0.003	0.8742	-0.017	0.3079
GBP	0.009	0.4194	0.010	0.3341
MYR	0.034	0.0808	0.045	0.0046
RUB	0.026	0.3325	0.039	0.1276
AUD	0.013	0.1320	0.009	0.2476
THB	-0.005	0.3621	-0.005	0.3662
CAD	-0.009	0.2905	-0.008	0.2503
Constant	-0.0001	0.0001	-0.0001	0.0001
Conditional Variance Equation				
β_0	-	-	0.000	0.6549
β_1	-	-	0.044	0.0190
β_2	-	-	0.944	0.0001
R-squared	0.98	-	0.98	-
Diagnostics:	Test statistics	Prob-values	Test statistics	Prob-values
ARCH(4)	5.196	0.0004	1.094	0.3588
ARCH(8)	2.914	0.0034	0.947	0.4768
ARCH(12)	2.198	0.0107	0.728	0.7245

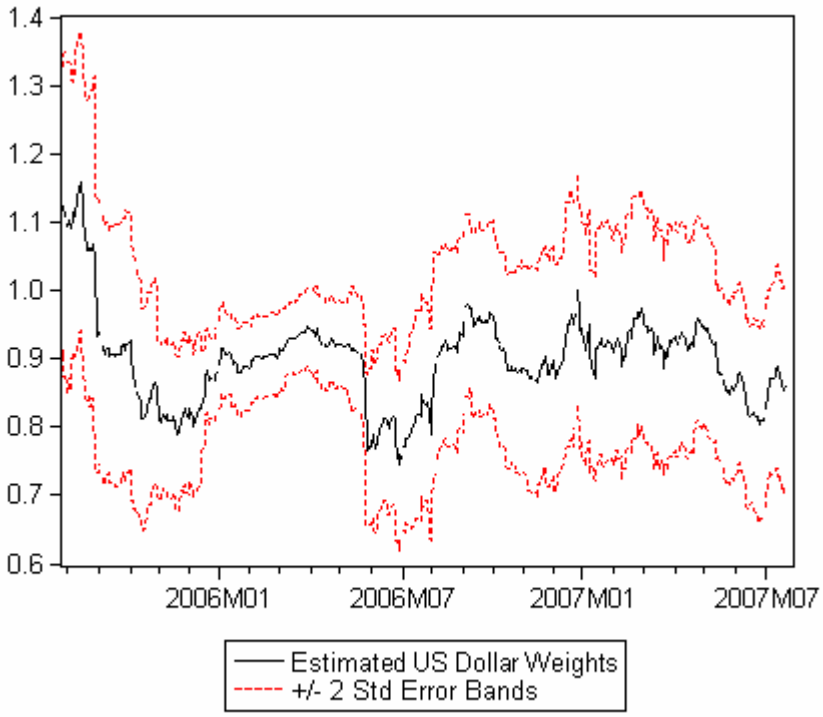
Note: White Heteroscedasticity-robust and Bollerslev-Wooldridge standard errors have been used for the OLS and GARCH(1,1) models, respectively.

The results indicate that the new regime has rather little flexibility. The coefficient for the USD is nearly one and therefore this particular Gordian knot has not yet been disentangled. There is weak evidence of a peg to a basket but the weights of the remaining currencies are very small. Despite claims to the contrary, an analysis following the principle "actions speak louder than words" therefore yields that policy continuity is in place in China. Alternatively one may say that the PBoC still has to walk the talk.[11]

The Frankel and Wei (2007) approach also allows one to trace the development of the *de facto* exchange rate system over time. In order to identify movement away from the USD peg towards a basket peg, we have also calculated the GARCH-in-mean specification as a rolling regression. The estimation results for the USD coefficient are presented in Figure 2.

[11] One reason for the gradual approach is that the institutional constraint that an efficient and market-oriented FX market, which provides the needed foundation for any move towards greater exchange rate flexibility, still does not exist in China. China´s FX market is limited in product scope to mainly spot trading in USD. Interbank forward and swap transactions were finally introduced in successive reform measures in August 2005, but the markets are shallow.

Figure 2: Rolling Regression Results for the Implicit Basket Weight of the USD (Solid Line) and ± 2 Standard Errors (Dashed Lines)



Note: The rolling regressions have been calculated using a bandwidth of 100 observations. The horizontal axis gives the initial span of 100 respective observations. Qualitatively similar results are obtained for other bandwidths.

The overall conclusion once again is that the RMB has remained pegged to the USD, with rather limited currency flexibility.

Although the Frankel and Wei (2007) approach makes intuitive sense, it has some drawbacks. In particular, one must bear in mind that the tests may be biased if the RMB exchange rate follows a nonlinear process. To measure how the previous rigid exchange rate system may be gradually phased out towards a more flexible exchange rate regime, we therefore additionally employ a smooth transition modelling approach to learn more about the smooth evolution of the currency regime over time.

4. Beyond the "Rule-of-Thumb" Framework

An important feature of the previous results is the finding that the Chinese authorities have tried to engineer a gradual shift in the RMB exchange rate.[12] Given this gradual shift, and in order to shed

[12] While China shared many initial conditions with the transition economies of Central-East Europe (CEE) and the Commonwealth of Independent States (CIS), it had a more stable political system compared to many CEE and CIS countries and the communist party of China rules the country as an autocrat without really imposing

further light on the new RMB basket, we now consider univariate time-varying smooth transition autoregression (TV-AR and TV-AR-GARCH) models as a refinement and in the hope of delineating the RMB/USD pattern more accurately.[13] Our working hypothesis is that the *de facto* RMB/USD exchange rate exhibits nonlinear features and that TV-AR models can adequately characterize the smooth nonlinear evolution of the Chinese exchange rate regimes.[14] An important rationale for this family of models is that all the relevant information is embodied in the most recent RMB/USD central parity, so that is becomes unnecessary to include further variables in the set of explanatory variables.

We first present a brief review of the methodological issues. The basic problem facing any econometrician is to determine the fundamental relationship between a dependent variable, $\Delta E_{RMB/USD}$, and a vector of regressors, expressed by X. The question is how best to specify the functional form $f\{\cdot\}$ in equation (3)

$$\Delta E_{RMB/USD} = f\{X_t\} + \varepsilon_t \,, \tag{3}$$

where ε_t is the residual. The methodology used here builds on the existing STAR literature to investigate the gradual Chinese policy approach towards the RMB/USD exchange rate. We obtain a smooth line capturing "shifts" in the RMB/USD relationship and which can be interpreted as the smooth transition trajectory between exchange rate regimes.

The modelling cycle, fully described by Teräsvirta (1994) and Lin and Teräsvirta (1994), comprises three stages. (*i*) We first specifiy and estimate a linear model which is tested against nonlinear alternatives using a battery of tests; (*ii*) if linearity is rejected, we specify and estimate the nonlinear model; and (*iii*) we evaluate the nonlinear model. Consider the return series $\{\Delta E_{\mathrm{RMB/USD},t}\}$, regressors

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itself as such. Unlike most of the CEE and CIS economies, China nevertheless adopted a strategy of gradual economic transformation that maintained the existing system but created new economic activities on top of it. This enabled China to avoid the initial transformation slump observed in CEE and CIS countries, and allowed it to generate high rates of economic growth that have now lasted for almost three decades. Given this experience, the PBoC has stated (see http://www.pbc.gov.cn/english//detail.asp?col=6400&ID=572) it will carry the exchange rate regime reform forward in a gradual manner to ensure sufficient resilience of all parties involved. The underlying worry is the potential for rioting if exporters lose sales and lay off workers, or even if exporters simply hire fewer workers each year at a time when nearly 10 million migrant workers are pouring into Chinese cities each year from rural areas.

[13] It would be straightforward to augment the framework to allow for further exogenous variables as additional regressors.

[14] This contrasts, for example, with the Markov regime-switching model which assumes an abrupt switch between regimes. Aside from potential nonlinearity, considerable research has also focused on structural change and time-varying parameters in time-series models. Structural breaks and parameter variation may occur because of institutional change, an evolving policy environment, or technological innovation. Recently, nonlinear models have been combined with model specifications that facilitate structural change and parameter time variation. For example, Holt and Craig (2006), Lundbergh et al. (2003), Skalin and Teräsvirta (2002), and van Dijk et al. (2003) combine the TV-AR model of Lin and Teräsvirta (1994) with smoothly time-varying parameters with STAR models to obtain a time-varying STAR (TV-STAR) model which considers the joint presence of nonlinearity and structural instability. Boero and Marrocu (2002) and Cao and Soofi (1999) have shown that nonlinear methods can be successfully employed in exchange rate prediction.

x_{it} = (1, $\Delta E_{\text{RMB/USD},t\text{-}1}$, …., $E_{\text{RMB/USD},t\text{-}1}$)', i = 1,2, and a white noise stochastic shock ε_t. We follow Skalin and Teräsvirta (2002) and Panos et al. (1997) by including the lagged level term $E_{\text{RMB/USD},t\text{-}1}$ as an explanatory variable and thereby allowing for the possibility of an error-correction mechanism (ECM). We expect the estimated coefficient of $E_{\text{RMB/USD},t\text{-}1}$ to be negative, i.e. we assume that the process is mean-reverting. The class of two-regime TV-AR processes is represented as

$$(4) \qquad \Delta E_t = \phi'_1 x_{1t} + \phi'_2 x_{2t} F(t, \gamma, c) + \varepsilon_t ,$$

for some transition function $F(\cdot)$: $\Re^3 \rightarrow [0, 1]$, slope or smoothness parameter $\gamma > 0$, location parameter c, and transition variable time t. The time index t is a short-cut which captures the gradual policy approach of the PBoC and the errors $\varepsilon_t \sim NID(0, \sigma^2)$.

The above specification is quite flexible, in that it embeds other paradigms as limiting cases. If the smoothness parameter γ and/or the vector ϕ_2 are zero, then the process collapses to a linear autoregression. As $\gamma \rightarrow \infty$, the regime switch becomes a single break and therefore the TV-AR becomes a self-exciting threshold autoregression (SETAR) model [Tsay (1989)].[15]

In equation (4) we have been deliberately vague about the precise functional form $F(\cdot)$ which is sufficiently broad to encompass various parameterisations. The transition function has to be twice continuously differentiable in γ and c. Following the vast majority of applied research and to simplify the exposition, we consider the logistic function

$$(5) \qquad F(\cdot) = \frac{1}{1+e^{-\gamma(t-c)}}$$

which allows the exchange rate to change in a possibly gradual and smooth manner. Instead of imposing a certain a priori view on the matter, the TV-AR model permits the data to determine the nature (duration and size) of the nonlinear transition process.

Estimation of a TV-AR model involves, in principle, a straightforward application of nonlinear least squares. When $\varepsilon_t \sim NID(0, \sigma^2)$ is valid, the nonlinear least squares is equivalent to maximum likelihood based on a Gaussian likelihood function. If $\varepsilon_t \sim NID(0, \sigma^2)$ is not valid, then nonlinear least squares can be interpreted as quasi maximum likelihood estimates which are still consistent under suitable regularity conditions. As pointed out by Granger and Teräsvirta (1993) and Teräsvirta (1994, pp. 216-217), whilst the other parameter estimates may converge rapidly, the estimate for γ may do so only very slowly, particular when the true parameter value is large. Therefore, reasonable

[15] van Dijk and Franses (1999) have generalised the STAR model by introducing further transition variables to obtain a multiple regime MRSTAR framework.

starting values for c and γ should be obtained from a two-dimensional grid search over possible c and γ parameters.

We first present results on the estimation of a provisional linear ECM model fitted to $E_{\text{RMB/USD}}$. The linear model takes the form

$$\Delta E_t = c + a_1 \Delta E_{t-1} + ... + a_p \Delta E_{t-p} + bE_{t-1} + \varepsilon_t \,. \tag{6}$$

The Akaike information criterion (AIC) and the Bayesian information criterion (BIC) have been used to determine the appropriate lag length. The best-fitting ECM and several diagnostics are recorded in Table 2 and 3, respectively.[16]

Table 2: Lag Order Selection Criteria

Lag	AIC	BIC
0	-11.35799	-11.34339
1	-11.37530	-11.35340
2	-11.38716	-11.35796
3	-11.38549	-11.34899
4	-11.38218	-11.33838
5	-11.37888	-11.32778

Note: Both information criteria indicate an optimal lag length $p = 2$.

[16] The overwhelming evidence in the empirical literature is that exchange rates are nonstationary. We have not investigated this issue because standard unit root tests are of questionable value when nonlinear TV-AR models are considered. See Skalin and Teräsvirta (2002).

Table 3: ECM Parameter Estimates

Parameters	Estimates	Prob-values
c	-0.007	0.0047
a_1	-0.161	0.0001
a_2	-0.123	0.0026
b	0.003	0.0059
Diagnostics:	Test statistics	Prob-values
LM(4)	0.594	0.6673
LM(8)	0.899	0.5171
LM(12)	0.916	0.5306
ARCH(4)	5.807	0.0001
ARCH(8)	3.174	0.0016
ARCH(12)	2.620	0.0021
JB	51.252	0.0001
BDS(2)	0.014	0.0001
BDS(4)	0.030	0.0001
BDS(6)	0.039	0.0001

Notes: LM(*k*) is the LM test of no remaining autocorrelation in the residuals up to and including lag *k*. RCH(*k*) is the LM test of no autoregressive conditional heteroscedasticity in the residuals up to and including lag *k*. JB is the Jarque-Bera test of normality of the residuals. Finally, BDS(m) is a test for nonlinearity in a series where *m* is the so-called embedding dimension. The sample period is 7/26/2005 – 12/19/2007.

The overall picture that emerges from Table 3 is one of no autocorrelation in the residuals but strong evidence of nonlinearity.[17] Furthermore, the hypotheses of no ARCH effects and normality are soundly rejected. The implication of this evidence is that estimating linear exchange rate models disregarding the presence of nonlinearity may yield misspecified models. As such, the results and conclusions of linear modelling approaches have to be received with reservations.

Based on these preliminary results, we next fit a TV-AR and a TV-AR-GARCH model to the data by using nonlinear least squares.[18] The basic TV-AR model corresponding to the case $k = 1$ in Lin and Teräsvirta (1996, p. 214) takes the form

$$\Delta E_t = \kappa + a\Delta E_{t-1} + bE_{t-1} + (\kappa' + a'\Delta E_{t-1} + b'E_{t-1)}) \cdot F(t,\gamma) + \varepsilon_t \,, \tag{7}$$

where

[17] Note, however, that the nonlinearity tests cannot actually pin down the proper form of nonlinearity.

[18] Our modelling approach implies that we assign a low probability to another discrete "one-off" appreciation. We believe that for the PBoC to make such a move, one of the following two conditions would need to be met. *(i)* Domestic inflation moves out of control; or *(ii)* another discrete jump would produce an international political gain that would be sufficient to make the appreciation worthwhile. Neither condition will ikely be met in 2008. First, there is no basis for sustained inflation in China and the currently high inflation is set to moderate in 2008. Second, it is unrealistic to believe that a meaningful political gain can be achieved prior to the U.S. presidential election in January 2009.

(8) $$F(t,\gamma) = \frac{1}{1+\exp\{-\gamma(t+c)\}} \ .$$

The parameter estimates of the TV-AR model capturing the gradual Chinese policy approach are given in Table 4.[19]

Table 4: TV-AR Estimation Results

Parameters	Estimates	Prob-values
κ	0.210	0.0767
a	-0.280	0.0073
b	-0.100	0.0768
κ'	-0.147	0.2937
a'	0.281	0.0733
b'	0.068	0.3139
γ	0.007	0.0001
c	-464.69	0.0001
Diagnostics	Test statistics	Prob-values
ARCH(4)	6.358	0.0001
ARCH(8)	3.395	0.0008
ARCH(12)	2.573	0.0025

Note: Sample period: 7/26/2005 – 12/19/2007.

The key coefficients γ and c are statistically significant, which itself indicates the presence of nonlinearity. The residual diagnostics, however, indicate some remaining heteroscedasticity. This suggests that the TV-AR model has not identified all of the nonlinearities in the data. Given the apparent ARCH effects, the following TV-AR-GARCH(1,1) model has also been considered:

(9) $$\Delta E_t = \kappa + a\Delta E_{t-1} + bE_{t-1} + (\kappa' + a'\Delta E_{t-1} + b'E_{t-1)}) \cdot F(t,\gamma) + \varepsilon_t \ ,$$

where

(10) $$F(t,\gamma) = \frac{1}{1+\exp\{-\gamma(t+c)\}}$$

and

(11) $$\varepsilon_t \sim N(0,h_t) \ , \ h_t = \beta_0 + \beta_1 e_{t-1}^2 + \beta_2 h_{t-1} \ .$$

The estimation results can be found in Table 5.

Table 5: TV-AR-GARCH(1,1) Estimation Results

Parameters	Estimates	Prob-values
κ	0.206	0.0356
a	-0.286	0.0032
b	-0.098	0.0356
κ'	-0.137	0.2517
a'	0.300	0.0609
b'	0.063	0.2730
γ	0.008	0.0001
c	-464.69	0.0001
Conditional variance equation		
β_0	9.65E-09	0.0085
β_1	0.048	0.0006
β_2	0.940	0.0001
Diagnostics	Test statistics	Prob-values
ARCH(4)	0.254	0.9075
ARCH(8)	0.498	0.8578
ARCH(12)	0.408	0.9606

Note: Sample period: 7/26/2005 – 12/19/2007.

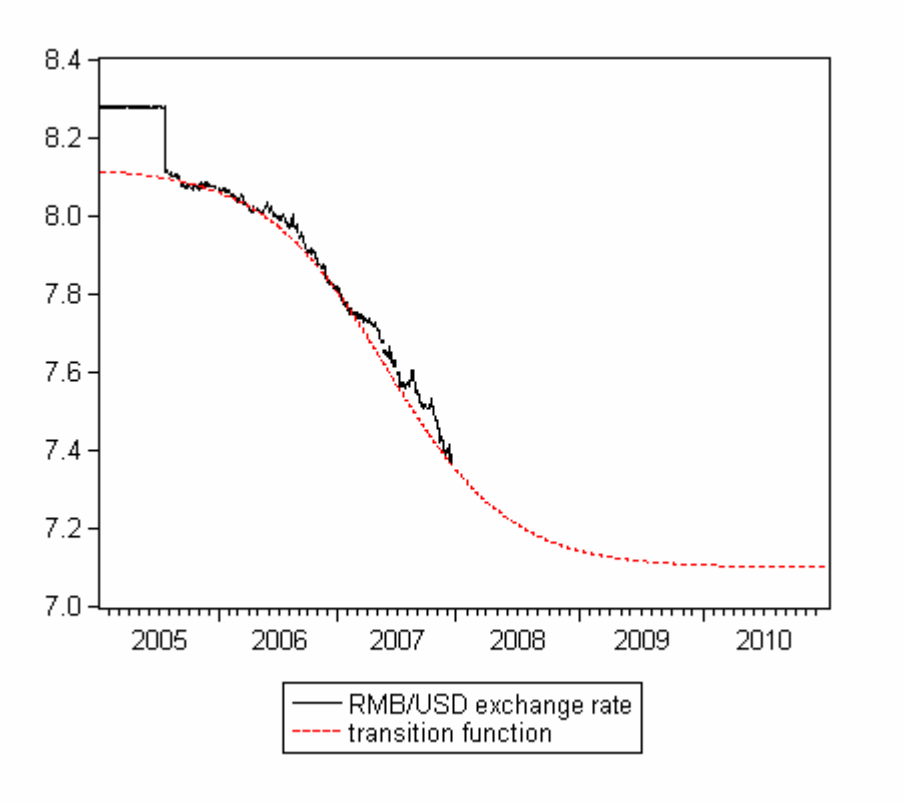
From Table 5 it is clear that the key coefficients are, again, statistically significant. Consistent with the gradual Chinese policy approach, the small size of the point estimate of γ indicates a slow-moving transition from one regime to the other.[20] In all, these results suggest that our intuition of the smooth TV-AR modelling framework is plausible and that the previous evidence for the linear Frankel and Wei (2007) modelling framework may be premature.

Next, we analyse the implied long run (deterministic) equilibrium for the TV-AR model, which is plotted in Figure 3. Visual evidence suggests that the nonlinear "skeleton" corresponds closely with the actual exchange rate dynamics, i.e. the TV-AR model´s ability to adequately characterise the gradual appreciation is clearly visible. Based on these findings and assuming no further breaks in the RMB/USD exchange rate, the deterministic extrapolation indicates that the RMB/USD exchange rate will appreciate smoothly from 8.09 RMB/USD, where it resided immediately after the initial appreciation in July 2005, to 7.10 in autumn 2009.

[19] Initially we have considered the same autoregressive order as in the linear ECM. Estimating corresponding TV-AR and TV-AR-GARCH models, however, does not yield reasonable results. As a consequence, we have dropped ΔE_{t-2}.

[20] When interpreting the γ parameter, one should keep in mind however that the asymptotic distribution of the smoothness parameter is, in any event, nonstandard under the hypothesis $\gamma = 0$. See van Dijk et al. (2002), pp. 19-21.

Figure 3: Actual Daily RMB/USD Exchange Rate and Estimated Logistic Transition Function



In summary we conclude that daily RMB/USD exchange rate since the beginning of 2005 can be modelled as a nonlinear TV_AR or TV-AR_GARCH model.[21]

5. Summary and Some Concluding Thoughts

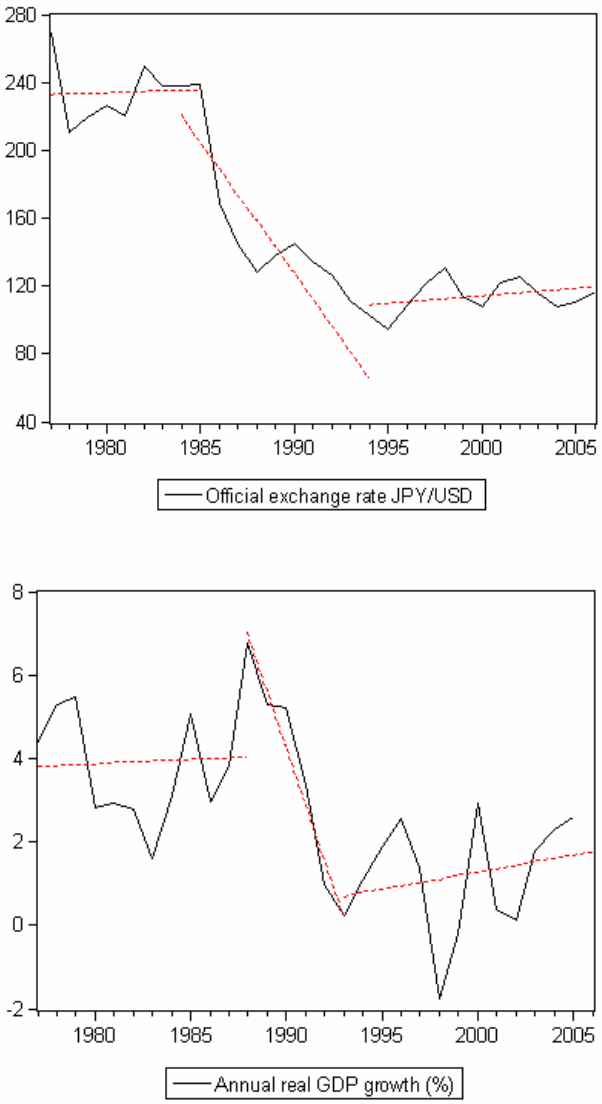
This paper presents some novel empirical evidence on the new renminbi exchange rate regime. Based upon the view that Chinese policy changes rarely ever take place overnight, we have examined the extent to which TV-AR and TV-AR-GARCH models contribute to our understanding of the gradual reform process underlying the new RMB exchange rate regime. There are several reasons to believe a priori that a TV-AR framework might be fruitful. First, previous research has found evidence of nonlinearities in exchange rates. Second, the gradual Chinese policy approach suggests a smooth transition TV-AR model. Third, the TV-AR approach is flexible enough to

[21] One potential problem is that nonlinearities are present but they are captured by the wrong type of nonlinear model. For the sake of completeness, we have also estimated TV-AR and TV-AR-GARCH models assuming that the smooth transition function can be adequately approximated by a polynomial function of t up to order k = 3. See Lin and Teräsvirta [1994, p. 214, eq. (2)]. Again, the estimated transition parameter appears to be significantly different from zero. Furthermore, the graphical information on the nonlinear transition is identical to the k = 1 case. The results are insufficiently different to justify a separate discussion but they are available from the authors upon request.

accommodate future policy changes by assuming a double-transition (three-regime) TV-AR model specification.

This study has brought to the fore the observation that changes in Chinese policy usually take place through a series of smaller steps.[22] The much-talked-about threat underlying this policy approach is the fear that a sharp appreciation of the RMB could seriously hurt Chinese GDP growth.

Figure 4: Japan´s Exchange Rate and GDP Growth, 1975 – 2005



[22] He Fan of the Chinese Academy of Social Sciences published recently an article in „China Daily“ (2007-08-07; see http://www.chinadaily.com.cn/opinion/2007-08/07/content_5448940.htm) suggesting that China might sell (one day) some of its USD treasuries. He believes that the RMB should be allowed to appreciate, but he also clearly indicates that the U.S. should not try to dictate the pace of RMB appreciation, particularly given that the RMB/USB exchange rate is a key price in China's economy. He Fan's writings also leave no doubt that he understands the financial risks that China is taking by holding so many dollar-denominated assets.

In many ways China today looks similar to Japan in the 1980s. Like Japan, China has high saving and investment shares, an export-led growth process, big current account surplus, and upward pressure upon its exchange rate. After the Plaza accord in the mid 1980s, the JPY appreciated by about 80 percent against the USD in a few years. Chinese policymakers have concluded that the blame for Japan´s "lost decade" lay largely with the appreciation of the JYP.[23] China has therefore only allowed the RMB to rise only gradually.

Amidst all the discussion about the RMB, one final thought is that the Chinese are bucking the recent trend to "move to the corners" when determining what type of exchange rate regime to run. Much recent economic literature has suggested that running intermediate exchange rate regimes, i.e. managed floats, basket pegs, crawling bands and the like, are too difficult to run for a country with open capital markets. Speculative pressures will sooner or later challenge the credibility of intermediate regimes and countries will thus be forced to move to the corners and adopt either full floats or hard pegs such as currency boards or dollarisation. Without doubt, the new exchange rate regime depends in large measure on China's ability to maintain capital controls – in the absence of deep, liquid foreign exchange markets, traders and investors cannot bring market forces to bear against Chinese monetary policy. In other words, once China can no longer maintain effective capital controls, a flexible exchange rate regime will become more likely.

[23] It is, however, questionable whether Japan´s real mistake was the sharp appreciation of the JYP. An alternative perception is that the intrinsic mistake was the loose monetary policy trying to offset the impact of the rising JYP. This inflated the bubble and then prevented the central bank to ease monetary policy once the bubble had burst.

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