

**A State Detection Mechanism, Productivity Bias and a Medium
Open Economy Real Business Cycle Model for Thailand
(1993-2005 Data)**

by

Piyapathu Ruchirat

in fulfilment for a Degree of Doctor in Philosophy,

Economics Section, Cardiff Business School, Cardiff University, September 2005.

UMI Number: U583983

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



UMI U583983

Published by ProQuest LLC 2013. Copyright in the Dissertation held by the Author.
Microform Edition © ProQuest LLC.

All rights reserved. This work is protected against
unauthorized copying under Title 17, United States Code.



ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346

Acknowledgment

This thesis is completed with the supervision by Professor Patrick Minford, Professor Laurence Copeland, and Professor James Davidson, and refereed by Professor Ronald MacDonald and Professor Kent Matthews. It has generous assistance from Prakriti Sofat, David Meenagh, Bruce Webb, and Eric Nowell of Liverpool University, Ruthira Naraidoo, and Mutita Akusuwan of Cambridge University. Special data assistance came from the Research Manager and Staff at Seamico Knight Fund Management Securities in Bangkok. Special thanks to Petpathu Ruktanonchai, Chatchalee Ruktanonchai, Dr. Pairoj and Mrs. Piyaon Ruktanonchai.

A lot of gratitude also goes to my dad Pichet Ruchirat, my friends and mentors Duha-Alkuwari, Somprasong Kosonboon and Lapinee Dhasanapongsakul, Sompong Pornupatham, David Agyeman, Hannah Croft, Ngoni Makotore, Juntip Bunprakaikaew, Suchada Maktara, Salinee Srivardhana, Sompong Putivisutisak, Peeranat Thongyotee, Farsaeng Chankasemporn, and my pastors Chris and Annie Cartwright, Steve and Helen Ball, Steve and Myra Harris, and finally Pastor Chaluy and Khun Raerai Ruangchan. The author is grateful for the contribution of the Economics Section and the Economic Friday Seminar participants. Special mention goes to the excellent Cardiff University Library and Computing and Support Staff of Cardiff Business School, especially Phil Webber, Louis Vallis, and Wayne Findlay.

Abstract

The first section is a study on the Thai Baht using an advanced regime-identification tool by Hamilton (1989) on the 1998-2005 monthly data, nesting the special case of a monetary model with emphasis on the real interest rate differential. Three scenarios post-crisis for the Thai Baht were identified by the nonlinear detection mechanism where the unobservable states are assumed to follow the Markov chain of events where past history does not matter. The states identified are described as panic, calm, and favourable markets for the currency. Furthermore, using the Markov-switching software developed by Krolzig (1998), it is possible to provide weak evidence that the nominal exchange rate moved to restore equilibrium in the fundamentals but not vice versa. The second section tested the productivity bias for the Thai quarterly data from 1993-2005, using Johansen cointegration method and found no evidence. The final section has the whole of the Thai economy specified and exogenous shocks sent to see the effects on the real exchange rate. In particular, a surge in productivity in the fully-specified economy causes the real exchange rate to appreciate, confirming the evidence for the productivity bias for the Thai Baht.

Key Words and Phrases: monetary approach, exchange rate determination, real interest rate differential model, markov-switching, real exchange rate, productivity bias, Balassa-Samuelson hypothesis, simulation, open economy, Real Business Cycle, rolling forecasts, Thailand, Baht.

AMS 1991 Subject Classifications. Primary: F4; Secondary: F43.

Contents

1	Introduction	13
1.1	Technical Summary	19
1.2	Pre-Crisis: the real sector did not seem to misbehave	23
1.3	The starting block: monetary factors drive the nominal exchange rate	26
1.3.1	History of monetary models and earlier models of the balance of pay- ments and exchange rate determination	28
2	Part I: What <i>just</i> happened to the Thai Baht?	34
2.1	Theoretical Groundwork	35
2.1.1	Purchasing Power Parity	35
2.2	Nominal Exchange Rate Models	41
2.2.1	The basic monetary model under fixed exchange rates	41
2.2.2	The basic monetary model under flexible exchange rates	44
2.3	Tests of the monetary models on Thai Data	53
2.3.1	The Real Interest Differential model: test on floating Baht against US Dollar	55
2.4	The Data	59
2.4.1	The Panel Unit Root Test	64
2.4.2	Extending the RID to include the Regime-Switching Feature	76
2.5	Part I: conclusion	129
2.6	Part I: Policy Implication and marker for further research	132

3	<i>Part II: On the Real Exchange Rate Determination</i>	133
3.1	The Productivity Bias Hypothesis	133
3.1.1	Introduction	133
3.1.2	The Productivity Bias Literature Review	134
3.1.3	Empirical Test on the Productivity Bias Hypothesis	138
3.1.4	The Data	145
3.1.5	Data Construction	147
3.1.6	Demand-side factors and their influence on the real exchange rate . .	171
3.2	Empirical Conclusion	173
3.2.1	Policy implications from <i>Part II</i>	173
3.2.2	A note on evidence of deviations from PPP	175
3.2.3	Persistence	176
3.3	<i>Part II: Conclusion</i>	177
4	<i>Part III: What will happen to the Baht if a real shock is sent to an artificial Thai economy?</i>	179
4.1	A Medium Open Economy Real Business Cycle model	179
4.2	The Lucas Model	179
4.3	The Sofat-Minford-Nowell-Meenagh (SMNM) model	182
4.3.1	The Household Sector	185
4.3.2	The Government Sector	190
4.3.3	The Industrial Sector	192
4.3.4	The Foreign Sector	193

4.3.5	Behavioural Equations	199
4.3.6	Exogenous Processes	204
4.3.7	Steady State Equations	206
4.3.8	The Data	208
4.3.9	Endogenous Variables	212
4.3.10	Exogenous Variables	213
4.3.11	The Algorithm	215
4.3.12	Calibration	215
4.3.13	Simulation	216
4.3.14	Various shocks and the effects on the artificial economy	219
4.4	Part III: Conclusion	232
5	Conclusion to the thesis	233
5.1	Marker for future research	234
6	References	237
7	Appendix 1: List of Symbols	258
7.1	<i>Greek alphabets: Lower Case</i>	258
7.2	<i>Greek alphabets: Upper Case</i>	259
7.3	<i>English alphabets: Lower Case</i>	259
7.4	<i>English alphabets: Upper Case</i>	262
8	Appendix 2: The Frankel Estimation	264

9 Appendix 3: Rolling Forecasts 270

9.1 The concept of a 12-month rolling forecast	270
--	-----

List of Tables

1 Summary of coefficient signs implied by various monetary models	58
2 Panel Unit Root Test between S_{vol} and f	68
3 The Trace Test between the nominal exchange rate and the monetary factors	69
4 The Maximum Eigenvalue test on the nominal exchange rate and the monetary fundamentals	70
5 The normalized cointegrating coefficients for the nominal exchange rate-fundamental long run relationship	70
6 Dependent variables' adjustment coefficients	71
7 The Granger Causality test between each pair of variables in Part I	75
8 Nested Models in the MS-VECM equation	80
9 Panel Unit Root Test between S_{vol} and f	81
10 Panel Unit Root Test between S_{vol} and f	81
11 The Common and Individual Unit Root tests for all variables in Part I	89
12 The Trace test to determine the number of cointegrating equation between s_{vol} and f	90
13 The Maximum Eigenvalue Rank test for the number of cointegrating equations	90
14 The unrestricted cointegrating coefficients for $SVOL$ and F	91
15 Unrestricted adjustment coefficients (α) for $D(SVOL)$ and $D(F)$	91
16 The cointegrating and adjustment coefficients for $SVOL$ and F	92

17	The Dependent Variable, cri, is stationary	95
18	The Layout of the Input File in GiveWin	106
19	Model selection: 2-regime case	111
20	Model selection: 3-regime case	116
21	The number of occurring regime, the probability of that happening and how long it lasts	120
22	MSIAH(3)-VAR(2) Maximum Likelihood estimation results	122
23	The Autoregressive coefficients for Regime 1	123
24	The t-values for Regime 1	124
25	The Autoregressive coefficients for Regime 2	124
26	The t-values for Regime 2	125
27	The Autoregressive coefficients for Regime 3	126
28	The t-values for Regime 3	126
29	MSMH(3)-VECM(2) Contemporaneous Correlation Table	127
30	Regime Classification for the MSMH(3)-VECM(2) model describing post-1997 Thai data	128
31	Thailand's major trading partners (2001 estimate)	143
32	Subsectors of Traded and Nontraded Sectors	148
33	The unrestricted cointegration rank test between the log of real exchange rate and the relative price indices	156
34	The trace test between the log of real exchange rate and the relative price indices	160

35	The max eigenvalue test between the log of real exchange rate and the relative price indices	160
36	Evidence of nonstationarity in the relative trade-nontrade price series	161
37	The real Baht-Dollar exchange rate is stationary	162
38	No cointegration between the log of real Baht-Dollar and the relative trade-nontrade prices	164
39	The trace test for long run relationship between the real exchange rate and the relative sectoral productivity	167
40	The trace test for the Productivity Bias following Bahmani-Oskooee and Rhee (1996) and Chinn (2000)	170
41	The maximum eigenvalue test for the Productivity Bias following Bahmani-Oskooee and Rhee (1996) and Chinn (2000)	171
42	The size of Thai and US bond markets	199
43	Thailand's minimum wage	208
44	Thailand's Policy Parameters and their calibrated values	217
45	ADF Test for the Historical Thai RER	218
46	Base differences from a productivity surge impact on all of the variables in the RBC model	231
47	Coefficients and Standard Errors from RID Estimation Results	265
48	The Breusch-Godfrey Serial Correlation LM Test	266

List of Figures

1	All the data series for the real interest rate differential model	60
---	---	----

2	The RID series plotted on the same diagram	61
3	The long-run relationship between the RID variables	73
4	The residuals from the cointegrating relation for each variable	74
5	The scattered and time series plots of the nominal exchange rate and the monetary fundamentals	87
6	The exogenously-determined (by the Markov chain) variable, cri, representing the crisis in the markov switching model	93
7	The first difference of the nominal exchange rate as a component of the de- pendent variable in the Markov-switching model	105
8	The best performance in detecting a two-regime market has a switch in both the mean and the heteroskedasticity	112
9	The mean, fitted, and 1-step prediction for the MSMH model	113
10	The best performing model for the three-state market is the fully specified MSIAH model	117
11	The first dependent variable DSvol in the multivariate Markov-switching, error- correcting model	118
12	The second multivariate dependent variable Df, in the Markov-switching, error-correcting model	119
13	The errors and residuals of the dependent variables DSvol and Df from the MSIAH(3)-VECM(2) model	130
14	Thailand's export destination by share of GDP	142
15	Thailand's import destination by share of GDP	143
16	Thailand's composition of GDP (all sectors as % of GDP)	148

17	The US composition of the GDP (all sectors as % of GDP)	149
18	Thai traded sector weight in GDP	150
19	The US traded sector weight in GDP	151
20	Thailand's nontraded sector weight in GDP	152
21	The US nontraded sector weight in GDP	153
22	Thai CPI and Thai CPI excluding raw food and energy	154
23	The Log of real exchange rate and the relative prices	155
24	The Thai real exchange rate	157
25	The Thai nominal exchange rate	157
26	The Thai real exchange rate based only on the traded goods sector (in logs)	161
27	Thai Real Exchange Rate and Sectoral Traded-nontraded Price Differential .	163
28	The Thai real exchange rate and relative sectoral traded-nontraded productivity	166
29	The Thai Overall and Sectoral Productivity	169
30	Differences from the base values of investment in the artificial Thai economy following a surge in productivity	220
31	Differences from base values of capital stock in the artificial Thai economy after a surge in productivity	221
32	Differences from base values of the Thai real wage following the productivity surge	222
33	Differences from base values of the Thai labour supply following a surge in the productivity	223
34	Differences from base values for the price levels in the artificial Thai economy following a productivity surge	224

35	Differences from the base values of the real interest rate following a productivity surge in the artificial Thai economy.	225
36	Differences from base values of the nominal and real exchange rates following a productivity surge	226
37	Differences from the base values of consumption in the artificial Thai economy following a productivity surge	227
38	Differences from base values of the exports and imports in the artificial Thai economy following a surge in productivity	228
39	OLS regression on Thai floating data	266
40	The Fair Set of instrumental variables provides the best first estimates for the RID theory on the Thai data	269

1 Introduction

In 1997 the Thai Baht fell sharply in the Asian Crisis. Much research has been done on the reasons for the crisis in general and for Thailand in particular. Takatoshi Ito (1998) has documented the unfolding of the Thai crisis. Earlier work on the currency crisis was in the response of the Mexican crisis of 1973-1982 and Argentina of 1978-1981 where the crises were preceded by the overly expansive policies. This 'first-generation' of crisis models show how a fixed exchange rate policy, combined with excessively expansionary pre-crisis fundamentals push the economy into crisis, with the private sector trying to profit from dismantling the inconsistent policies (Flood and Marion, 1998). Initiated by Maurice Obstfeld (Obstfeld, 1994), the second set of the crises models, known as the 'second-generation' crisis models are designed to capture features of the speculative attack in Europe and Mexico in the 1990s. In this case, central banks may decide to abandon the defense of an exchange rate peg when the cost of doing so—in terms of unemployment and domestic recession—become too large. This change of perspective implied that crises may be driven by self-fulfilling expectations, since the cost of defending an exchange peg may depend on the anticipation that the peg will be maintained. This second set of models differ from the first in two ways. Firstly, in the countries facing speculative attacks, the state of the business cycle and the banking system as well as borrowing constraints imposed by monetary policies in partner countries prevented authorities from using traditional methods to support exchange-rate parities. Secondly, the speculative attacks suffered by some European currencies in the early 1990s seemed unrelated to the economic fundamentals predicted by the first generation models. Even more recently attempts were made to create the third generation of crisis

models to explain the recent Mexican and Asian currency crises. The second generation emphasis on unemployment and recession did not explain the Mexican 1994 and the Asian crisis of 1997. What caused the last two crises were not due to fiscal imbalances nor weaknesses in the real sector, but financial vulnerability, as formally modelled by Kaminsky and Reinhart (1999). Daron Acemoglu, Simon Johnson, James Robinson, and Yungyong Thaicharoen (2003) argue that macroeconomic policies in developing countries are often the manifestation of deeper institutions and interest groups. R. Gelos and S. Wei, (2002) find that investors respond negatively to corruption. J. Du and S. Wei (2004), find that countries with more insider trading have more variable stock markets. All of these problems seem to have contributed to the Thai economic and social downfall even before 1997, when the accumulated problems amounted to the diminishing confidence in the Thai economy as a whole, its financial sector and the domestic currency, resulting in both a run in the banking system and a run on the domestic currency.

In this thesis, I step back from the analysis of the crisis itself and attempt to model the behaviour of the Thai Baht using a variety of different approaches. It is my hope that from these we may obtain some insights into the factors affecting the Baht and hence, by implication, into the possible causes of the crisis. The first model I use is the monetary approach and consider a number of its variants. In particular, I consider a version of a monetary model with Markov switching. In this context I use an identification tool due to James Hamilton (1989). Although theory predicts a systematic relationship between monetary policy and the exchange rate, the empirical evidence is weak. Eichenbaum and Evans (1995) find a typical delay of three years in the maximum response of bilateral US Dollar exchange rates to US interest rate shocks, a phenomenon since known as delayed

overshooting. Chen and Rogoff (2003) document a weak effect of interest rate differentials on exchange rates, even after controlling for commodity prices, while Grilli and Roubini (1996) find that contractionary monetary policy in non-US G7 countries induces exchange rate depreciation rather than appreciation. These findings are not only at odds with standard models of the exchange rate, but also challenge theoretical results that assume a link between monetary policy and the exchange rate. In this thesis I set out to investigate if this is the case for Thailand since 1993, when modern economic data became available.

The difficulty in tying the floating exchange rate with monetary fundamentals, such as money supplies and interest rates, has long been a puzzle in international macroeconomics. Meese and Rogoff (1983) first established that, although theories state that the exchange rate is determined by such fundamental variables as money supplies, outputs, and interest rates, floating exchange rates between countries with roughly similar inflation rates are in fact well approximated as random walks. According to this seminal finding, fundamental variables do not help predict future changes in exchange rate. Meese and Rogoff evaluated the out-of-sample fit of several models of exchange rates, using data from the 1970s and found that by such measures of forecast accuracy as the mean-squared deviation between predicted and actual exchange rates, accuracy generally increased when one simply forecast the exchange rate to remain unchanged compared to when one used the predictions from the exchange rate models. On occasion, at longer horizons and over different time periods, various versions of fundamental-based models have not found success in maintaining their robustness. Cheung, Chinn, and Pascual (2002) conclude that:

Remark 1 *“The results do not point to any given model/specification combination as being*

very successful. On the other hand..., it may be that one model will do well for one exchange rate, and not for another."

The Meese and Rogoff result (that exchange rate rates are dominated by the random walk) does not imply that they are not explained by fundamentals because there is now so much evidence that the fundamentals (money supply differentials, interest rate differentials, productivity differentials, etc.) themselves follow unit root processes. Hence there is no inconsistency. The predictions from such fundamentals models will follow random walks also and to test them requires checking on the correlations between their innovations.

Evidence for the relationship between monetary policy and the exchange rate, however, is emerging, with the development of better econometric tool over time. Engel and West (2005) show analytically that in a rational expectations present value model, an asset price manifests near random walk behavior if fundamentals are $I(1)$ and the factor for discounting future fundamentals is near one. Their result helps explain the well known puzzle that fundamental variables such as relative money supplies, outputs, inflation and interest rates provide little help in predicting changes in floating exchange rates. Additionally, Engel and West (2005) show that the data do exhibit a related link, suggested by standard models, that the exchange rate helps predict these fundamentals. The implication from this new evidence is that exchange rates and fundamentals are linked in a way that is broadly consistent with asset pricing models of the exchange rate. In this thesis the focus is on the medium-long term. At higher frequency and on a short-medium term, Michael Ehrmann and Marcel Fratzcher (Ehrmann and Fratzscher, 2005) of the European Central Bank recently published the superiority of the real-time macro news data on the USD/DM and USD/Euro during

1993-2003. Their detailed results show that news about fundamentals can explain relatively well the direction, but only to a much smaller extent the magnitude of exchange rate developments taking a medium term, i.e. monthly horizon. Ehrmann and Fratzscher (2005) show that the exchange rate model using real-time data outperforms the same exchange rate model using what they called ‘vintage’ data: the former correctly explains 73% of the directional changes of the exchange rate, whereas the latter only accounts for 60% of the directional changes. This suggests that we can improve our understanding of movements in exchange rates at the short- to medium-term horizon by focusing on real-time data. Second, we find that news about the US economy have a larger impact on exchange rates than news emanating from the euro area. Ehrmann and Fratzscher show that this may reflect not only the relatively greater importance of the US economy, but is at least partly explained by the fact that US announcements are usually released earlier than comparable euro area or German announcements, which gives US announcements a relatively higher news content. Their third finding is of particular relevance to this thesis: that the effects of news on exchange rates are asymmetric in that *they crucially depend on market conditions*. More precisely, news releases have a particularly large effect on exchange rates when there is a high degree of market uncertainty, in the sense that previous news did not provide a clear signal about the direction of the economy (which warrants our assumption that historical data does not matter in the case of the nominal exchange rates). In addition, exchange rates tend to react more strongly to news in periods when previous exchange rate volatility has been high. I find the evidence to this in *Part I*. A more traditional estimation to seven quarterly Asian exchange rates by Menzie Chinn (1999) found evidence for such a traditional sticky price model in the tradition of Jacob Frankel (1979) for Thailand, the only evidence amongst all 7

Asian currencies. My results in *Part I* support Chinn (1999) that – once again in the case of Thailand – models that assume PPP for the broad price indices can find success.

As Chinn (1999) reported, most investigations of nominal exchange rate determination, including that in *Part I*, rely upon purchasing power parity holding in the long run. In other words, that the long run real exchange rate is constant. Because this assumption is violated in the region empirically (Isard and Symansky (1997) and Chinn (2000)), it is necessary to allow the long run real exchange rate to vary over time. Chinn (1999) modified a monetary model by letting the aggregate price index be given as a weighted average of log price indices of traded and nontraded goods. This is the Balassa-Samuelson model of the real exchange rate, which is determined by relative productivity growth in the traded and non-traded sector (the productivity bias hypothesis). Such tests are performed in *Part II*, where I find evidence that this ‘bias’ affects the Baht.

In the third model, I take a complete Real Business Cycle (RBC) model of Thailand, and calibrate it for the Thai economy in order to see whether in such a full model productivity can account for the movements of the Baht. What I find is that this is the case: productivity growth has an effect on the cyclical movements of the exchange rate while lowering the real rate in the long run.

What I have found, therefore, from these three approaches to the Baht is that money and productivity both can be regarded as affecting the currency. This conclusion emerges from separate models, each stressing either money or productivity. Further work is needed in order to establish the relative importance of these two mechanisms, building on what I hope is the helpful analysis presented here.

1.1 Technical Summary

This thesis provides a state identification tool which allows policymakers to see what scenario (high/medium/low risk) that a variable of interest could find itself in, given a set of known variables and unknown influences. It also provides in the general application a link between the two sets of variables and show how one set move to restore another in an equilibrium. In the context of economics, the tool allows the dynamics of the nominal exchange rates and monetary fundamentals to be explained. Using this tool, the nonstationarity of the nominal exchange rate is established across time, providing the explanation as to why in an exchange rate market there can be a flip of equilibrium from one to another without the visible explanatory variables having necessarily changed.

The motivation of this thesis is in threefold. Firstly the thesis is to reintroduce to the reader the idea that monetary factors are the driving force behind the nominal exchange rate, particularly in the case of the Thai Baht, against the popular currency of denomination, the US Dollar. Secondly the advancement in the econometric theory as well as in the technical and computing ability means that one is able to revisit a simple theory that can be used to describe the nominal exchange rate movements and finds a strong evidence, having taken into account the nonstationary nature of the data. In particular, the thesis revisits the real interest rate differential (hereafter the RID theory) by Jeffrey Frankel, which was published in 1979. Significant evidence was found for this particular type of what is known loosely as monetary models. The author then uses this evidence to provide for an explanation for what is termed the 'crisis of confidence' in the nominal Baht after the 1997-98 crisis. The first part of the thesis is an opportunity to introduce the reader to a very versatile tool

frequently used in the business cycle analysis to detect a state and date the business cycles, whose characteristic the real Baht-Dollar exchange rate is later shown to exhibit during the last decade of the Thai data in *Part III*. The application to the nominal exchange rate and fundamentals is also of interest since the link between them has not been conclusively established in the literature. The use of the real business cycle workhorse in the third part of the thesis also enables the real exchange rate's cyclical behaviour to be explained without the need to resort to nominal rigidities.

The second motivation of the thesis is that it is inadequate to look at the nominal exchange rate model on its own, as numbers without real values are not very useful. The real value of a domestic money should decline as more goods are being produced, other things being equal, as more goods are being sold at the same world price (the assumption of a medium sized economy reflects the fact that Thailand does not affect the world price of each good it produces). However, this explanation is inadequate, as each country's total output comprises of different sectors and those that are traded between countries will affect the price of the domestic money used as a medium of the exchange of goods more than those that are not. As the relative sectoral productivity—where traded sector is relatively large—rises, the real exchange rate ought to appreciate, according to what is called the productivity bias hypothesis initiated by Harrod. Thailand has a relatively large traded sector (60%) and thus the real rate ought to reflect this. However, it was the US Dollar which dominated the headlines, continuously appreciating in the past decade, particularly in the second half of the 1990s, where the US productivity surge coincided with its climb against other major currencies in the world. This thesis investigates the second part of the productivity bias

hypothesis in the second part of the thesis³. In particular, *Part II* looks at the long run relationship between the real Baht-Dollar exchange rate and the relative sectoral productivity, and the relationship between the real rate and the relative sectoral prices.

The third part of the thesis has the whole of the Thai economy specified, albeit on the assumption that money and the government spending does not matter. It will be shown in *Part III* that, even without specifying the wage and price rigidity, it is possible to see from the baseline simulation results that the simulated values of the real exchange rate exhibit a cyclical pattern.

This thesis is divided into three parts. The first one focuses on the monetary explanation of the nominal exchange rate and the second and third based on the real side. The first part of the thesis attempts to explain what happened ex-post to the nominal Thai Baht. The first study is the finding of evidence for the monetary model where the real interest rate differential matters. When such evidence is found, an investigation turns into a state detection tool based on the assumption that the nominal exchange rate is driven by monetary factors. The second part of the thesis tests the productivity bias hypothesis (also known as the Harrod-Balassa-Samuelson hypothesis) for Thailand. *Part II* uses the updated panel cointegration method to detect the evidence of the productivity bias and is unable to provide a clear evidence whether the relative sectoral productivity gap is strengthening the real Baht-Dollar rate. *Part III* specifies the whole of the economy and sees the effects of various shocks that affect it, in particular the impact of the productivity surge on the real exchange rate. Hence in *Part III*, with the fully specified economy, a supply side shock in the form of technology or productivity shock is applied and the evidence for the productivity bias

³The first part of the hypothesis assumes that the purchasing power parity holds.

is found. The underlying intuition for the use of a technique usually associated with the business cycle literature in *Part I* is that, once the link between a nominal exchange rate and monetary factors was established, the nominal exchange rate data—which also exhibit cyclical movements—in the form of Baht per USD generated by the non-linear technique is shown to behave as expected (ie. to be in crisis, high volatility, or calm period as they did in the data), during the post-crisis timescale up to and inclusive of April 2005.

As the nominal exchange rate is assumed to be explained by the monetary model called the Real Interest Rate Differential model in *Part I*, the thesis begins why such explanation should be given to the nominal rate and the history of the monetary model is given. This will help readers in understanding how monetary factors and the theory of the nominal exchange rate are linked. The important assumption of the Purchasing Power Parity, which is assumed throughout the thesis, is explained and the nominal exchange rate models described. Then the empirical test on the Real Interest Rate Differential model is performed on the Thai data. When the evidence has been established, the RID model is nested within the nonlinear state detection mechanism called the Markov-switching model, based on the Markov chain of events. The results are then analysed and reported. Then we start the second part of thesis, looking at the real exchange rate and how it historically is related to the relative sectoral productivity differential within and between the Thai and the US economy. In the third part of the thesis, the whole structure of the Thai economy is explained in the context of the representative agent model with rational expectations. Then an experiment is performed on the artificial economy and the results from the baseline simulations are reported in terms of their differences from the base values.

1.2 Pre-Crisis: the real sector did not seem to misbehave

In Thailand, overall consumer and producer price inflation (hereafter CPI and PPI) was moderate in the aftermath of the devaluation. The Thai CPI rose roughly 11% between June 1997 and June 1998 and only rose a further 1% by March 2000. Despite the fact that there was such a moderate rise in inflation, such rise was much less than the rate of depreciation in the respective exchange rate. For Thailand, tradable goods prices rose substantially, with the rate of increase being similar in magnitude to the rate of depreciation of the won and the Baht (Burnside et al., 2000). On fiscal deficits and debts, Thailand had been running fiscal surpluses and had fairly modest debt to GDP ratios. The overall fiscal position of the Thai government—inclusive of interest payments—was positive, with a surplus of around 3% of GDP in 1994-5 and 0.7% of GDP in 1996. The amount of government debt held by domestic residents was very small prior to 1997. The public sector external debt is roughly 10% of the GDP prior to 1997. Since the crisis, Thailand ran fiscal deficits and accumulated substantial amount of new debt (some of which was the \$12 Billion loan⁴ from the International Monetary Fund (IMF)). By the end of 1998, the Thai government's domestic debt had jumped to almost 10% of GDP, while external public sector debt rose to almost 25% of GDP. So it is generally acknowledged that traditional measures of government deficits or debt gave no indication of the currency crises to occur in Thailand, and that the Thai government debt situation worsened after the crisis. Various models of speculative attacks have been deployed with limited success mainly due to each country's unique socio-political set up. The objective of this thesis is to deploy a tool that is shown here to

⁴This was fully repaid in 2003, a year ahead of the IMF schedule.

approximate the various states that a researcher's defined variable behaves within a region and different scenario. First the researcher selects a variable of concern (currency crises in this case, but it could be anything such as terrorist attacks, as Enders (2004) and Enders and Sandler (2004) illustrate), compute that from a set of critical variables (the ones he/she thinks cause the dependent variable to move along the time scale), feed the columns of the explanatory variable alongside the explained variable (only two columns of data to go in the computation), select the number of possible scenario (3 being the most sophisticated at the time of writing), press the button and if the climbing technique finds a solution, the probability of each of the 3 events happening is displayed, along with how long it is computed (expected by the computer software) to last. In the Thai Baht case the results shown explain the chronological events well. This technique, however, does not forecast well but explains the past well, so it is a better tool for reviewing what just happened in a very short computing time (seconds), more reliably than to be a technique to plan a future policy/strategy, something that is better achieved using a whole economy setup, which is done [by specification and simulation] in the second half. The second technique takes a longer computing time (a few minutes) but give a laboratory (controlled experiment) answer to the question: what happens to the economy if productivity/real world interest/etc. suddenly shoots up. For both experiments the number of observations until the time of print were still relatively small, especially when compared to the real time data used in finance. Nonetheless it gives a rough picture as supposed to a refined one which may not be what policymakers are looking for when they are asking questions. Due to a deeply specified model, the second technique is only applicable to a small number of countries, Thailand and the UK being two of them.

My assumptions in the thesis

The essence of this thesis is that the nominal exchange rate can be sufficiently explained in terms of monetary factors. The current account is not included as an explanatory variable for the nominal exchange rate crisis (our variable of interest which is defined according to the assumptions in Frankel's 1979 real interest rate differential model) as this less frequent series cannot be approximated from existing variables due to variable conditions in savings and investment⁵. It is also assumed that the Purchasing Power Parity holds for the two models that were investigated. Later in the second half of the thesis, the Thai economy is approximated by a medium-sized open economy real business cycle model⁶. The Thai artificial economy responds to various shocks set up under controlled experiments using post-crisis Thai data from various reputable sources. One of such experiment is to send a productivity shock large enough to affect the relatively volatile data and see how it affects the real exchange rate. If real exchange rate responds negatively to the positive productivity shock (or if the real exchange rate appreciates when there is a surge in productivity, as a result of a technological leap for example), the economy is said to exhibit the productivity bias. This experiment is recognised in the macroeconomic profession as testing the Balassa-Samuelson effect and there is indeed such evidence in the post-crisis Thai data.

⁵Both of which were later considered in our artificial medium sized open economy business cycle model for Thailand.

⁶The development and improvement of which has been undertaken between the Julian Hodge Institute of Applied Economics at Cardiff University and the Liverpool Research Group at the University of Liverpool, United Kingdom.

1.3 The starting block: monetary factors drive the nominal exchange rate

The monetary approach of the exchange rate asserts that changes in the supply of and demand for money are the primary determinants of exchange rate movements. The basic idea of the monetary model is that since the exchange rate is the relative price of two national monies (currencies), it is useful to view the exchange rate as determined by the relative demands and relative supplies of these monies (or currencies).

Although regarded as an incomplete theory of exchange rate determination because of its ignorance of other important explanatory variables, the monetary model nonetheless correctly warns that the pursuit of overly expansionary monetary policies will exert downward pressure on the currency's value, and vice versa. The monetary model of exchange rate determination can be derived from a basic model of the demand for money. If it is assumed that the Purchasing Power Parity (PPP) holds at all times, then the equilibrium exchange rate can be shown to be completely determined by trends in relative money supply growth.

This thesis seeks to return the academic attention to the contribution of the monetary approach to the analysis of balance of payments and the exchange rate determination and update its usefulness not only as a long term description of the exchange rate determination but also in a more up-to-date, forecastable, albeit *ad hoc*, model. It is set out to outline the groundwork being done in the literature, notably contributions by Chicago economists and the work undertaken under the IMF research program. The first section sets out the theoretical groundwork for the basic monetary model for the floating exchange rate and the fixed exchange rate models. It then introduced a contribution by Jacob Frenkel in accounting for the Real Interest Differential (RID) in the exchange rate literature. Later uncovered

interest parity (UIP), Rational Expectations, and the sticky price assumption is introduced. In the mid-1970s, significant understanding was achieved by Rodiger Dornbusch's groundbreaking explanation of the nominal exchange rate 'over/under-shooting' its long-run level immediately after an unanticipated money supply announcements, gradually returning to the long-run value after prices have fully adjusted. I tested the Frenkel RID model's fit on Thailand during the floating period from 2nd July, 1997 to 2nd April 2004, and extended the Frenkel model to include regime-switching, a non-linear technique for capturing the variable in the unobservable state it is thought to be in. The section that followed tested the two ideological lines of argument in the monetary approach to the balance of payments and exchange rate determination and saw what performed better on the Thai data over the fixed exchange rate period (from where data first became available⁷ (1993-1997)). After developing and providing evidence for the monetary approach to the balance of payments, I then moved on to test the Balassa-Samuelson (Balassa, (1964) and Samuelson, (1964)) hypothesis on the Thai data using the recently extended real business cycle model to open economy (Minford et. al. (2005)).

⁷Thailand has been on the fixed exchange rate since 1984, however the country really only opened up to the world economy—especially to short-term capital inflows—since the commencement of the Bangkok International Banking Facilities (BIBF) in 1993.

1.3.1 History of monetary models and earlier models of the balance of payments and exchange rate determination

Conceptually, the earliest models relating the current account to the exchange rate⁸ followed an “*elasticities approach*” in the Marshallian (Marshall, 1923) tradition of treating an exchange rate as a relative price that cleared a market with well-defined flow demand and supply curves. There the standard model—such as those of Machlup (1939) and Harberler (1949)—analyzes the effect of an exchange rate change on the current account in terms of separate markets for home-produced and foreign tradable goods, typically abstracting from the existence of any nontradable goods. Subsequent contributions to the literature sought to integrate the elasticities approach with an analysis of the national income accounts in the Keynesian tradition. These latter contributions emphasized that an exchange rate change could only affect the current account balance if it induced a change in domestic absorption relative to domestic production. This approach has a number of limitations. First, the import demand functions and export supply functions depend only on the nominal prices of the goods in question, rather than on relative prices and appropriate scale variables such as real income and productive capacity. Secondly, the concept of a trade imbalance implies that goods are paid for with an asset that has not been explicitly modelled. Thirdly, changes in the trade balance correspond identically in the national income accounts to changes in the difference between domestic production and domestic absorption, neither of which enters the model explicitly. The resulting equations then provide only a partial equilibrium framework for analyzing the balance-of-payments effects of exchange rate changes. The elasticities approach to devaluation proved unsatisfac-

⁸Contributors include Bickerdike (1920), Marshall (1923), Lerner (1944), Robinson (1947), and Metzler (1949).

tory in the immediate post-war period of full and over-full employment, due to its implicit assumption of the existence of unemployed resources that could be mobilised to produce the additional exports and import substitutes required to satisfy a favourable impact effect.

The response to the dissatisfaction of the elasticities approach as a model of balance of payment and thus exchange rate determination led to S. Alexander's *absorption approach*, which argued that a favourable effect from devaluation alone (in a fully employed economy) depends not on the elasticities but on the inflation resulting from the devaluation in these conditions producing a reduction in aggregate absorption relative to aggregate productive capacity. In this analysis the 'real balance effect,' by which the rise in prices (as a result of the excess demand generated by devaluation) deflates the real value of the domestic money supply and so induces a reduction in spending out of income. This approach was modelled formally in the 1950s by Robinson (1947), Harberger (1950), Meade (1951), and Alexander (1952), among others. Their integrated elasticities approach with the Keynesian focus on national income emphasized that a devaluation of the home currency lowered the relative price of the home good and thereby introducing a shift in demand's composition, which led to an increase in home output (unless the economy was initially producing at full capacity) and a decline in foreign output. This approach recognised that the effects on home output and income would have feedback effects on trade flows, and thus a devaluation that improved the trade balance would do so by less than the amount suggested by a simple elasticities approach in which these feedback effects were ignored (Kenen, 1985, p. 647). What came out of the efforts to reconcile the elasticities and absorption approaches was the recognition that a fully employed economy cannot use devaluation alone as a policy instrument for correcting a balance-of-payments deficit. Instead the country must use a combination of expenditure-

reducing and expenditure-switching policies. This general principle had been known and was developed in James Meade's *The Theory of International Economic Policy: The Balance of Payments*. In *The Balance of Payments* Meade presented a short-run equilibrium analysis of the inadequacies of the two approaches. Additionally, Meade identified the fixing of the interest rate level as a monetary policy tool, a procedure which automatically excludes the monetary consequences of devaluation by assuming them to be absorbed by monetary authorities. Meade's analysis was subsequently rejected and not implemented largely as a result of the inaccessibility of policymakers to his idea of monetary policy tool⁹. Analytically, the main limitation of the integrated elasticities-absorption model is that it is based on a static approach to national income analysis rather than an intertemporal optimization approach.

Early 1970's saw a return to focus of the static elasticities-absorption model. The collapse of the Bretton Woods system brought about exchange rate changes that sparked renewed interest in the time profiles of the responses of traded-good prices and quantities to changes in the exchange rate. The development of the 'J-curve' conveyed the thought that a country's current account balance—measured in home currency units—could be expected initially to fall following a devaluation of the home currency, and only subsequently improve. The underlying premise was that in the short run, import prices in home-currency terms would rise more rapidly than export prices, whereas trade volumes would only respond with a lag. Hume's (Hume, 1752) automatic adjustment mechanism after a shock resulting in balance of payments deficit would lead to an outflow of 'specie' and a reduction in money

⁹The failure of British demand-management policy after the 1967 devaluation was said to be a result of this misunderstanding.

supply, moving the money market into equilibrium. In a Keynesian world of downward price and wage rigidity, this would entail lower output and employment than in the pre-shock equilibrium. For this reason the monetary authorities, in their preference to full employment as a primary goal of public policy, would not passively follow an automatic adjustment process to operate, but rather attempt to neutralize the effects of the balance of payments deficit on the money supply, preventing the shift in the money market and keeping the economy at the pre-shock level.

Robert Mundell recognised the incompleteness of this characterization of what he called ‘the international disequilibrium system’ (Mundell, 1961) with a continuing balance of payment deficit, particularly the unsustainable unbalanced international payments position over the long run. This implied that monetary policy alone would not in general be sufficient to preserve full employment on a sustainable basis.. According to this line of argument, sustainability not only required balance of payments equilibrium along with full employment and, according to the Tinbergen’s made-famous principle (Tinbergen, 1952), the attainment of any given number of independent policy targets generally required at least an equal number of policy instruments. Mundell (1960, 1961) expressed his concern with the theory of the policy mix on the assumption of international capital mobility. His work led to the recognition that the central bank does not control the money supply and employment but domestic credit and the balance of payments. In addition, Fleming (1962) and Mundell (1962, 1963) introduced capital mobility into the theory of economy policy. McKinnon and Oates (1966) and McKinnon (1969) were among the first to show that the Fleming-Mundell (hereafter the Mundell-Fleming model) view of economic policy depend strategically on sterilizing reserve flows. If those flows are allowed to affect the money stock, they erode the influence of

monetary policy even in the absence of capital mobility, and weaken the influence of fiscal policy unless capital mobility is high.

Later Mundell (1969) and others adopted a more general definition of the assignment problem, specifically as the task of establishing rules or guidelines indicating how each particular policy instrument should be adjusted to insure that the dynamic system converged to a position of simultaneous internal and external equilibrium. One of the major inferences from the Mundell-Fleming model (Mundell (1968), Fleming (1962)) was the relative effectiveness of monetary and fiscal policies depended on both the nature of exchange rate arrangements and the degree of capital mobility. The insight of the classic Mundell-Fleming model was that the net excess demand for foreign exchange is just the overall balance of payments (current plus capital account). Under a free float this must be equal to zero and, when combined this equilibrium condition with other equilibrium conditions for the goods (the IS curve) and the money market (the LM curve), the exchange rate—along with other endogenous variables such as real output and interest rate and the comparative static effects of fiscal and monetary policies—can be determined. Such integration of asset markets and capital mobility into open-economy macroeconomics is a major innovation of the Mundell-Fleming model.

Nevertheless, the Mundell-Fleming model contains a major flaw, in that the model is cast almost entirely in flow terms. In particular, the model allows current account imbalances to be offset by flows across the capital account without any requirement of eventual stock equilibrium in the holding of net foreign assets. Back in the 1950s, Polak (1957) and Johnson (1958) had stressed the distinction between the stock and flow equilibria in the open-economy context, which was to become a signature of the monetary approach to the balance

of payments, and subsequently the monetary approach to the exchange rate determination. The basic setup and assumptions of the basic and more sophisticated versions of monetary models are outlined below.

2 *Part I: What just happened to the Thai Baht?*

In *Part I* the concern is to explain what happened to the Baht post-crisis (the crisis date being 2nd July, 1997, our sample begins in May 1998, through to April 2005). Since the nominal rate was devalued, managed and left to float, it is of interest to practitioners and policymakers to have some kind of benchmark to let them know if their asset is in the right currency by providing them with a powerful technique that is simple to use and has results that are quick to analyze at a glance. Knowing the state that our concerned variable is in enables decisions to be made one period in advance (since the result automatically includes a one-step forecast). This could be shifting the assets to another currency or to plan future purchases and/or investment decisions in the country. Seeing the nominal exchange rate in various states normally unobservable also provide the policymakers with caution. As our nominal exchange rate is set up to be driven by monetary factors (policymakers can add their policy parameter but this weakens the power of the test), this test is like a more elaborate version of the Dornbusch model in more dimensions than just over time and magnitude. The nominal exchange rate here (or could be any other variable of concern, but the explanatory set of variables have to be assumed and set up accordingly) is shown to behave like the story it is meant to tell, but perhaps in other cases it may not be at the timing it is meant to be. The regime-switching methodology not only tells us when the variable is said to be in what state (each state is dictated by the variance and as such the states are related to one another and move from one to the other depending on the result parameters), it also tells us how long the nominal exchange rate (or whichever variable is of the researcher's concern) is going to be in each state and when it is coming out of that state into what state as we can

read all of these from one A4-size sheet). Given the story behind each variable, it is now possible to see how it behaves in terms of our policy scenario. This is the first part of the thesis. I am now going to lay out the foundations of my basic explanatory story governing the definition of a nominal exchange rate.

2.1 Theoretical Groundwork

2.1.1 Purchasing Power Parity By basic theoretical construction, the earliest form of theories of exchange rate determination began with what became known as the Purchasing Power Parity (PPP) theory. The intellectual origins of PPP began in the early 1800s, with the writings of John Wheatley and David Ricardo. The fundamental building block of the PPP condition is the law of one price (LOOP). The law of one price views that there should not be arbitrage between goods bought in different countries. In absolute, natural log, terms, it can be written as:

$$s_t = p_{i,t} - p_{i,t}^*, \quad (1)$$

$p_{i,t}$ denotes the log of the price of good i in terms of the domestic currency at time t , $p_{i,t}^*$ is the log of the price of good i in terms of the foreign currency at time t , and s_t is the log of the nominal exchange rate expressed as the domestic price of the foreign currency at time t . According to Equation 1, the absolute version of the LOOP postulates that the same good should have the same price across countries if prices are expressed in terms of the same currency of denomination. The LOOP is argued to hold based on the idea of frictionless arbitrage like no transportation costs and no differential taxes applied between the two markets. These means that there can be no tariffs on imports or other types of

restrictions on trade. Since transport costs and trade restrictions do exist in the real world this would tend to drive prices for similar goods apart. Transport costs should make a good cheaper in the exporting market and more expensive in the importing market. Similarly, an import tariff would drive a wedge between the prices of an identical good in two trading countries' markets, raising it in the import market relative to the export market price. Thus the greater are transportation costs and trade restrictions between countries, the less likely for the costs of market baskets to be equalized. The existence of nontraded goods in the production process also causes the breakdown in the Law of One Price since many items that are homogeneous, nevertheless sell for different prices because they require a non-tradable input in the production process. Similarly, imperfect information also causes the Law of One Price to fail, since it assumes that individuals have good, even perfect, information about the prices of goods in other markets. Only with this knowledge will profit-seekers begin to export goods to the high price market and import goods from the low price market. The assumption of perfect substitutability between goods across different countries is crucial for verifying the LOOP. In its relative version, the LOOP postulates the relatively weaker condition:

$$\Delta s_t = \Delta p_{i,t} - \Delta p_{i,t}^* \quad (2)$$

The absolute LOOP implies the relative LOOP, but not vice versa.

With the predecessors unaware of these possible causes of market failure, the Law of One Price developed into the concept of Purchasing Power Parity where there is supposed to be no arbitrage between money. The idea being that if money (or currency) X is worth more

than money or currency Y (in the sense of currency X buying more goods than currency Y), then the consumer would buy (or choose to hold) money X.

By summing all the traded goods in each country, the absolute version of the Purchasing Power Parity requires:

$$\sum_{i=1}^N \alpha_i P_{i,t} = S_t \sum_{i=1}^N \alpha_i P_{i,t}^*, \quad (3)$$

the weights in the summation satisfy $\sum_{i=1}^N \alpha_i = 1$. If the price indices are constructed using a geometric index, the weighted sum after taking logarithms is:

$$\sum_{i=1}^N \gamma_i p_{i,t} = s_t + \sum_{i=1}^N \gamma_i p_{i,t}^*, \quad (4)$$

where the geometric weights in the summation satisfy $\sum_{i=1}^N \gamma_i = 1$, lower-case letters denote logarithms. The weights α_i or γ_i are based on a national price index (Cassel's formulation of the PPP (Cassel, 1916), used the consumer price index (CPI)). If the national price levels are P_t and P_t^* or in logarithms, p_t and p_t^* , then (according to whether the arithmetic or geometric index is used), Equation 3 or Equation 4 can be used to derive the absolute PPP condition:

$$s_t = p_t - p_t^* \quad (5)$$

From Equation 5, it is easy to see that the real exchange rate, in logarithmic form:

$$q_t \equiv s_t - p_t + p_t^* \quad (6)$$

may be viewed as a measure of the deviation from the PPP. Deriving PPP from the

LOOP has various index number problems. For example equations 3 and 4 implicitly assume that the same weights are relevant in each country, whereas price index weights will typically differ across different countries and will also tend to shift through time. In practice, researchers often assume that PPP should hold approximately using the price indices of each country.

The Purchasing Power Parity relationship is derived from the idea that there should not be any arbitrage between the same good purchased in two different countries. If the good is cheaper in the US, then the consumer should purchase it there. The theorem implies that the real exchange rate gives information about the competitive position of the average firm in a country, and that large deviations from the Absolute Purchasing Power Parity will cause an imbalance between exports and imports of goods and services which will eventually affect relative prices in the two countries and the exchange rate. At the economy level, large deviations from Absolute PPP will cause an imbalance between exports and imports of goods and services. This will eventually affect relative prices in the two countries, and the exchange rate. Absolute PPP may not hold because of the systematic violations of the law of one price mentioned earlier, and the international differences in consumption bundles.

Relative PPP (RPPP) is said to hold when the rate of depreciation of one currency relative to another matches the difference in aggregate price inflation between the two countries concerned. If the nominal exchange rate is defined as the price of one currency in terms of another, then the real exchange rate is the nominal exchange rate adjusted for relative national price level differences:

$$\Delta s_t = \Delta p_t - \Delta p_t^* \quad (7)$$

RPPP tells us about the relation between the exchange rate and the percentage changes in the prices at home and abroad, as opposed to absolute price levels earlier. Relative PPP takes the inflation rates as determined exogenously, say by money supply and the level of economic activity. It also says that the exchange rate between two countries must change to reflect differences in inflation rates between these countries. If Absolute PPP holds, so will Relative PPP, and Relative PPP may hold even if there are persistent deviations in the average absolute price levels across countries. In contrast with the Absolute PPP, the deviation from Relative PPP can always be computed, even in cases where the consumption bundles differ across countries. In this case, it is still possible to compare changes in the prices of these baskets of goods even if one cannot compare different consumption bundles directly. When PPP holds, the real exchange rate is a constant so that movements in the real exchange rate represent deviations from PPP. Thus a discussion of the real exchange rate amounts to the discussion of PPP.

In the PPP equilibrium stories, it is the behavior of profit-seeking importers and exporters that forces the exchange rate to adjust to the PPP level. These activities would be recorded on the current account of a country's balance of payments. Thus, it is reasonable to say that the PPP theory is based on *current* account transactions. This contrasts with the interest rate parity theory in which the behavior of investors seeking the highest rates of return on investments motivates adjustments in the exchange rate. Since investors are trading assets, these transactions would appear on a country's *capital* account of its balance of payments. Thus, without the interest rate parity theory the Purchasing Power Parity on its own incorrectly records transactions on one-current-account and thus would end up registering more activity on the balance of payments in terms of the current account (rather

than separately) as was done in recent years. The interest parity condition can be used to develop a model of exchange rate determination. That is, investor behavior in asset markets (which generates interest parity) can also explain why the exchange rate may rise and fall in response to market changes. However, in the basic monetary model this assumption is not yet required. The theory of interest parity will be discussed later as our analysis of the monetary model develops.

2.2 Nominal Exchange Rate Models

As mentioned previously, the theory of nominal exchange rate determination includes those that place monetary factors as the driving force of the nominal exchange rate movements. Such models of the nominal exchange rate determination are commonly referred to as the ‘monetary’ models and are described in terms of a country’s exchange rate arrangement and under a price assumption (whether prices are fixed or flexible). In Part I of the thesis, the focus will be where prices are allowed to move freely. The flexible price assumption makes the whole computation easier and the dynamic clearer, which also suits our relatively small sample.

2.2.1 The basic monetary model under fixed exchange rates

Derivation of the basic monetary model under the fixed exchange rate system with flexible prices assumption With fixed exchange rates, a country’s inflation cannot deviate from the world rate. The early flexible price monetary model is built upon two main assumptions, one of continuous purchasing power parity (PPP) in the earlier section, and the other is one on assuming the existence of money demand like that of Friedman (1957, 1959) who developed a model for money demand based on the general theory of asset demand. Money demand, like the demand for any other asset, should be a function of wealth and the returns of other assets relative to money. His money demand function, in general form, is as follows:

$$\frac{M^d}{P} = f(Y_p, r_e - r_m, r_b - r_m, \pi^e - r_m) \quad (8)$$

where Y_p = permanent income (the expected long-run average of current and future income),

r_m = the expected return on money,

r_b = the expected return on bonds,

r_e = the expected return on stocks, and

π^e = the expected inflation rate (the expected return on goods, since inflation is the increase in the price (value) of goods).

Money demand is positively related to permanent income. However, since permanent income is a long-run average, it is considered to be more stable than current income, and thus regarded as unlikely to be the source of a lot of fluctuation in money demand.

The other terms in Friedman's money demand function are the expected returns on bonds, stocks and goods relative to the expected return on money. These items are negatively related to money demand: the higher the returns of bonds, equity and goods relative the return on money, the lower the quantity of money demanded. Friedman did not assume the return on money to be zero. The return on money depended on the services provided on bank deposits and the interest on some checkable deposits.

In discrete time, the derivation of the basic monetary model under the fixed exchange rate is as follows. We define the monetary base ($M0$) to be the sum of reserves (R) and domestic credit (D):

$$M0 \equiv R + D; \tag{9}$$

take the discrete change of these terms:

$$\Delta M0 = \Delta R + \Delta D; \quad (10)$$

multiply through by $\frac{M0}{M0}$ and write each term on the right hand side as:

$$\frac{M0}{M0} \Delta M0 = \frac{M0}{M0} * \frac{R}{R} \Delta R + \frac{M0}{M0} * \frac{D}{D} \Delta D; \quad (11)$$

and crossing out the numerator $M0$ for each term, we have:

$$\frac{\Delta M0}{M0} = \frac{R}{M0} * \frac{\Delta R}{R} + \frac{D}{M0} * \frac{\Delta D}{D}. \quad (12)$$

If we denote $\frac{\Delta M0}{M0} = \Delta m0$, $\frac{\Delta R}{R} = \Delta re$, and $\frac{\Delta D}{D} = \Delta d$ and define $\frac{R}{M0}$ as θ (approximately the reserve elasticity of the money demand). As $\frac{D}{M0}$ is approximately the domestic credit elasticity of money demand, it is then equal to $1 - \theta$ since $D \equiv M - R$ and we obtain an approximation of the local log linearization:

$$\Delta m0 \simeq \theta \Delta re + (1 - \theta) \Delta d, \quad (13)$$

which constitutes a basic monetary model under a fixed exchange rate. *In this model the change in the monetary base will result in a change in the domestic credit and the level of foreign exchange reserves of the country.*

2.2.2 The basic monetary model under flexible exchange rates The monetary approach to the exchange rate determination views the exchange rate as moving to equilibrate the international demand for stocks of assets, rather than the demand for flows of goods. When prices are perfectly flexible, changes in the nominal interest rate reflect changes in the expected inflation rate. On the other hand, a friction in a domestic economy is first introduced in price levels, namely that nominal prices are sticky (at least in the short run). We first consider the assumption of flexible prices before introducing a friction in terms of price rigidity into our basic monetary model (what will be referred to as the fixed price case).

Flexible Price Monetary Models Under a regime of flexible (floating) exchange rate, PPP becomes a theory of the exchange rate determination. The monetary model of exchange rate determination consists of two stable money demand functions, continuous stock equilibrium in the money market, uncovered interest parity, and purchasing power parity. It is assumed here that the economy is small and faces an exogenously given foreign price level and [an exogenously given] rate of interest (assume that both are constant for simplicity) and that the economy is at full employment. Under flexible exchange rates, the money stock is exogenous. Central to the monetary approach is the money market equilibrium between the demand and the supply of money:

$$m_t^d - p_t = \phi y_t - \lambda i_t \quad (14)$$

m_t^d is the log of nominal money demand;

p_t price level, so that $m_t^d - p_t$ represents real money demand;

ϕ income elasticity of money demand and $\lambda > 0$;

y_t log of output;

i_t nominal interest rate;

$$m_t^d = m_t = m_t^s; \quad (15)$$

m_t^s represents the log of nominal money supply;

m_t represents equilibrium level of the log of nominal quantity of money.

Equation 14 is a Cagan-style money demand function, and Equation 15 is the condition for money market equilibrium. In discrete time, the arbitrage conditions are, firstly, the Purchasing Power Parity given in Equation 1. In addition, the uncovered interest parity relation:

$$i_t = i_t^* + \Delta s_{t+1}^e; \quad (16)$$

where i_t^* represents the level of nominal interest rate for the foreign country (the US in this case) and Δs_{t+1}^e expected rate of currency depreciation (or appreciation) in the next period is assumed to hold. The last building block of this approach is the Fisher conditions for the home country:

$$i_t = \bar{i} + \Delta p_{t+1}^e \quad (17)$$

Δp_{t+1}^e the expected change in price in the next period, which by definition is the expected inflation rate, π_{t+1}^e .

Similarly, for the foreign country:

$$i_t^* = \bar{i}^* + \Delta p_{t+1}^{e*} \quad (18)$$

Substituting Equations 1 and 15 into Equation 14 and for simplicity the foreign price level p^* is assumed to be zero we obtain:

$$s_t = m_t - \phi y_t + \lambda i_t \quad (19)$$

If we assume that the foreign interest rate in Equation 16 also takes the value of zero, we obtain the relationship:

$$s_t = m_t - \phi y_t + \lambda \Delta s_{t+1}^e \quad (20)$$

Equation 20 states that an x percentage increase in the domestic money supply leads to an x percentage rise (a depreciation) in the domestic currency. Here the assumed homogeneity of money in prices in Equation 14 and the continuous holding of the Purchasing Power Parity (Equation 1) means that the exchange rate is homogeneous of degree 1 in the money supply. An increase in income leads to an exchange rate appreciation by an amount equal to the change in y times the income elasticity ϕ . Without the extra assumptions about the coefficients, the solution for the nominal exchange rate is:

$$s_t = (m_t - m_t^*) - (\phi y_t - \phi^* y_t^*) + (\lambda i_t - \lambda^* i_t^*) \quad (21)$$

Equation 21 is the fundamental equation for the flexible-price monetary model, it is often assumed for simplicity that the income and interest elasticities are the same across countries

($\phi = \phi^*$ and $\lambda = \lambda^*$) so that the fundamental flexible-price monetary model equation becomes:

$$s_t = (m_t - m_t^*) - \phi (y_t - y_t^*) + \lambda (i_t - i_t^*) \quad (22)$$

According to the flexible-price monetary model setup in Equation 22, an increase in the domestic money supply relative to the foreign money stock induces a depreciation of the domestic currency in terms of the foreign currency. A rise in domestic real income, other things being equal, creates excess demand for the domestic money stock. To increase their real money balances, the domestic residents must reduce their expenditure and prices fall until money market equilibrium is reached. Via purchasing power parity, the fall in the domestic prices (with foreign prices staying constant) implies an appreciation of the domestic currency in terms of the foreign currency. As from Equation 19 to Equation 20, invoking the uncovered interest parity yields:

$$s_t = (m_t - m_t^*) - \phi (y_t - y_t^*) + \lambda (\Delta s_{t+1}^e) \quad (23)$$

With Rational Expectations (RE), agents are assumed to form their expectations about the expected future spot rate. With RE, agents form their expectations about the next period ($t + 1$) based on the information set available at time t .

Reparameterize Equation 23:

$$s_t = (1 + \lambda)^{-1} (m_t - m_t^*) - \phi (1 + \lambda)^{-1} (y_t - y_t^*) + \lambda (1 + \lambda)^{-1} (\Delta s_{t+1}^e) \quad (24)$$

and iterating forward to get the rational expectations solution:

$$s_t = (1 + \lambda)^{-1} \sum_{i=0}^{\infty} \left(\frac{\lambda}{1 + \lambda} \right)^i E_t [(m_{t+i} - m_{t+i}^*) - \phi^{-1} (y_{t+i} - y_{t+i}^*)] \quad (25)$$

$E_t [.]$ denotes the expectation conditional on the information set available at time t .

Equation 25 represents only one solution from a potentially infinite set.

In general, the exchange rate determined according to Equation 25, say \tilde{s}_t , has multiple RE solutions according to:

$$s_t = \tilde{s}_t + Bub_t \quad (26)$$

where the rational bubble Bub_t satisfies:

$$E_t (Bub_{t+1}) = \lambda^{-1} (1 + \lambda) Bub_t \quad (27)$$

\tilde{s}_t therefore represents the rational expectations solution to the Flexible-Price Monetary Model in the absence of rational bubbles, which represent significant departures from the fundamentals of the model which would not be detected in earlier specifications. The Flexible-Price Monetary Model concentrates on equilibrium in only one (out of six¹⁰) market: the money market. It does so by assuming perfect substitutability of domestic and foreign assets. By doing so the domestic and foreign bond markets become a single market. In the floating exchange rate, the exchange rate adjusts freely to equilibrate supply and demand in the foreign exchange market. If the goods and the labour markets are also assumed to hold, equilibrium in the last three markets is implied. By Walras' law¹¹, equilibrium of

¹⁰The others are goods, labour, foreign exchange, domestic and foreign bond markets.

¹¹The Walras' Law states that equilibrium in $n - 1$ markets of an n -market system implies equilibrium in the n -th market.

the full system is then determined by equilibrium conditions for the money market. The flexible-price model is thus implicitly a market-clearing general equilibrium model in which continuous purchasing power parity among national price levels is assumed (Taylor, 1995). The very high volatility in the 1970s casts serious doubts on the assumption of continuous purchasing power parity. This led to the development of sticky-price monetary models.

Sticky Price, Overshooting and Real Interest Differential Models The early flexible-price variant of the monetary approach assumes continuous purchasing power parity (Equation 1). Under continuous PPP, the real exchange rate (q_t , as in Equation 6, which is the exchange rate adjusted for the differences in national price levels) cannot vary by definition. The experience with the floating exchange rate has been the wide fluctuations in the real rates of exchange among major currencies and this brought about the development of the ‘sticky price’ monetary model (SPMM) which is credited to Rodiger Dornbusch (1976).

The Sticky Price Monetary Models - the Dornbusch ‘Overshooting’ model The poor description of the flexible-price monetary models in the 1970s led to parallel development of other classes of exchange rate models. The first is the sticky price monetary models. The second strand focused its attention on the analysis of exchange rate movements within a general portfolio balance framework. Another strand of the theoretical literature looked at exchange rate behaviour within an optimising general equilibrium framework, often in a two-country setting. The monetary and the portfolio balance models, both developed during the earlier phase of the recent float, focused largely on freely floating exchange rates.

The sticky-price monetary model (SPMM) was largely credited to Dornbusch (1976). The model allows short-term overshooting of the nominal and real exchange rates above their long-run equilibrium levels. In the SPMM, jump variables such as exchange rates and interest rates are assumed to compensate for stickiness in other variables, notably goods prices. Since goods prices are sticky in the short run, an initial fall in the real money supply causes a rise in interest rates in order to clear the money market. The rise in domestic interest rates leads to a capital inflow and an appreciation of the nominal exchange

rate. So long as the expected foreign exchange loss (the expected rate of depreciation) is less than the known capital market gain (the interest differential), risk-neutral investors will continue to borrow abroad to buy domestic assets. A short-run equilibrium is achieved when the expected rate of depreciation is just equal to the interest rate differential (i.e. when uncovered interest parity holds). Since the expected rate of depreciation must be non-zero for a non-zero interest rate differential, the exchange rate must have overshoot its long-run, purchasing-power-parity equilibrium. In the medium run, however, domestic prices begin to fall in response to the fall in the money supply. This alleviates pressure in the money market (the real money supply rises) and domestic interest rates start to fall. The exchange rate then depreciates slowly towards long-run purchasing power parity. This model can explain the apparent paradox that the exchange rates of countries with relatively high interest rates tend to be expected to depreciate as the initial interest rate rise induces a sharp exchange rate depreciation is followed by a slow depreciation as prices adjust. This continues until long-run purchasing power parity is satisfied.

In continuous time, the SPM model's characteristics can be seen in a three-equation structural model, holding foreign variables and domestic income constant:

$$\dot{s} = i - i^* \quad (28)$$

$$m = p + \phi \bar{y} - \lambda i \quad (29)$$

$$\dot{p} = \gamma [\alpha + \beta (s - p) - \bar{y}] \quad (30)$$

Variables with a bar denotes their long-run equilibrium values. \dot{s} represents a continuous movement of the nominal exchange rate. \dot{p} represents a continuous movement of the price level. \bar{y} represents the long-run equilibrium level of output. Equation 28 is the uncovered interest parity in continuous time. Equation 29 is a domestic money-market equilibrium condition. Here in this section domestic prices cannot be normalized to zero. Movements in nominal exchange rate can have an effect on the domestic price level via Equation 30. Equation 30 replaces the equation for movements in aggregate output. It is a Phillips curve relationship relating domestic price movements to excess aggregate demand, which is assumed to be a function of an autonomous component α , and a component depending upon international competitiveness which can be thought of as net export demand, with foreign prices held constant and normalised so that their logarithm is zero.

Unlike in the Mundell-Fleming model, in the sticky-price monetary model output is no longer demand determined. Excess aggregate demand simply leads to inflation rather than an increase in output. The key difference between the two models results from substituting a price adjustment equation for an output adjustment equation, which is sufficient for generating monetary neutrality in the model. Some might even argue that the Dornbusch model assumes money neutrality since, if output must be at the 'natural' level and interest rates must be at the level of foreign interest rates, the monetary equilibrium equation (29) shows that prices must be proportional to money in the long run. Similarly, long-run goods market equilibrium (set $\dot{p} = 0$ in Equation 30). Thus, a form of long run PPP may hold in the Dornbusch model, but strictly as a result of money neutrality. Because of the neutrality of money in this model, it is often referred to as the sticky-price monetary model.

2.3 Tests of the monetary models on Thai Data

The flexible-price model of the monetary approach of the exchange rate is sometimes referred to as the 'Chicago' approach whereas the sticky price version is sometimes known as the 'Keynesian' one since the latter assumes that prices are sticky, at least in the short run. In the first approach, changes in the nominal interest rate reflect changes in the expected inflation rate. The domestic currency is expected to lose value through inflation and depreciation when the domestic interest rate rises relative to the foreign interest rate. Demand for the domestic currency falls relative to the foreign currency, which causes it to depreciate instantly. This rise (since the exchange rate is defined as the price of foreign currency) in the exchange rate means that we get a positive relationship between the exchange rate and the nominal interest differential. In the Keynesian or sticky-price approach, as prices are sticky, changes in the nominal interest rate reflect changes in the tightness of monetary policy. When the domestic interest rate rises relative to the foreign rate, it is because there has been a contraction in the domestic money supply relative to domestic money demand without a matching fall in prices. The higher interest rate at home than abroad attracts a capital inflow, which causes the domestic currency to appreciate instantly. Thus in the Keynesian view we get a negative relationship between the exchange rate and the nominal interest differential.

The Chicago theory describes well the periods with large variation in the inflation differential, for example when Frenkel (1976) applied the approach to the German hyperinflation period of 1920's. On the other hand, the Keynesian theory is a more appropriate description of the data when variation in the inflation differential is small, as in the 1950s Canadian float

when Robert Mundell first applied the concept to the Canadian Dollar when it was floating against the US Dollar. Frankel (1979) develops a model which is also a version of the asset view of the exchange rates, emphasizing the role of expectations and rapid adjustment in the capital markets. He combined the Keynesian assumption of sticky prices with the Chicago assumption that the rates of inflation can be persistent. Frankel's monthly data were tested on the Mark/Dollar exchange rate from July 1974 to February 1978. He found that the Mark/Dollar exchange rate is negatively related to the nominal interest differential, but positively related to the expected long-run inflation differential. In addition, the Mark/Dollar rate differs or overshoots its equilibrium value by an amount proportional to the real interest differential, that is, the nominal interest differential minus the expected inflation differential. In Frankel's words:

Remark 2 *"If the nominal interest differential is high merely because money is tight, then the exchange rate is equal to its equilibrium value, which over time increases at the rate of the inflation differential."*

2.3.1 The Real Interest Differential model: test on floating Baht against US

Dollar Frankel's theory yields an equation of exchange rate determination in which the spot rate is expressed as a function of the relative money supply, relative income level, the nominal interest differential (with the sign hypothesized negative), and the expected long-run inflation differential (with the sign hypothesized positive).

The theory starts with two fundamental assumptions. First, covered (or closed) interest rate parity:

$$d = i - i^* \quad (31)$$

i the domestic rate of interest

i^* the foreign rate of interest

d is the forward discount, defined in Equation (31) as the log of the forward rate minus the log of the current spot rate.

Under perfect capital mobility (i.e. in the absence of capital controls and transactions costs), covered interest parity must hold exactly since its failure would imply unexploited opportunities for profits (known as the no-arbitrage argument). For this reason, Frankel also defined d as the expected rate of depreciation, $d = \dot{s}^e$, so thereupon Equation 31 represents a stronger condition of uncovered (or open) interest parity. If there is no uncertainty (as in a perfect foresight economy), then the forward discount is equal to the expected rate of depreciation. If there is uncertainty and market participants are risk averse, then the no-risk-premium assumption is a strong one. Frankel's second assumption is that the expected rate of depreciation is a function of the gap between the current spot rate and an equilibrium

rate, and of the expected long-run inflation differential between the domestic and foreign countries:

$$s^e = -\varrho (s - \bar{s}) + \pi - \pi^* \quad (32)$$

s is the log of the spot rate

\bar{s} is the equilibrium exchange rate

π is the current rate of expected long-run inflation (or long-run rate of monetary growth known to the public) at home

π^* is the current rate of expected long-run inflation abroad.

ϱ is the speed of adjustment parameter for the exchange rate deviation from equilibrium

The log of the equilibrium exchange rate \bar{s} is defined to increase at the rate $\pi - \pi^*$.

Equation 32 says that *in the short run* the exchange rate is expected to return to its equilibrium value at a rate which is proportional to the current gap, and that in the long run, when $s = \bar{s}$, it is expected to change at the long-run rate $\pi - \pi^*$, call this ds . Let $di = ds$, this gives:

$$s - \bar{s} = -\frac{1}{\varrho} [(r - \pi) - (i^* - \pi^*)] \quad (33)$$

Frankel describes the term in square brackets as the real interest differential, but strictly speaking it is not accurate (as he himself noted) since the nominal interest rates are short term while the expected inflation rates are long term. Frankel shows that $s - \bar{s}$ turns out to be proportional to the short-term real interest differential $[(i - Dp) - (i^* - Dp^*)]$. Equation 33 can be described as follows: when a tight domestic monetary policy causes the nominal

interest differential to rise above its long-run level, an incipient capital inflow causes the value of the currency to rise proportionately above its equilibrium level. \bar{s} is assumed to be governed by PPP in the long run:

$$\bar{s} = \bar{p} - \bar{p}^* \quad (34)$$

where \bar{p} and \bar{p}^* are defined as logs of the equilibrium price levels at home and abroad. A money demand equation as in Equations 14 and 29 is also assumed:

$$m = p + \phi y - \lambda i \quad (35)$$

The same condition holds abroad:

$$m^* = p + \phi y^* - \lambda i^* \quad (36)$$

Here again it is assumed for simplicity that the income and interest elasticities are the same across countries ($\phi = \phi^*$ and $\lambda = \lambda^*$) 21:

$$m - m^* = p - p^* + \phi (y - y^*) - \lambda (i - i^*) \quad (37)$$

Bars denote equilibrium values in the long run $s = \bar{s}, \bar{i} - \bar{i}^* = \pi - \pi^*$, we obtain:

$$\bar{s} = \bar{p} - \bar{p}^* \quad (38)$$

and

$$\bar{s} = \bar{m} - \bar{m}^* - \phi (\bar{y} - \bar{y}^*) + \lambda (\pi - \pi^*) \quad (39)$$

In full equilibrium a given increase in the money supply inflates prices and thus raises the exchange rate proportionately. An increase in income or a fall in the expected rate of inflation raises the demand for money and thus lowers the exchange rate. Substituting Equation 39 into Equation 38 and assuming that the current equilibrium money supplies and income levels are given by their current actual levels, we obtain a complete equation of spot rate determination:

$$s = m - m^* - \phi(y - y^*) - \frac{1}{\varrho}(i - i^*) + \left(\frac{1}{\varrho} + \lambda\right)(\pi - \pi^*) \quad (40)$$

Testing Equation 40 with the error term for the Thai data:

$$s = c + \alpha_m(m - m^*) + \alpha_y(y - y^*) + \alpha_r(i - i^*) + \alpha_\pi(\pi - \pi^*) + u \quad (41)$$

The parameters α_m , α_y , α_r , α_π will be approximated by the Johansen-Juselius (1990) estimates. For ease of comparison I have summarized the expected signs and magnitude in the Table 1 below.

	α_m	α_y	α_i	α_π
FPM	1	negative	zero	positive
SPM	1	negative	negative	zero
RID	1	negative	negative	positive

Table 1: Summary of coefficient signs implied by various monetary models

2.4 The Data

All data are taken from *Datastream Advance* by Thomson from June 1998 to April 2005. For consistent data representation, all the data (except the rates of interest) are rebased base in comparison to June 2000 data (our known ‘normal’ period). The nominal exchange rate series s_t is the spot world market rates of the Thai Baht per US Dollar in index form . The relative money supplies are $M1^{12}$ for both countries in billions of Baht, rebased with reference to June 2000 =100. The Thai interest rate is the repo 30-day rates, and the US Certificate of Deposit over 30 days, which is very close to the short US repo 30-day rates (which is only available from August 2001) is used. The long-term government bond yield is used for Thailand and the US Treasury Benchmark Bond (30 years) at reduced rates are used to represent the relative expected inflation rates in both countries. Inflation rates are calculated by subtracting the previous period’s value from the current period value with respect to the previous period value and multiplied by 100 to render the percentage rates of inflation. The time series of the five variables (one dependent, four explanatory) are plotted against time below:

Various questions may be asked: Are the nominal exchange rates driven by the monetary fundamentals?; Do the fundamentals combine so that their effects result in the shown movements of the nominal exchange rate?; Is the Thai nominal exchange rate connected to the monetary fundamentals?; Does one help explain the other? The analysis starts by looking at the plotted graphs of all the series on the same axes and scales.:Money supply and income look like they could be related but are the linear combinations of all the

¹²Johansen and Juselius (1990) also use M1 in their investigation into the demand equation for the Finnish and Danish Data since M1 ‘enters strongly’ into their demand equation.

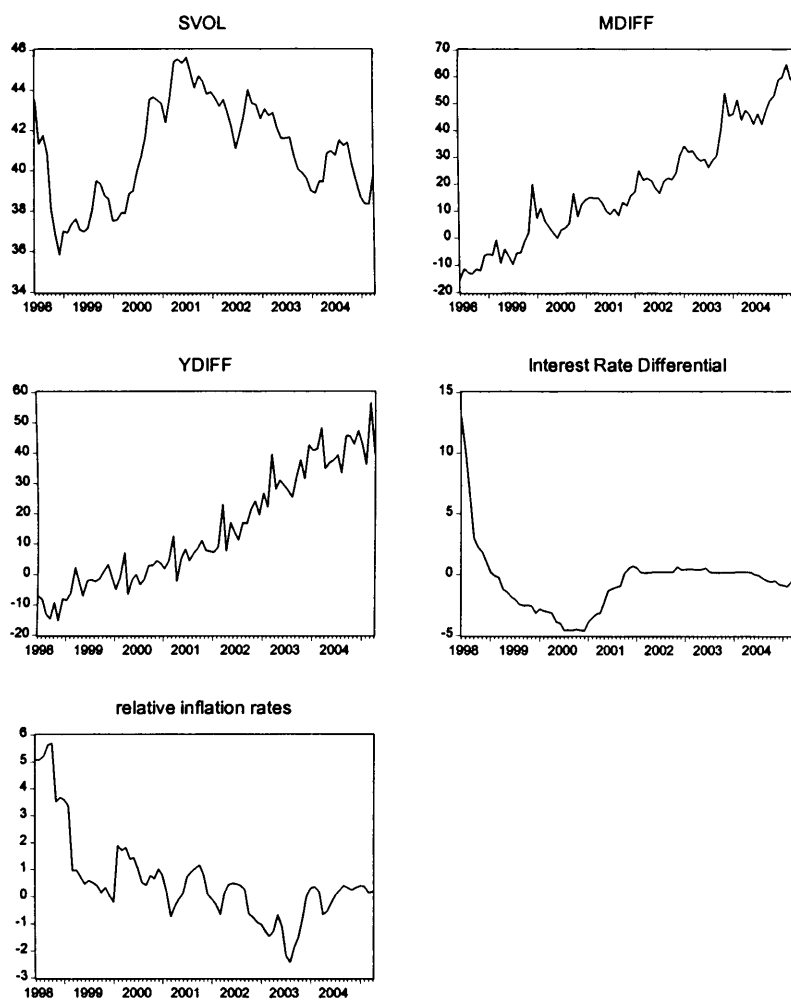


Figure 1: All the data series for the real interest rate differential model

series stationary?

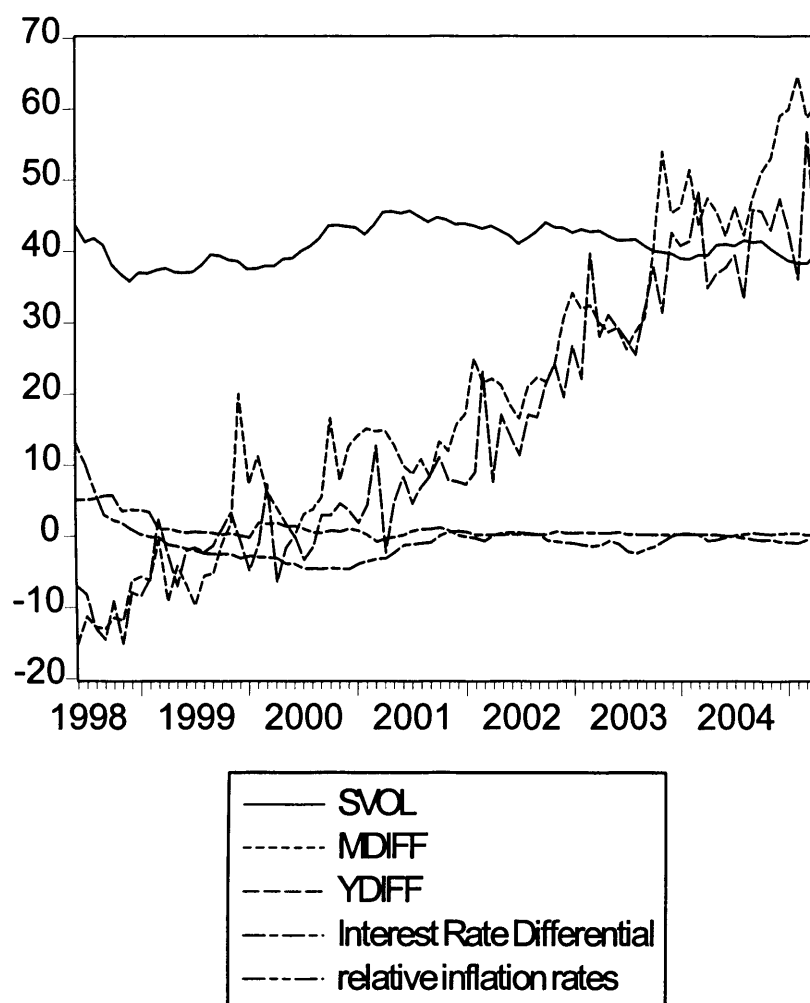


Figure 2: The RID series plotted on the same diagram

The researcher is interested in seeing if there is any long run relationship between them, specifically the effects of the monetary factors on the nominal exchange rate. Prior to the investigation, one needs to know if each of the series is stationary. The evidence of nonstationarity, specifically of order 1, will enable us to proceed with the research.

The Unit Root Test The structural approach to time series modelling uses economic theory to model the relationship among the variables of interest. Unfortunately, economic theory is often not rich enough to provide a dynamic specification that identifies all of these relationships. Furthermore, estimation and inference are complicated by the fact that endogenous variables may appear on both the left and right sides of equations. These problems lead to alternative, non-structural approaches to modelling the relationship among several variables. The finding that many macro time series may contain a unit root has spurred the development of the theory of non-stationary time series analysis. Engle and Granger (1987) pointed out that a linear combination of two or more non-stationary series may be stationary. If such a stationary linear combination exists, the non-stationary time series are said to be cointegrated. The stationary linear combination is called the cointegrating equation and may be interpreted as a long-run equilibrium relationship among the variables.

Standard inference procedures do not apply to regressions which contain an integrated dependent variable or integrated regressors. Therefore, it is important to check whether a series is stationary or not before using it in a regression. The formal method to test the stationarity of a series is the unit root test.

Specifying a relation in terms of levels of the economic variables, say $y = \alpha + \beta x + u$, often produces empirical results in which the R^2 is quite high, but the Durbin-Watson statistic is quite low. This happens because economic time series are dominated by smooth, long term trends. That is, the variables behave individually as nonstationary random walks. In a model which includes two such variables it is possible to choose coefficients which may appear to be stationary. But such an empirical result tells us little of the short run relationship between y_t and x_t . In fact, if the two series are both $I(1)$ then we will often

reject the hypothesis of no relationship between them even when none exists.

2.4.1 The Panel Unit Root Test Recent literature suggests that panel-based unit root tests have higher power than unit root tests based on individual time series. In the latest version of Eviews (Eviews 5), the software will compute one of the following five types of panel unit root tests: Levin, Lin and Chu (2002), Breitung (2000), Im, Pesaran and Shin (2003), Fisher-type tests using ADF and PP tests (Maddala and Wu (1999) and Choi (2001)) and Hadri (1999)¹³.

Panel Unit Root Details Panel unit root tests are similar, but not identical, to unit root tests carried out on a single series. The different unit root tests are classified on the basis of whether there are restrictions on the autoregressive process across cross-sections or series. Consider an AR(1) process for panel data:

$$y_{it} = \rho_i y_{it-1} + X_{it} \delta_i + \varepsilon_{it}, \quad (42)$$

where $i = 1, 2, \dots, N$ represents the number of cross section units (series) that are observed over the periods $t, t = 1, 2, \dots, T_i$.

The X_{it} represent the exogenous variables in the model, including any fixed effects or individual trends, ρ_i are the autoregressive coefficients, and the errors ε_{it} are assumed to be mutually independent idiosyncratic disturbance. If $|\rho_i| < 1$, y_i is said to be weakly or trend-stationary. On the other hand, if $|\rho_i| = 1$, then y_i contains a unit root.

Two assumptions can be made about ρ_i . First Levin, Lin and Chu (LLC), Breitung, and

¹³As noted in Eviews 5's Help section, while these tests are commonly termed "panel unit root" tests, theoretically they are simply multiple-series unit root tests that have been applied to panel data structures (where the presence of cross-sections generates "multiple series" out of a single series).

Hadri tests all assume that the persistence parameters are common across cross-sections so that $\rho_i = \rho$ for all i . Im, Pesaran and Shin (IPS) and Fisher-ADF and Fisher-PP tests, on the other hand, allow ρ_i to vary freely across cross-sections.

Tests with a Common Unit Root Process Levin, Lin and Chu (LLC), Breitung and Hadri tests all assume that there is a common unit root process, so that ρ_i is identical across cross-sections. The first two tests employ a null hypothesis of a unit root, while the Hadri test uses a null of no unit root.

LLC and Breitung both consider the following basic ADF specification:

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{it-j} + X'_{it} \delta + \varepsilon_{it} \quad (43)$$

where we assume a common $\alpha = \rho - 1$, but allow the lag order for the difference terms, p_i , to vary across cross-sections. The null and alternative hypotheses for the tests may be written as:

$$H_0 : \alpha = 0.$$

$$H_1 : \alpha < 0.$$

Under the null hypothesis, there is a unit root, while under the alternative, there is no unit root.

The Levin, Lin and Chu test derives estimates of α from proxies for Δy_{it} and y_{it} that are standardized and free of autocorrelations and deterministic components. They show that under the null, a modified t -statistic for the resulting $\hat{\alpha}$ is asymptotically normally distributed

$$t_{\alpha}^* = \frac{t_{\alpha} - \left(NT\right) S_N \hat{\sigma}^{-2} se(\hat{\alpha}) \mu_{m\tilde{T}^*}}{\sigma_{m\tilde{T}^*}} \rightarrow N(0, 1) \quad (44)$$

where t_{α} is the standard t -statistic for $\hat{\alpha} = 0$, $\hat{\sigma}^2$ is the estimated variance of the error term η , $se(\hat{\alpha})$ is the standard error of $\hat{\alpha}$, and:

$$\tilde{T} = T - \left(\frac{\sum_i p_i}{N} \right) - 1 \quad (45)$$

The remaining terms involve complicated moment calculations and are described in Levin et al. (2002). The average standard deviation ratio, S_N , is defined as the mean of the ratios of the long-run standard deviation to the innovation standard deviation for each individual. Its estimate is derived using kernel-based techniques. The remaining two terms, $\mu_{m\tilde{T}^*}$ and $\sigma_{m\tilde{T}^*}$ are adjustment terms for the mean and standard deviation.

The Breitung method (Breitung, 2000) differs from the LLC test in two ways. First, only the autoregressive portion (and not the exogenous components) is removed when constructing the standardized proxies, and second, the proxies are transformed and detrended. Breitung shows that, under the null, the resulting estimator α^* is asymptotically distributed as a standard normal.

The Hadri panel unit root test (Hadri, 2000) is similar to the KPSS unit root test and has a null hypothesis of no unit root in any of the series in the panel. Like the KPSS test, the Hadri test is based on the residuals from the individual OLS regressions of y_{it} on a constant and a trend.

Tests with Individual Unit Root Processes The Im, Pesaran, and Shin, and the Fisher-ADF and PP tests all allow for individual unit root processes so that ρ_i may vary

across cross-sections. The tests are all characterized by the combining of individual unit root tests to derive a panel-specific result.

The Im, Pesaran and Shin test (Im et al., 2003) begins by specifying a separate ADF regression for each cross section. After estimating the separate ADF regressions, the average of t -statistics for α_i from the individual regressions is then adjusted to arrive at the desired test statistics.

The Fisher-ADF and Fisher-PP tests were proposed by Maddala and Wu (1999) and by Choi (2001). They use the Fisher's (1932) results to combine the p-values from individual unit root tests.

From our new sample from June 1998 to April 2005, the Panel unit root test summary from Eviews 5 is as follows. The tests are performed on series *lns*, *mdiff*, *ydiff*, *idiff*, and *pidiff* and the exogenous variables have individual effects. There is an automatic selection of maximum lags and the automatic selection of lags is based on Schwartz Information Criteria (SIC): 0-5. The Newey-West bandwidth selection is performed, using Bartlett kernel.

Figure 1 shows all of the series in volume (Baht per US Dollar for *svol*), percentage (*idiff*), and indices (*mdiff*, *ydiff* and *pidiff* all have the same base month, which is June 2000). The group unit root test showing individual effects and individual linear trends show conclusive results that there is evidence of a common unit root process (the LLC and Breitung fail to reject the unit root null and the Hadri test strongly rejects the null of no unit root). In the individual unit root category, only one test strongly rejects the individual unit root null (the PP-Fisher Chi-square test) whilst the IPS and ADF-Fisher tests failed to reject the null of individual unit root process. The results from the group or panel unit root test from Eviews 5.0 is given in the table immediately below cannot reject the null of

unit root:

Sample from June 1998 to April 2005			Cross-	
Method	Statistic	Prob**	Sections	Obs
Null: Common unit root				
Levin, Lin and Chu t^*	2.0917	0.9818	5	400
Breitung t-stat	-0.8287	0.2037	5	395
<i>Null: Individual unit root</i>				
<i>Im, Pesaran and Shin W-stat</i>	0.35649	0.6393	5	400
<i>ADF-Fisher Chi-square</i>	10.6320	0.3869	5	400
<i>PP-Fisher Chi-square</i>	34.1445	0.0002***	5	410
Null: No common unit root				
Hadri Z-stat	15.0526	0.0000***	5	415

Table 2: Panel Unit Root Test between Svol and f

**The probabilities for the Fisher tests are computed using an asymptotic chi-square distribution. All other tests assume asymptotic normality.

*** reject at 99% level.

From the table above, five out of six tests provide strong support of a unit root in the group data. Hence, the Johansen cointegration test will be performed to find out about the long-run relationship(s) amongst the variables.

Based on the group unit root results above, a cointegration test is performed on the five series with lags interval 1 to 2 in first differences. The author started off restricting the relative velocity of money (relative money supplies) to be unity in the test but soon discovered

that the unrestricted coefficient of the relative money supplies turns out to be very close to unity (0.9950), showing that the observed data display almost fully flexible prices as imposed by the theory, therefore the author chose to use instead estimated coefficients and other results from the unrestricted cointegration rank test from Eviews 5.0. The cointegration rank test (Trace) indicates that 1 cointegration equation is found at the 0.05 level. As the reader can see below, the Trace test and the Maximum Eigenvalue tests disagree as to the number of cointegrating equation. From here on we use the evidence that there is at least one cointegrating relationship to assume that there is one cointegrating relation between the nominal exchange rate and the monetary variables.

Unrestricted cointegration				
rank test (Trace)			0.05	
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value	Prob**
None*	0.3205	75.3847	69.8189	0.0168
At most 1	0.2628	44.4765	47.8561	0.1003
At most 2	0.1656	20.0810	29.7971	0.4174
At most 3	0.0649	5.5979	15.4947	0.7425
At most 4	0.0029	0.2338	3.8415	0.6287

Table 3: The Trace Test between the nominal exchange rate and the monetary factors

Trace test from the above table indicates 2 cointegrating equation at the 0.05 level.

* denotes rejection of the hypothesis at the 0.05 level.

**MacKinnon-Haug-Michelis (1999) p-values.

Max-eigenvalue test indicates 1 cointegrating equations at the 0.05 level.

Unrestricted cointegration				
rank test (Max Eigenvalue)		Max-Eigen	0.05	
Hypothesized No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob**
None	0.3205	30.9082	33.8769	0.1086
At most 1	0.2628	24.3955	27.5843	0.1215
At most 2	0.1656	14.4831	21.1316	0.3267
At most 3	0.0649	5.3641	14.265	0.6953
At most 4	0.0029	0.2338	3.8415	0.6287

Table 4: The Maximum Eigenvalue test on the nominal exchange rate and the monetary fundamentals

* denotes rejection of the hypothesis at the 0.05 level.

**MacKinnon-Haug-Michelis (1999) *p*-values.

There is one cointegrating equation with the Log Likelihood -615.6336. The normalized cointegrating coefficients (standard error in parentheses) are as follow (all coefficients represent the equation on the left hand side = 0 in Eviews):

SVOL	MDIFF	YDIFF	IDIFF	PIDIFF
1.0000	-0.9950	1.2555	-1.5646	2.9505
	(0.1775)	(0.2126)	(0.5225)	(0.8502)

Table 5: The normalized cointegrating coefficients for the nominal exchange rate-fundamental long run relationship

All of the cointegrating coefficients are highly significant, only one (IDIFF) has the wrong

Dependent variable	Adjustment coefficients (s.e. in parentheses)
D(SVOL)	-0.0266
	(0.0201)
D(MDIFF)	0.3779
	(0.1249)
D(YDIFF)	-0.3702
	(0.1470)
D(IDIFF)	-0.0002
	(0.0107)
D(PIDIFF)	-0.0329
	(0.0159)

Table 6: Dependent variables' adjustment coefficients

sign. For the adjustment coefficients (since there is a correction to the mean for the nominal exchange rate), only $D(MDIFF)$ and $D(YDIFF)$ are significant, and only $D(MDIFF)$ has the wrong sign (all adjustments should reduce the deviation and move towards the mean, and thus all adjustment coefficients should be negatively-signed).

This translates to our starting equation (the signs of $ydiff$, $idiff$ and $pidiff$ need to be reversed, since all of the variables previously all sum to zero on the right hand side of the equation). Our fundamentals then equal:

$$f_1 = 0.9950mdiff - 1.2555ydiff + 1.5649idiff - 2.9505pidiff + 42.7317 \quad (46)$$

The diagram below depicts the long run relationship between the nominal exchange rate and the monetary fundamentals, as the reader can see it fluctuates and varies over time with moments of extremely high volatility in how related they are over time.

The residuals from the cointegrating relation for each explanatory variables are plotted in the Figure below:

In exploring the relationship between variables, I tested the Pairwise Granger Causality Test with two lags and found the following:

From the table, we can conclude that there is 90% evidence that $svol$ 'Granger Causes' $idiff$. However, there is stronger evidence still that $idiff$ 'Granger Causes' $svol$ (95%). In addition, there is 95% evidence that $idiff$ granger causes $mdiff$ but very strong evidence (99%) that $mdiff$ granger causes $ydiff$ and 90% evidence that $mdiff$ granger causes $idiff$, and also 90% evidence that $pidiff$ granger causes $idiff$. Finally, there is 95% evidence that $idiff$ granger causes $pidiff$. With regard to causation argument in the literature,

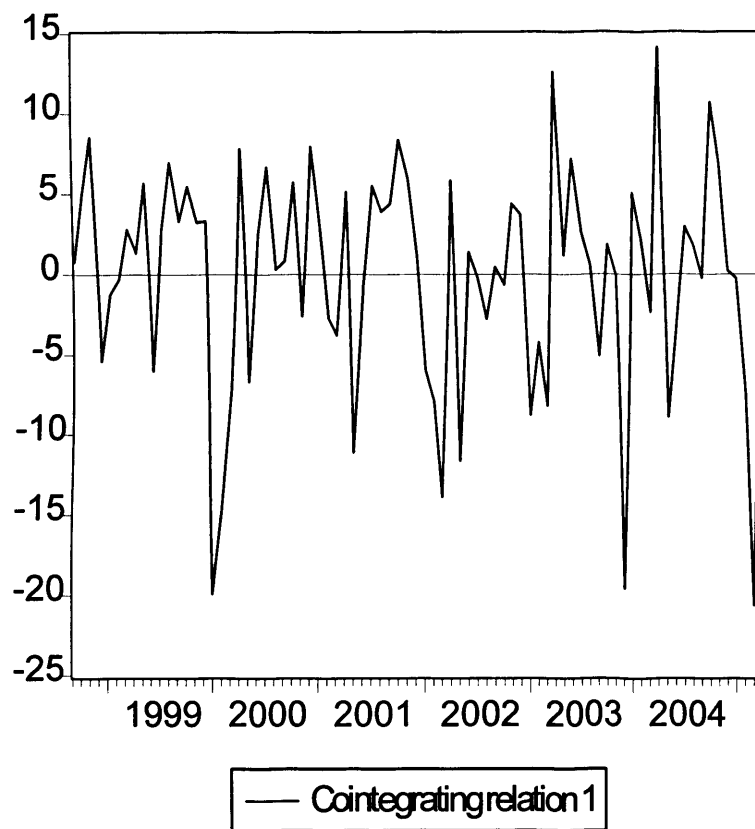


Figure 3: The long-run relationship between the RID variables

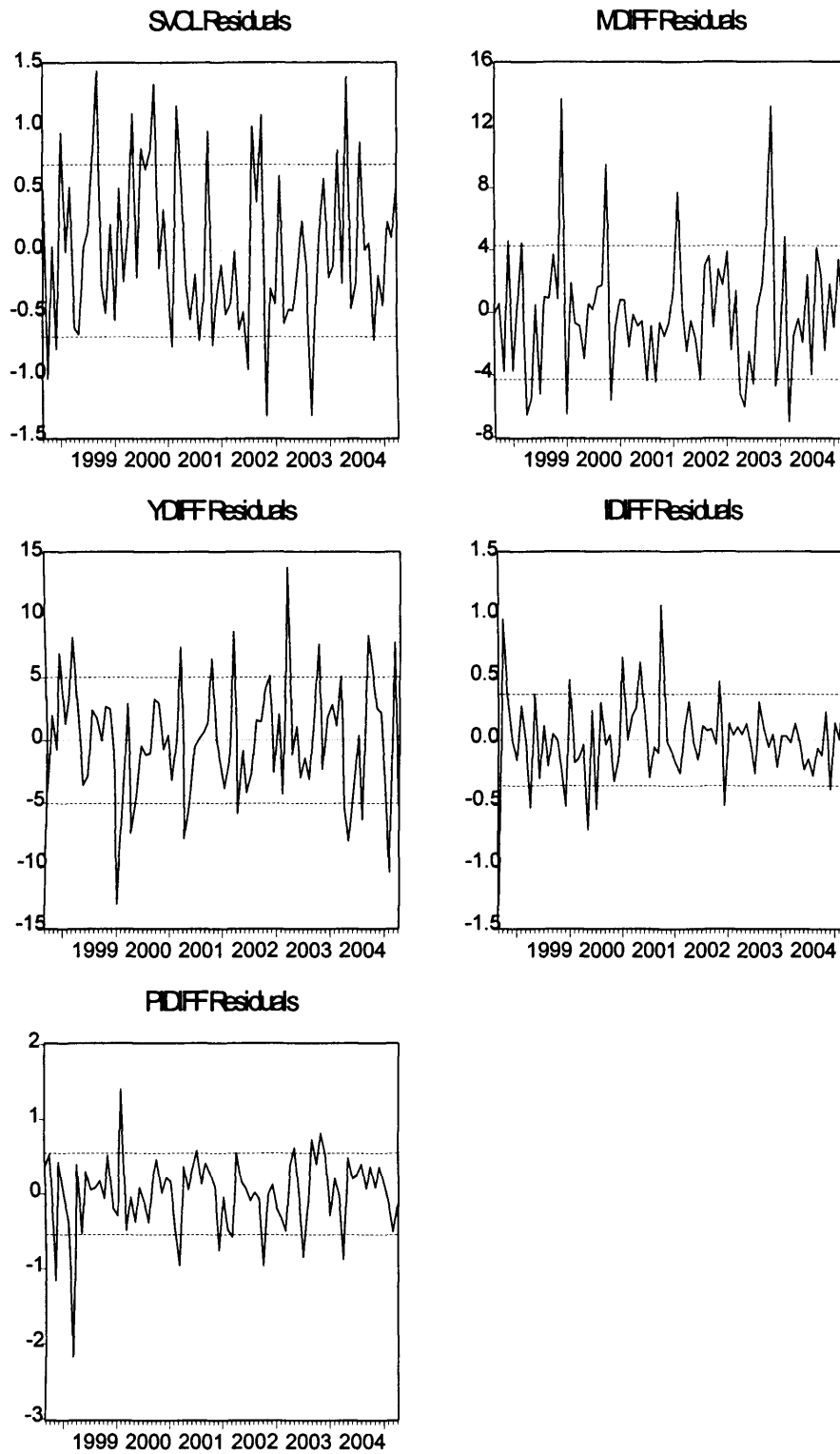


Figure 4: The residuals from the cointegrating relation for each variable

Pairwise Granger Causality Tests	Obs	F-Statistic	Probability
MDIFF does not Granger Cause SVOL	81	0.0206	0.9796
SVOL does not Granger Cause MDIFF		1.0866	0.3425
YDIFF does not Granger Cause SVOL	81	2.0671	0.1336
SVOL does not Granger Cause YDIFF		0.0324	0.9682
IDIFF does not Granger Cause SVOL	81	3.6710	0.0301
SVOL does not Granger Cause IDIFF		2.7563	0.0699
PIDIFF does not Granger Cause SVOL	81	1.4267	0.2465
SVOL does not Granger Cause PIDIFF		0.0067	0.9934
YDIFF does not Granger Cause MDIFF	81	4.4770	0.0145
MDIFF does not Granger Cause YDIFF		6.3127	0.0029
IDIFF does not Granger Cause MDIFF	81	0.1022	0.9030
MDIFF does not Granger Cause IDIFF		2.7513	0.0702
PIDIFF does not Granger Cause MDIFF	81	0.5744	0.5655
MDIFF does not Granger Cause PIDIFF		1.0933	0.3403
IDIFF does not Granger Cause YDIFF	81	0.2947	0.7456
YDIFF does not Granger Cause IDIFF		2.2081	0.1169
PIDIFF does not Granger Cause YDIFF	81	1.3200	0.2732
YDIFF does not Granger Cause PIDIFF		0.2885	0.7502
PIDIFF does not Granger Cause IDIFF	81	3.0080	0.0553
IDIFF does not Granger Cause PIDIFF		3.1352	0.0492

Table 7: The Granger Causality test between each pair of variables in Part I

here most of the evidence indicate the causation from right to left (monetary fundamentals on the nominal exchange rate, rather than the other way round).

2.4.2 Extending the RID to include the Regime-Switching Feature The effort of trying to fit a monetary model to data is further extended by Frömmel et al. (2002). Their use of Markov-switching to capture the change the monetary fundamental scenarios are justified by the use of practitioners' survey suggesting time-varying influence of a limited set of fundamentals on the exchange rate. It so happens that their best-performing model is that of the extended Real Interest Rate Differential (RID) approach which is robust against several modifications. Their justification of the number of regimes is somewhat arbitrary, but this remains the case in most regime-switching literature. Since Frömmel et al.'s (2002) extension to the RID could not capture the time-varying effects in the coefficients and was outperformed by the random walk, better techniques were made available by Krolzig (1996) who generalized Hamilton's regime switching model to capture the time-varying effects of the various parts of the processes. Sarno, Valente and Wohar (2004) adopted the technique well known to the business cycle literature to the exchange-rate-and-fundamentals data in order to see whether exchange rates or the fundamentals move to restore equilibrium. Sarno et al. (2004) work was able to distinguish clearly when the nominal exchange rate is in one particular regime or the other. In their paper strong evidence was provided that adjustment towards long-run equilibrium takes different forms depending on whether the country in question is in a fixed or a floating exchange rate regime. This followed their previous attempt to find evidence linking monetary fundamentals with the nominal exchange rate (Neely and Sarno, 2002). Rapach and Wohar (2002) investigate whether exchange rates

or fundamentals adjust where there is a deviation away from long-run equilibrium. They find that departures from equilibrium may be restored via movements in the exchange rate or in fundamentals or both, suggesting that fundamentals may not be weakly exogenous with respect to the exchange rate. Rapach and Wohar's work lends support to Engel and West (2005) that for countries and data where exchange rates and fundamentals appear to be linked by a long-run relationship, it may be the case, as in Engel and West (2005), that exchange rates help predict fundamentals, rather than the other way round. In the floating period of the Thai Baht, the nominal exchange rate (as opposed to the fundamentals) should move to restore the equilibrium and thus we expect their coefficients in the MS-VECM based on RID (or monetary) fundamentals to be significant. More recently, Sekioua (2003) used a non-linear technique in the form of the Threshold Autoregressive (TAR) model to investigate the link between nominal exchange rate and monetary fundamentals (i.e. the empirical test of the monetary model) and found the evidence for both nonlinearity and nonstationarity. Her result indicates non-linear mean reversion of the deviation of the exchange rate from monetary fundamentals as well as finding that large deviations have faster speed of mean reversion than small variations. My results in Table 25, using a different technique, also confirm this.

The Regime Switching methodology The extended 3-regime switching system based on Hamilton (1994)'s switching regression is as follows:

$$\begin{aligned}
& \beta_1 x_t + \varepsilon_t \quad \text{if } z_t = 1 \\
y_t = & \beta_2 x_t + \varepsilon_t \quad \text{if } z_t = 2 \\
& \beta_3 x_t + \varepsilon_t \quad \text{if } z_t = 3
\end{aligned} \tag{47}$$

y_t is the explained time series, our crisis variable, *cri*.

x_t is a vector of exogenous regressors, $x_t = [s, f]'$.

β_t is a vector of real numbers, whose values depend on the non-observable state variable z_t .

Our explained time series here is the circumstance in which the nominal exchange rate ends up in each time period (as opposed to Frömmel et al. (2002)'s 12-month percentage change of an exchange rate).

ε_t is the Gaussian white noise.

The state variable z_t is assumed to follow an ergodic (steady-state) first-order Markov process and is characterised by the matrix Π , consisting of the transition probabilities p_{ij}

from state i to state j :

$$\Pi = \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix} \quad \text{in the case of three states}$$

$p_{ij} = \Pr(z_t = j | z_{t-1} = i)$. The probabilities $\Pr(z_t = j | r_1 \dots r_T)$ can be calculated for each date once the coefficients of the model and the transition matrix has been estimated. This series of probabilities are called the *smoothed* probabilities, in contrast to the probabilities series $\Pr(z_t = j | r_1, \dots, r_t)$, which are the probabilities of being in state j , based on the information up to and including date t (the *filter* probabilities). For the last date, when $t = T$, the smoothed probability equals the filter probability. Based on the Real Interest

Differential (RID) model, the set of fundamentals covers relative changes in money supply (Δm_t), industrial production (Δy_t), the repurchase agreement rate (Δi_t^s) as the short-term interest rate and the long term government bond yield (Δi_t^l) as the long term interest rate. Equation 47 can be rewritten, in the case of three states, as:

$$\begin{aligned}
& c_1 + \alpha_{m_1} (m - m^*) + \alpha_{y_1} (y - y^*) + \alpha_{r_1} (i - i^*) + \alpha_{\pi_1} (\pi - \pi^*) + \varepsilon_t, \quad z_t=1 \\
s_t = & c_2 + \alpha_{m_2} (m - m^*) + \alpha_{y_2} (y - y^*) + \alpha_{r_2} (i - i^*) + \alpha_{\pi_2} (\pi - \pi^*) + \varepsilon_t, \quad z_t=2 \\
& c_3 + \alpha_{m_3} (m - m^*) + \alpha_{y_3} (y - y^*) + \alpha_{r_3} (i - i^*) + \alpha_{\pi_3} (\pi - \pi^*) + \varepsilon_t, \quad z_t=3
\end{aligned} \tag{48}$$

Increasing evidence suggests that the conditional distribution of nominal exchange rate changes is well described by a mixture of normal distributions and that a Markov-switching model may be a good characterization of exchange rate behaviour (Engel and Hamilton (1990), LeBaron (1992), Engel (1994), Engel and Hakkio (1996), Engel and Kim (1999), Clarida et al. (2003)). One major advantage of the Markov switching model (thereafter MS-VAR) lies in its flexibility (Krolzig, 1997). The model estimated in Givewin 2 (a Windows interface of Ox Professional) can capture one of the following models:

The Real Interest Differential model is nested in the y_t variable ($y_t = [s_t, f_t]'$) in this Markov-switching vector error correction (MS-VECM) model:

$$\Delta y_t = v(z_t) + \Pi(z_t) y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i(z_t) \Delta y_{t-i} + \omega_t, \tag{49}$$

where $\Pi(z_t) = \alpha(z_t) \beta'$, $\omega_t \sim NIID(\mathbf{0}, \Sigma(z_t))$ and $z_t = 1, 2, 3$

Testing for Structural Break Taking note of the Lucas Critique, we have undertaken the test for one possible change (only one due to the econometric difficulty in identifying the

Model	Characteristics captured
MSH	regime-dependent heteroscedasticity
MSI	regime-dependent intercept
MSIH	regime-dependent intercept and heteroscedasticity
MSM	regime-dependent mean
MSMH	regime-dependent mean and heteroscedasticity
MSIA	regime-dependent intercept
MSIAH	regime-dependent intercept and heteroscedasticity
SETAR	(self-exciting) threshold autoregression
SR	switching regression

Table 8: Nested Models in the MS-VECM equation

number of breaks) In the presence of heteroskedasticity¹⁴ (which we rejected at 10% but not 5%), the Chow Test is not valid so the results need to be interpreted with caution.

Rigobon (2000) was one of the first to propose a procedure to test¹⁵ for the stability of parameters when the data exhibits heteroskedasticity, simultaneous equations and omitted variable all at once. His test under bivariate setting performs well (type two error under 10%) under the conditions that the heteroskedasticity is important (the shift in the variance of the variables under study is at least by five times) and the coefficients are not too large (less than 0.80 in the simulations).

¹⁴The VEC Residual Heteroskedasticity Tests with no cross terms (only levels and squares) show the joint test to have the Chi-Square of 369.736 with 330 d.f. and 0.065 probability.

¹⁵The implementation of this test is still under development at MIT.

Change of Policy Thailand adopted monetary targetting from July 1997 to May 2000, thereafter the country's central bank started inflation targetting. According to the data, there are five time frame possibilities for the breaks, measured by the largest percentage change in each variable as recorded in the table below:

The Chow Forecast Test: Forecast from May 2000 to April 2005 shows clear rejection of the null hypothesis of no structural break:

F-Stat	3.8334	Prob 0.001
Log Likelihood Ratio	217.714	Prob 0.000

Table 9: Panel Unit Root Test between Svol and f

	Chow Breakpoint Test	for a break in May 2000
F-Stat	28.5937	Prob 0.000
Log Likelihood Ratio	90.0279	Prob 0.000

Table 10: Panel Unit Root Test between Svol and f

With strong evidence of a structural break, the investigation into the shifts of regimes may now proceed.

Markov Switching Error Correction Procedure A Markov-switching vector equilibrium correction model is a vector equilibrium model with shifts in some of the parameters.

$$\Delta y_t = v(z_t) + \alpha(z_t) [\beta' y_{t-1}] + \sum_{k=1}^{p-1} \Gamma_i(z_t) \Delta y_{t-k} + u_t, \quad (50)$$

where the innovations u_t are conditionally Gaussian, $u_t | z_t \sim NID(0, \Sigma(z_t))$.

The procedure extends, to nonstationary systems, Hamilton's (1988, 1989) Markov switching regime framework. Regimes are reconstructed by inferring the probabilities of the unobserved regimes conditional on an available information set.

As Enders (2004) notes, a principal feature of cointegrated variables is that their time paths are influenced by the extent of any deviation from long-run equilibrium (after all, if the system is to return to long-run equilibrium at all, the movements of at least some of the variables must respond to the magnitude of the disequilibrium). In the error-correction model, the short-term dynamics of the system's variables are influenced by the deviation from long-term equilibrium.

One of the reasons that Hamilton's Markov-Switching model is chosen over the basic threshold model here is that the Hamilton's model specifies regime switches to be exogenous. In contrast to the Threshold Autoregressive (TAR) model (which looks similar in construction), in a Markov-switching model, there are fixed probabilities of a regime change and thus the switching process is actually a first-order Markov process (history—except current state—does not matter). Hamilton (1988, 1989) did not explain the reason why regime changes occur, but since our dependent variable here is constructed based on a monetary model, regime changes in this context occur out of a macroeconomic (and/or behavioral finance) theory¹⁶. Secondly, Hamilton did not explain why regime changes occur when they do. Again in our macroeconomic story, it is easy to see that currency crashes may occur as a result of weak fundamentals or self-fulfilling or a combination of both. What we do not

¹⁶Admittedly, the monetary model is still rather ad-hoc in nature and thus a full investigation into the whole economy specification in terms of an extended real business cycle model follows to complete the whole picture about the real side of the economy, which is not our concern here in *Part I*.

know is why they occur when they do. My task here is to provide evidence that the Thai currency crashes when it does and that there is a strong link to the monetary story ¹⁷ when it does.

The MS-VECM model is closely related to the notion of the multiple equilibria in dynamic economic theory. Each regime is characterized by an attractor of the system defined by the drift $v(z_t)$ and the long-run equilibrium $\mu(z_t)$:

$$\Delta y_t - v(z_t) = \alpha [\beta' y_{t-1} - \mu(z_t)] + \sum_{k=1}^{p-1} \Gamma_k [\Delta y_{t-k} - v(z_t)] + u_t \quad (51)$$

Both Δy_t and $\beta' y_t$ are expressed as deviations from their regime and time-dependent means $v(z_t)$, and $\mu(z_t)$.

In a bivariate setting with one lag, where the long-term relation is determined by the cointegration vector $\beta' = (1:-1)$ and the long-run equilibrium

$$\mu(z_t) = E[y_{1t} - y_{2t}] \quad (52)$$

Each regime m is associated with a particular attractor (μ_m, v_m^*) , given by the equilibrium growth rate v_m^* and the equilibrium mean μ_m .

$$\begin{bmatrix} \Delta y_{1t} - v^*(z_t) \\ \Delta y_{2t} - \gamma - v^*(z_t) \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} (y_{1t-1} - y_{2t-1} - \mu(z_t)) + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad (53)$$

Changes in the state z_t of the currency market are associated with shifts in the common equilibrium growth rate and in the equilibrium mean $\mu(z_t)$. In the case of the nominal

¹⁷See our unrestricted cointegrating vector/equation in the previous section, where the Frankel (1979) RID model is almost fully supported by the Thai data post Asian crisis.

exchange rate the shift in the mean is rare and is henceforth not taken into account.

In the multivariate setup this becomes:

$$\Delta y_t = v(z_t) + \sum_{i=1}^{p-1} \Gamma_i(z_t) \Delta y_{t-i} + \Pi(z_t) y_{t-1} + \varepsilon_t, \quad (54)$$

where $\Gamma_i = -\sum_{j=i+1}^p \Pi_j$ are matrices of parameters, and $\Pi = \sum_{i=1}^p \Pi_i - \mathbf{I}$ is the long-run impact matrix whose rank r determines the number of cointegrating vectors (Johansen (1995), Krolzig (1999)). The larger the matrix Π is, the greater the response of the previous period's deviation from long-run equilibrium. If $\Pi = 0$, the model reduces to one without an error correction or cointegration, i.e. a traditional VAR in first differences since the change in y_t (or Δy_t) does not respond to the previous period's deviation from long-run equilibrium.

Apart from regime shifts in the intercept, shifts may be allowed for elsewhere. The multivariate model of the Thai Baht and the Thai monetary fundamentals comprises of the nominal exchange rate (s_t , or *svol* as in the dataset) or and the monetary fundamentals:

$$y_t = [s_t, f_t]' \quad (55)$$

where f , our fundamentals, is determined on the basis of the real interest rate differential model by Frankel (Frankel, 1979):

$$f = \alpha_m (m_t - m_t^*) - \alpha_y (y_t - y_t^*) - \alpha_r (i_t - i_t^*) + \alpha_\pi (\pi_t - \pi_t^*) + \alpha \quad (56)$$

as hypothesized in Table 1 and coefficients from the first cointegrating equation in the previous section.

$$f = 0.9950 (m_t - m_t^*) - 1.2554 (y_t - y_t^*) + 1.5649 (i_t - i_t^*) - 2.9505 (\pi_t - \pi_t^*) + 42.7317 \quad (57)$$

f , the so-called fundamental term was initially suggested by Mark and Sul (2001) to be thought of as a ‘generic representation of the long-run equilibrium exchange rate implied by modern theories of exchange rate determination.’ Here it is implied by a theory from Frankel (1979) article. Our Equation 57 is estimated from the Frankel (1979) Real Interest Differential theory, a variant of a monetary model. Coefficients are chosen from the Johansen-Juselius regression since the estimated coefficients from the Frankel estimation are not valid. The sum of the coefficients of the nominal interest rate differential and the expected inflation differential comes to $1.5649 - 2.9505 = -1.3856$ with the wrong sign from that hypothesized by the theory—with the decomposed elasticities of 1.5649 and -2.9505 for the liquidity effects and the expected inflation respectively. This thesis improves upon Abhyankar et al. (2004) who estimated only the first two parts (relative money supplies and relative output or income) ¹⁸. In the dataset, I call the nominal exchange rate *svol*, and this will be used interchangeably with s_t in this section to denote the quantity of domestic currency per US Dollar, as opposed to the growth rate or the logarithmic value of the domestic currency.

The cointegrating relation between *svol* and f From the figures below, f_1 (the less volatile series in the top left corner) more plausibly tracks the nominal exchange rate series (*svol*) and is chosen as our starting equation for the switching model. However compared

¹⁸ Abhyankar et al. (2004) however, estimate $\Delta_k s_{t+k} = \alpha + \beta_k u_t + \varepsilon_{t+k}$ (where Δ_k denotes the k -difference operator) in their empirical analysis.

to the observed *svol* which is our nominal exchange rate series, f_1 is still much more volatile. Note that since fundamentals here can be said to reflect the confidence in the nominal exchange rate, the tracked fundamental values can be negative, which just implies the lack in confidence in the currency. Most of the f_1 values are plausible without the market pulling the value to be over or under these raw or fundamental elements.

From the time series plot there is no trend in either series and so the following VAR with two lags (to allow for our monthly data) with no trend in the cointegration space is as follows:

$$x_t = \nu + \sum_{i=1}^2 A_i x_{t-i} + \mu_t, \quad (58)$$

where $x_t = [svol, f]'$.

The equilibrium correction mechanism corresponds to the nonlinearity in the nominal exchange rate literature, which considers the fundamentals as a stock which is adjusted towards the optimal demand of the representative agents in the market. Thus the cointegrating variable $svol_t - f_t$ (hereafter defined as cri_t , shortened from ‘the crisis of confidence in a currency’) can be interpreted as the measurement of how far the nominal exchange rate is from their long-run equilibrium value, which, according to the monetary model assumption in the Frankel model, is the zero mean (no deviation between the two series). Intuitively it can be added that when the nominal exchange rate and the monetary fundamentals co-move, the currency market (which is our unobserved variable) takes a life of its own and pull the nominal rate away from what the fundamentals themselves dictate that it should be in the long run. The plotted values from the two series are given in the graph below

(plotted against the observed nominal exchange rate series, *svol*). As the reader can see ‘the exchange rate according to the fundamentals’ values are very realistic, although varying enormously (and have high peaks in 2000, towards the end of 2003 and early 2005 where the observed nominal exchange rate data show none), they have no non-positive values.

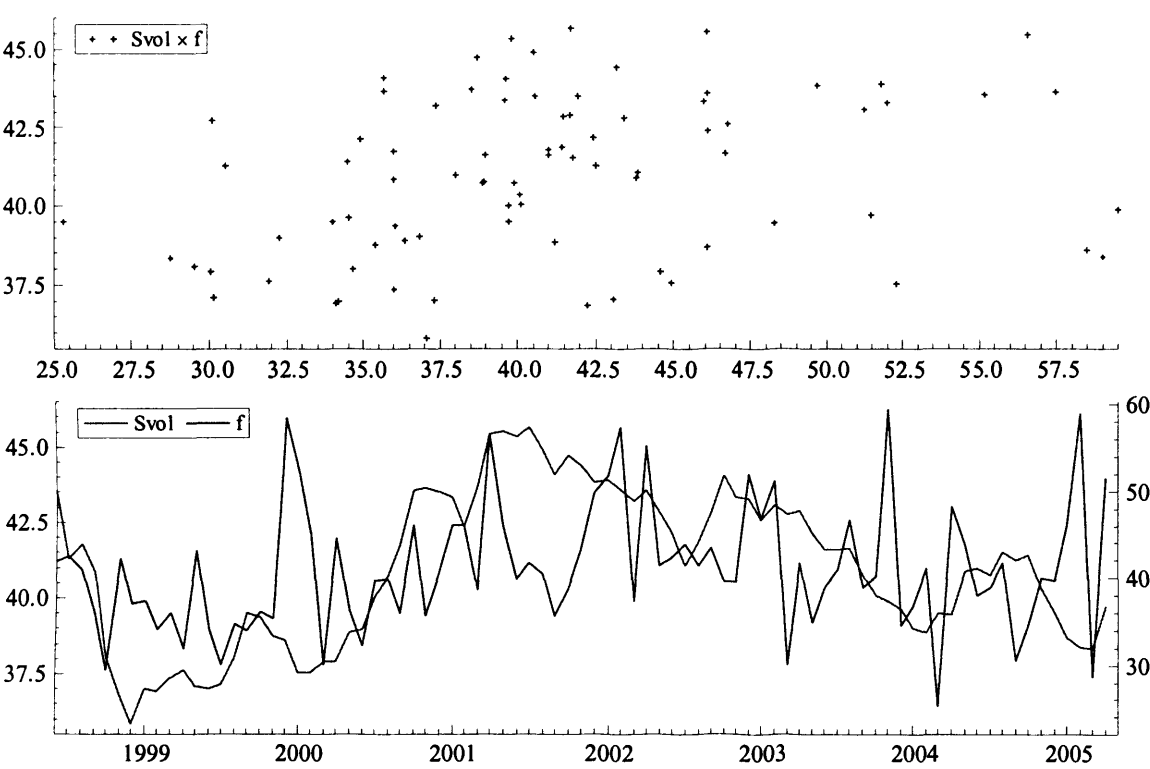


Figure 5: The scattered and time series plots of the nominal exchange rate and the monetary fundamentals

The upper half of Figure shows the scatter plot between the nominal exchange rate (Baht per Dollar, designated *svol*) and what the fundamentals dictate each nominal exchange rate should be (*f*). The lower part of the diagram shows the two series plotted against its own scale (*f* scale on the right hand side). One can see in better detail how *f* fares as opposed to the observed series. Without the help of a more complicated signalling tool, there is little

to gain by observing ex-post how both series evolve.

Hence the monetary model is embedded in the Markov-switching structure. Since there was evidence for a structural break (which maybe more than one, but the determination of the number of breaks is still being developed by econometricians and uses too many observations for our interest here) enables the switch to take place between three different states of the market. In other words, nonlinearity is introduced between three timelines ('crisis' state is induced by outside factors such as Keynes's animal spirits, market sentiment, sunspots, herd behaviour, irrational behaviour in the market, etc.). We will assume here that each trader possesses only the knowledge of the monetary fundamentals and does not have rational expectations. Their behaviour will be illustrated by the 'switching' between processes driven exogenously by a Markov chain.

To implement the more sophisticated Markov Switching vector error correction model, a long run relationship between the nominal exchange rate (*svol*) and the monetary fundamentals as a group (*f*) needs to be established. As we have estimated the individual impact of the individual monetary fundamental series on the nominal exchange rate series, we should then expect that there would be a similarly strong relationship between the nominal exchange rate series and the whole group of the monetary factors. A group unit root test confirms our hypothesis.

**The probabilities for the Fisher tests are computed using an asymptotic chi-square distribution. All other tests assume asymptotic normality.

*** reject at 99% level.

At 95% all except the Hadri test suggest the evidence of the unit root, with stronger evidence on individual unit root processes (at 99%). The Hadri test cannot reject the null

Sample from June 1998 to April 2005			Cross-	
Method	Statistic	Prob**	Sections	Obs
Null: Common Unit Root				
Levin, Lin and Chu t^*	-1.8310	0.0336	2	162
Breitung t-stat	-1.6698	0.0475	2	160
<i>Null: Individual Unit Root</i>				
<i>Im, Pesaran and Shin W-stat</i>	<i>-5.5332</i>	<i>0.0000</i>	<i>2</i>	<i>162</i>
<i>ADF-Fisher Chi-square</i>	<i>36.0184</i>	<i>0.0000</i>	<i>2</i>	<i>162</i>
<i>PP-Fisher Chi-square</i>	<i>36.2480</i>	<i>0.0000</i>	<i>2</i>	<i>163</i>
Null: No common unit root				
Hadri Z-stat	1.1449	0.1261	2	165

Table 11: The Common and Individual Unit Root tests for all variables in Part

hypothesis of no unit root at 10%. So conclusively all tests point to the common unit root among the two variables, *svol* and *f*.

Both the Trace and the Maximum Eigenvalue statistics indicate 1 cointegrating equation at the 95% level.

The Trace rank test		Trace	0.05 Critical	
Hypothesized No. of CE(s)	Eigenvalue	Statistic	Value	Prob.**
None*	0.2641	27.6037	15.4945	0.0005
At most 1	0.0418	3.3760	3.8415	0.0661

Table 12: The Trace test to determine the number of cointegrating equation between *svol* and *f*

Trace test indicates 1 cointegrating equation at the 0.05 level.

* denotes rejection of the hypothesis at the 0.05 level.

** MacKinnon-Haug-Michelis (1999) p-values.

Max Eigenvalue rank test		Max-Eigen	0.05 Critical	
Hypothesized No. of CE(s)	Eigenvalue	Statistic	Value	Prob.**
None	0.3205	30.9082	33.8769	0.1086
At most 1	0.2628	24.3955	27.5843	0.1215
At most 2	0.1656	14.4831	21.1316	0.3267
At most 3	0.0649	5.3641	14.265	0.6953
At most 4	0.0029	0.2338	3.8415	0.6287

Table 13: The Maximum Eigenvalue Rank test for the number of cointegrating equations

Max-eigenvalue test indicates 1 cointegrating equations at the 0.05 level.

* denotes rejection of the hypothesis at the 0.05 level.

**MacKinnon-Haug-Michelis (1999) p -values.

Unrestricted cointegrating coefficients	
(normalized by $b' \cdot S_{11} \cdot b = 1$)	
SVOL	F
-0.2657	0.2401
0.3704	0.0383

Table 14: The unrestricted cointegrating coefficients for SVOL and F

Unrestricted adjustment coefficients	(alpha)	
D(SVOL)	0.1096	-0.1454
D(F)	-4.0450	-0.2392

Table 15: Unrestricted adjustment coefficients (alpha) for D(SVOL) and D(F)

While some research report the difficulty in establishing the empirical significance of the link between monetary fundamentals and the nominal exchange rate due to cumbersome econometric problems (Mark (1995), Kilian (1999), Berkowitz and Giorgianni (2001)), more recent research such as Groen (2000), Mark and Sul (2001), Rapach and Wohar (2002) suggest that the fundamentals described by Equation 56 co-move in the long run with the nominal exchange rate and therefore determine its equilibrium level. Equation 56 implies that the nominal exchange rate and the fundamentals exhibit a common stochastic trend and are cointegrated with cointegrating vector $[1, -1]$ ¹⁹ if the departure from the exchange

¹⁹-1 is a close approximation from the estimate of -0.9 and is used here instead of -0.9 for simplicity in

1 Cointegrating equation:	Log likelihood -351.5751
Normalized cointegrating coefficients	
(s.e. in parentheses)	
SVOL	F
1.0000	-0.9038
	(0.1599)
Adjustment coefficients	
(s.e. in parentheses)	
D(SVOL)	-0.0291
	(0.0228)
D(F)	1.0748
	(0.2131)

Table 16: The cointegrating and adjustment coefficients for SVOL and F

rate-monetary fundamentals relationship $svol - f$ or cri_t is stationary, given that $svol_t$ and f_t are $I(1)$. The cointegration rank $Svol-f$ has been interpreted as a long run deviation from the equilibrium (known as ‘crisis of confidence’ in the domestic currency).

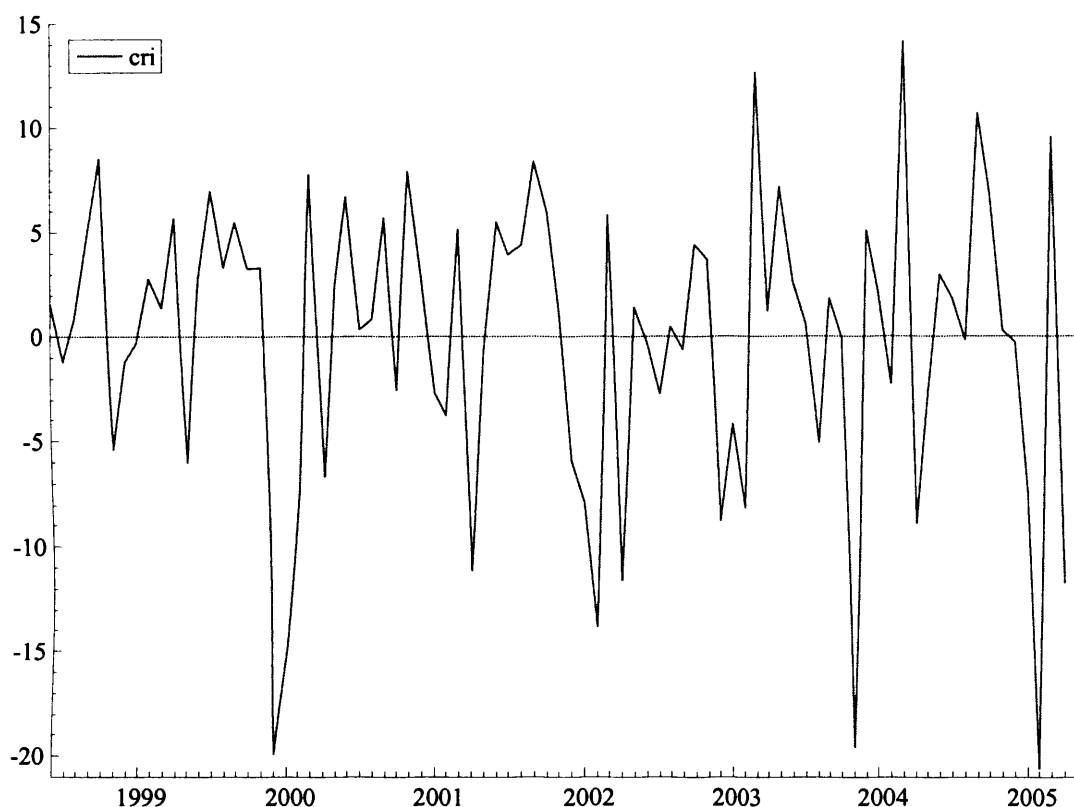


Figure 6: The exogenously-determined (by the Markov chain) variable, cri , representing the crisis in the markov switching model

For a cointegration rank $K-1$ of the K -dimensional system, there is only one stochastic trend in the system and $K-1$ linearly combinations of the data which are stationary. Thus the stochastic trend of the system is given by the monetary fundamentals. While the fundamentals are weakly exogenous for the long run equilibrium, the nominal exchange rate calculation.

adjusts towards equilibrium.

$$\Delta Svol = v_1 + 0.1096(Svol_{t-1} - f_{t-1}) + \dots + \varepsilon_{1t}$$

$$(-0.1454)$$

$$\Delta f = v_2 + \dots + \varepsilon_{2t}.$$

The VAR(p) representation is a finite pure VAR approximation of the VARMA representation of an MS-VAR process. In the co-movement (next) section, the cointegrating vectors are used within the Markov-switching vector equilibrium model, nesting in effect the monetary relations within the context of trader behaviour (Panic, Calm, Positive) in the currency market (specifically the World Market closing spot rates of the Baht against the US Dollar).

The dependent variable, *cri*, is stationary:

Given $s_t, f_t \sim I(1)$, the nominal exchange rate and the fundamentals exhibit a common stochastic trend and are cointegrated with cointegrating vector $[1, -1]$, and thus a unique cointegrating relationship represented by $(s_t - f_t)$ should exist. The cointegrating variable $s_t - f_t$ is the deviation from the long-run equilibrium.

In the business cycle context, the three regimes are quite easily classified, since intuitively output and employment move together. In the exchange rate-fundamental context, the classification of regimes is not quite straightforward as the nominal exchange rate does not always depreciate when fundamentals are favourable (we would expect the opposite to occur).

The MSIAH(3)-VECM(2) is selected for the Thai data, receiving unanimous support from all three of the information criteria and is evidently superior to its linear counterpart. This allows for regime shifts in the intercept, autoregressive, and the heteroskedastic components in the error term. In addition the form switches nonlinearly between three states, and two

Null Hypothesis: CRI has a unit root		
Exogenous: Constant		
Bandwidth: 2 (Newey-West using Bartlett kernel)		
	Adj. t-stat	Probability*
Phillips-Perron test statistic	-8.7611	0.0000
Test critical values: 1% level	-3.5123	
5% level	-2.8972	
10% level	-2.5859	
*Mackinnon (1996) one-sided p-values.		
Residual variance (no correction)		41.1907
HAC corrected variance (Bartlett kernel)		43.3224

Table 17: The Dependent Variable, cri, is stationary



lags. Compare to Equation 50 where a more general form is specified, without the shift (no varying z_t) in the intercept and in the autoregressive term, the MSIAH-VECM in general form is written as follows:

$$\Delta y_t = v(z_t)_t + \sum_{i=1}^{p-1} \Gamma_i(z_t) \Delta y_{t-1} + \Pi(z_t) y_{t-1} + u_t \quad (59)$$

where $\Pi_t = \alpha\beta'$, and $u_t \sim NIID(0, \Sigma(z_t))$, in other words, the disturbance term has heteroskedasticity varying (switching) between states 1, 2, ..., M z_t being the states $z_t \in \{1, \dots, M\}$. An MS-VECM can be estimated using a two-stage maximum likelihood procedure. The first stage of this procedure consists of Johansen (1988, 1991) maximum likelihood cointegration procedure to test for the number of cointegrating relationships in the system and to estimate the cointegration matrix. This was possible without having to explicitly model the Markovian regime shifts (Saikkonen (1992) and Saikkonen and Luukkonen (1997)). The second stage consists of the implementation of an expectation-maximization (EM) algorithm for maximum likelihood estimation that yields estimates of the remaining parameters of the model (Dempster et al. (1977), Hamilton (1993), Kim and Nelson (2000), Krolzig (1999)). The author uses the MSVAR software developed by Hans-Martin Krolzig (Krolzig and Toro, 1999) for post-war business cycle transitions for the US employment and output data and more recently for detecting European Business Cycles (Artis et al., 2004). In both papers some of the parameters in the model change according to the phase of the business cycle, here they change due to unobservable states in the Baht/Dollar currency market, which could be due to shifts in market sentiment/self-fulfilling expectations.

Here in our analytical framework the states are governed by a discrete state Markov

process. The states correspond to different regimes or phases of the currency trade (crisis, high volatility, normal). The state dependent component is simultaneously estimated in a Markov-switching vector-equilibrium-correction model where short- and long-run dynamics are jointly modelled (Krolzig and Toro, 1999). Our nominal exchange rate (the Thai Baht against the US Dollar) and RID fundamentals are found to have a common cyclical component and the long run dynamics are characterized by a cointegrating vector including the nominal exchange rate, monetary fundamental including the real interest differential between the two countries. A three-regime model with changing intercept, and the autoregressive component turns out to be a good description of the data. The regimes correspond to the periods of currency trading where the market is calm, experiencing high volatility in the levels of the currency traded, and when the market experiences a crash.

It is possible to investigate the response of the variables to a change from the ergodic probabilities to a sure state (crisis or normal, say). In this investigation, the dynamics is made richer by having an error correcting term capturing the long run relationship, three regimes and changing intercept and (the autoregressive component in the) variance. The analysis extends to the short run as well as the long run.

It is also noted by Krolzig and Toro (2000) that there is often confusion in the literature about Markov-switching models and non-linearities. The non-linearities in Krolzig and Toro (2000) and in my model stem from the fact that the mean and variance of the process are state dependent. In the MSx-Ax models, the autoregressive parameters are also state dependent. Hence the response of exchange rate and monetary fundamentals to a change from regime 2 to regime 1 is not simply the mirror image with negative coefficients of the response of the variable of a change from regime 1 to regime 2 (in the two-regime case).

In models where the autoregressive parameters are not state dependent, the exchange rate-fundamental comovements can be observed by looking at the path of the exchange rate and monetary fundamentals when moving from the steady-state probabilities to a sure regime. In this case, the conditional expectation in crisis scenarios (regimes) is not the mirror image of the conditional expectation in ‘confident’ periods of the exchange rate-fundamentals co-movement.

The Co-movement of Exchange Rate and RID (Monetary) Fundamentals In the original Hamilton (1989) model of the US business cycle, the Markov-Switching Autoregressive (MS-AR) model is used as an empirical vehicle for characterizing macroeconomic fluctuations. There contractions and expansions are modelled as switching regimes of the stochastic process generating the growth rate of real GNP. Here the ups and downswings of the nominal exchange rates are modelled as switching regimes of the stochastic process generating the growth rate of the Baht Δs_t :

$$\Delta s_t - \mu(z_t) = \alpha_1 (\Delta s_{t-1} - \mu(z_{t-1})) + \alpha_2 (\Delta s_{t-2} - \mu(z_{t-2})) + u_t \quad (60)$$

In the Hamilton setting, regimes are associated with different conditional distributions of the change of the nominal exchange rate, where the mean μ_1 is positive in the first regime (‘crisis’ since the rise in s is the loss in value given the definition (the number of the domestic currency units per a foreign currency unit) and negative in the second (‘bull’ market, where the domestic currency gains in value against the foreign currency). The variance of the disturbance term, $u_t \sim NID(0, \sigma^2)$, is assumed to be the same in both regimes. The general idea behind the Hamilton class of regime-switching models is that the parameters

of a VAR depend upon a stochastic unobservable regime variable $z_t \in \{1, \dots, M\}$. The stochastic process generating the unobservable regimes is an ergodic Markov chain defined by the transition probabilities:

$$p_{ij} = \Pr(z_{t+1} = j \mid z_t = i), \quad (61)$$

$$\sum_{j=1}^M p_{ij} = 1, \forall i, j \in \{1, \dots, M\}.$$

Earlier we applied Johansen's cointegration analysis to a VAR with 2 lags:

$$y_t = v + \sum_{i=1}^2 A_i y_{t-i} + u_t$$

where $y_t = [s : f]'$ for the long run equilibrium $s_t - \gamma f_t = cri_t$. $\gamma = 0.9$ or approximately

1 from the cointegrating equation. In economic terms, the cointegrating combination

$$cri_t = s_t - f_t \quad (62)$$

reflects the long run nominal exchange rate change due to the accumulation of the fundamental 'values' (in Baht terms), the bigger the values, the more crisis of confidence, and this has been termed cri_t .

The class of MS-VECM(2) models with shifts in the intercept ν is the outcome of the model selection procedures for the lag length 2. Following Krolzig's (1996) two-stage procedure, the cointegration results from the last section are used on this stage of our analysis:

$$\Delta y_t = v(z_t) + \Gamma_1 \Delta y_{t-1} + \alpha cri_{t-1} + u_t, \quad u_t \sim NID(0, \Sigma(z_t)) \quad (63)$$

where $cri_{t-1} = s_{t-1} - f_{t-1}$ has been normalized such that $E[cri_t] = 0$.

The equilibrium correction mechanism considers the fundamentals as a stock which is partially adjusted towards the optimal money demand of consumers.

f_t is the long-run equilibrium of the nominal exchange rate, determined by the monetary fundamentals.

t is a time subscript.

Our fundamentals, based on Frankel (1979) model is given by:

$$f = \alpha_m (m_t - m_t^*) - \alpha_y (y_t - y_t^*) - \alpha_r (i_t - i_t^*) + \alpha_\pi (\pi_t - \pi_t^*) + \alpha \quad (64)$$

as hypothesized in Table 1 and coefficients from the first cointegrating equation in the previous section.

$$\hat{f} = 0.9950 (m_t - m_t^*) - 1.2555 (y_t - y_t^*) + 1.5649 (i_t - i_t^*) - 2.9505 (\pi_t - \pi_t^*) + 42.7317 \quad (65)$$

f , the so-called fundamental term was initially suggested by Mark and Sul (2001) to be thought of as a ‘generic representation of the long-run equilibrium exchange rate implied by modern theories of exchange rate determination.’ Here it is implied by a theory from the Frankel (1979) article. Our Equation 65 is derived from Frankel (1979) Real Interest Differential theory, a variant of a monetary model. Coefficients are chosen from the Johansen-Juselius regression since the estimated coefficients from the Frankel estimation are not valid. The sum of the coefficients of the nominal interest rate differential and the expected inflation differential comes to $1.5648 - 2.9504 = -1.3856$ with the wrong sign from that hypothesized by the theory—with the decomposed elasticities of 1.5648 and -2.9504 for the liquidity effects and the expected inflation respectively. This thesis improves upon

Abhyankar et al. (2004) who estimated only the first two parts (relative money supplies and relative output or income) ²⁰. The cointegrating variable $s_t - \gamma^{21} f_t$ can be interpreted as a fundamentals-based measurement of the nominal exchange rate's long run deviation from equilibrium.

While some research report the difficulty in establishing the empirical significance of the link between monetary fundamentals and the nominal exchange rate due to cumbersome econometric problems (Mark (1995), Kilian (1999), Berkowitz and Giorgianni (2001)), more recent research such as Groen (2000), Mark and Sul (2001), Rapach and Wohar (2002) suggest that the fundamentals described by Equation 65 co-move in the long run with the nominal exchange rate and therefore determine its equilibrium level. Equation 63 implies that the nominal exchange rate and the fundamentals (hidden in the term cri_{t-1}) exhibit a common stochastic trend and are cointegrated with cointegrating vector $[1, -1]$ if the departure from the exchange rate-monetary fundamentals relationship u_t is stationary, given that s_t and f_t are $I(1)$.

The intuition behind the use of the MS-VAR model in this exchange rate-monetary link literature is as follows. As the business cycle is defined as the comovement of macroeconomic series, so is the nominal exchange rate defined to comove with the monetary fundamentals (for which we have found strong evidence). Also in the MS-VAR there is an unobserved state driven by an ergodic Markov process common to the series. This could be interpreted that if we were to take the link between the nominal exchange rate and the monetary

²⁰ Abhyankar et al. (2004) however, estimate $\Delta_k s_{t+k} = \alpha + \beta_k u_t + \varepsilon_{t+k}$ (where Δ_k denotes the k -difference operator) in their empirical analysis.

²¹ $\gamma = -1$ or -0.9 from the cointegrating equation estimate. -1 is used throughout for simplicity.

factors seriously (in other words that the monetary fundamentals are the underlying forces driving the nominal exchange rate) then the unobserved state common to the monetary fundamentals is assumed to also to be the driving force behind the nominal exchange rate. By generating the dynamic factor structures in the form of MS-VAR, this research strategy provides a synthesis of the dynamic factor and the non-linear approach for the modelling of macroeconomic fluctuations (Krolzig, 2001).

The Hamilton's application is hereby improved upon and the third regime (state, z_t) introduced, since two regimes are too restrictive. A number of authors including Arias and Erlandsson were to settle for two states, tranquil and crisis, in their application of the early warning system for the nominal exchange rate in six South-East Asian countries including Thailand. My result differs from theirs in that after 1999, the Baht found itself in two further 'crises of confidence'²² between May to July 2002 and in April 2005.

The regimes are associated with different conditional distributions of the change in the log level or the growth rate of the nominal Thai-US dollar exchange rate, where the mean μ_1 is positive in the first regime ('bear' or 'crisis,' state where the Baht suffers a large negative shock which results in a drop in value since *svol* is defined as the number of Bahts per 1 US Dollar) and negative in the second regime (or the Bull or 'high-volatility' market, where the Baht strengthens). Where there are three regimes, the middle (second) regime designates the normal, sometimes with high volatility market, $\mu_1 < 0$, and instead our third regime

²²Since the Baht has been devalued and the fixed exchange rate system abandoned, the author classifies the currency crisis as the loss in the confidence in the Baht against the US Dollar, to which the value of the Baht was closely tied in the fixed exchange rate system where a basket of major trading partners' currencies contributed to the value of the Baht before the 2nd July, 1997.

depicts the calm situation where the shock μ_1 is zero. The variance of the disturbance term, $u_t \sim NID(0, \sigma^2)$ is assumed to be the same in both regimes.

Changes in the state z_t in the currency trading are associated with shifts in the common equilibrium growth rate and in the equilibrium mean $\mu(z_t)$. Regime shifts are persistent ($p_{ij} \neq p_{ii}$ for some i, j) but not permanent ($p_{ii} \neq 1$ for all i) for an ergodic and irreducible Markov chain. MS-VECM exhibit equilibrium as well as error correction mechanisms: in each regime disequilibria are adjusted by the vector equilibrium correction mechanisms. Since the regimes themselves are generated by stationary irreducible Markov chain, the errors arising from regime shifts themselves are corrected towards the stationary distribution of the regimes.

As pointed out by Krolzig and Toro (1999), the assumed properties of the Markov chain have important implications for the analysis of the long-run properties of the system. Cointegrated systems with Markovian regime shifts can be characterized as non-Gaussian cointegrated VARs of infinite order. This property of cointegrated MS-VAR processes allows the author to base the cointegration analysis of such data generating processes (DGPs) on procedures available for infinite order VARs. This concept came from Krolzig (1996), there a limited information approach to cointegration was proposed using a pure finite-order VAR approximation of the underlying DGP without modelling the Markov switching of the first stage. Conditional on the cointegration matrix, the remaining structural parameters are estimated in the second stage. By following Krolzig (1996)'s two-stage procedure, the cointegration properties of the data are studied within a linear vector autoregressive representation using maximum likelihood techniques. The analysis is based on the existence of a finite-order VARMA representation for MS-VAR models.

The first stage of the maximum likelihood procedure involves approximating the VARMA with a finite-order VAR model and applying Johansen's maximum likelihood procedure (Johansen, 1995b). In the second stage, conditional on the estimated cointegrated matrix, the remaining parameters of the vector equilibrium correction representation of the MS-VAR process are estimated with the Expectation Maximization (EM) algorithm (Dempster et al., 1977). Johansen's cointegration analysis was applied to a VAR with 2 lag (see Table 18).

A multivariate ARMA analysis is undertaken with $y = [Ds, Df]'$ as our dependent variable and u as our exogenous, with two dummies, one called IMF, designating the periods (months) described the Baht as being in currency crisis (July 1997-January 1999: June 1998-January 1999 being our sample). Since there was strong evidence of the structural break in May 2000, when the Bank of Thailand switched to an inflation target (as opposed to the monetary target since July 1997), another dummy variable (hereby called D2000M5). S3 designates the starting values of the unobservable states.

The values of the starting dummy S3 are given according to this rule. First of all, 0 denotes regime 1, 1 denotes regime 2, and 2 denotes regime 3. Second of all, the initial dummy values for S3 are given according to the $DSvol$, whether the first difference from the last period has been positive (a fall in confidence in or value of currency from the last period), zero (no change), or negative (an increase in confidence in the domestic currency value). The Figure above plots the first difference compared to the IMF defined currency crisis dummy.

Initial state values for all 3 regimes (scenarios) *Regime 1: Crisis of Confidence*
in Currency Value are allocated to all other periods except the following periods:

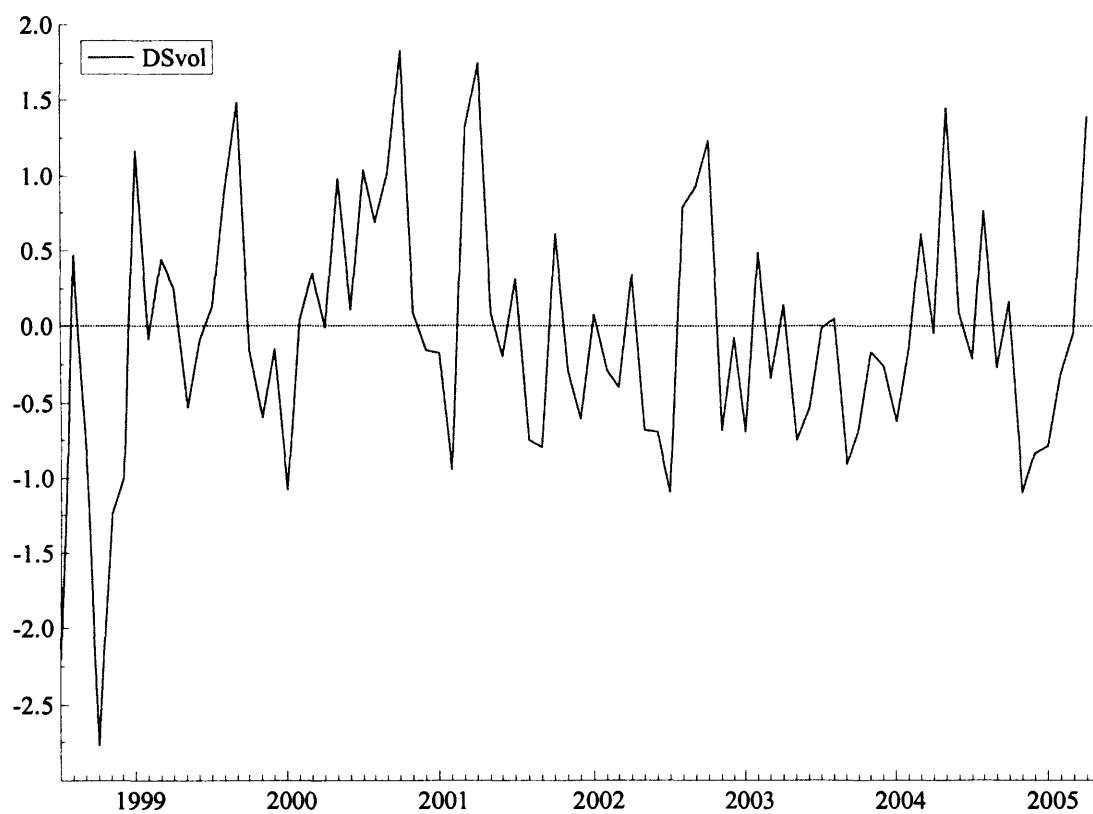


Figure 7: The first difference of the nominal exchange rate as a component of the dependent variable in the Markov-switching model

Regime 2: calm, no drastic change in confidence in the domestic currency: 1999M3–M4, 2000M10–12, 2001M9, 2002M2, 2002M5, 2003M7, 2003M11, 2005M1.

Regime 3: Confidence in Currency: 1999M1–M2, 2000M1–M9, 2001M2–M7, 2003M2, 2004M2–M5, 2004M8–M10, 2005M3–M4.

The maximum likelihood estimation is then computed in GiveWin. The variable is then placed in the adjacent column to that of the first difference in the nominal exchange rate (Ds) and the first difference in the RID monetary fundamentals (Df). Hence the input file has the following format (columns representing variables and rows representing observations:

Observations	Dsvol	Df	u	IMF	D2000M5	S3
1998 - 7	-2.2	0.578422	-1.20599	1	0	1
.
2005 - 4	0.69	0.177981	0.83146	0	1	2

Table 18: The Layout of the Input File in GiveWin

The state dimension M of the Markov chain and the order p of the autoregression are selected on the basis of the $\text{ARMA}(p^*, q^*)$ -representation of $\text{MSM}(M)$ - $\text{AR}(p)$ and $\text{MSI}(M)$ - $\text{AR}(p)$ processes. The Akaike information criterion (AIC) and the Schwarz criterion (SC) were employed to assist in choosing the appropriate order of the $\text{ARMA}(p, q)$ processes. With these results, one is able to select MS models which could have generated the selected ARMA representation and thus can be expected to be consistent with the data.

In the class of $\text{MSI}(M, q)$ - $\text{AR}(p)$ models, under regularity conditions, the $\text{ARMA}(p^*, q^*)$ representation corresponds to a unique generating $\text{MSI}(M, q)$ - $\text{AR}(p)$ process. The selected MSM-AR and MSI-AR models are hereby considered as take-off points as suggested by

Krolzig (1997) for the estimation of more general MS models. The next step involves estimating $MSM(M)$ -AR(p) and $MSI(M)$ -AR(p) models and then compared with the resulting classifications of the nominal exchange rate movements (crash, high volatility, normal periods).

The introduction of error correction (Engle and Granger (1987)) Differencing is sensitive to short-term noise components and biased estimates when series have long-run equilibrium relationship. With differencing, $y_t = \gamma x_t + \mu_t$ becomes $\Delta y_t = \gamma \Delta x_t + \varepsilon_t$ but $\varepsilon_t = \mu_t - \mu_{t-1}$ and μ_t and μ_{t-1} are not independent when a long-run equilibrium between y and x exists²³. When a linear combination between 2 integrated variables results in a stationary error term, y_t and x_t are said to be cointegrated. Cointegration can be viewed as the statistical expression of the nature of equilibrium relationships. Variables may drift apart in the short run but, if they diverge without bound, no equilibrium relationship could be said to exist. Hence, in this context, economic significance can be defined in terms of testing for equilibrium and an interpretation of cointegrated variables is that they share a common stochastic trends (Stock and Watson, 1988).

Cointegration implies an error-correction model (by Granger Representation Theorem), which is superior to modelling integrated data in first-differences or in levels (Engle and Granger, 1987). Rearranging dynamic model in this form gives stationary variables as well as a clear long-run component (if cointegration exists). In a general error correction model:

²³For example, if one shocks μ_t at time t , future y 's cannot merely 'grow along' with x (i.e. $\mu_{t+i} = 0$ and $\varepsilon_{t+i} = 0$) when an equilibrium relationship in their levels exists. The gap between y and x must be closed.

$$\Delta y_t = \delta_1 (L) \Delta y_{t-1} + \omega_1 (L) \Delta x_{t-1} + \gamma_1 z_{t-1} + \mu_{1t} \quad (66)$$

$$\Delta x_t = \delta_2 (L) \Delta y_{t-1} + \omega_2 (L) \Delta x_{t-1} + \gamma_2 z_{t-1} + \mu_{2t}, \quad (67)$$

The dynamic structure is captured by the difference terms, while the correction term z_{t-1} captures the levels (long run) information. There is a need to use lags to circumvent simultaneous equation problems (as in the VAR models and in the link between reduced form and structural models). By examining the data, the appropriate number of lags of the variables can be determined, as in Table 18.

Initial values calculation From Equation 62 and Equation 65 respectively, the values of f_t and thus cri_t are obtained. cri_t are the deviation from the fundamental-determined equilibrium, and f are the values of those fundamentals determining it. In order to test the multivariate MS-VECM, both s_t and f_t as dependent variables have to be first-differenced (as dictated by the error-correcting format). The dependent variable ‘crash’ is subsequently generated. Equation 63 says that if the departure from the exchange rate-monetary fundamentals relationship cri_t is stationary, given $s_t, f_t \sim I(1)$, the nominal exchange rate and the fundamentals exhibit a common stochastic trend and are cointegrated with cointegrating vector $[1, -0.9038]$ or $[1, -1]$ in the MS calculation. By the Granger representation theorem (Engle and Granger, 1987), the nominal exchange rate and the fundamentals must possess a VECM representation in which cri_t play the part of the equilibrium error. A linear VECM is used to show the relative importance of the nominal exchange rate and the fundamentals in restoring equilibrium in the long-run relationship linking exchange rates and fundamentals

during the recent floating period of the Thai Baht. A generalized standard linear VECM, which is capable of allowing all the VECM parameters to change over time and identify the various states (calm, high volatility, and crash) that characterize the sample period in this study. In order to capture the movements of the nominal exchange rate and fundamentals, Equation 62 is used as a basis for estimating regime switching, in order to measure changes in monetary fundamental scenarios and see how that affect the nominal exchange rates in the floating period for the Thai Baht since July 1997. Krolzig (1997, 1999) MS-VAR package for Ox enables the regime shifts/switches to occur anywhere within the vector autoregression. His program enables us to explore a possibility that shifts in monetary fundamentals could potentially contribute to a currency crash and in the MS-VECM specification, allowances were made with regard to the equilibrium as well as error correction mechanisms, as in each regime disequilibria are adjusted by the vector equilibrium correction mechanism. Since the regimes themselves are generated by stationary irreducible Markov chain, the errors arising from regime shifts themselves are corrected towards the stationary distribution of the regimes²⁴. We first test the null hypothesis whether the Markov Switching which is a nonlinear alternative is indeed superior to their linear counterpart.

For 2 regimes and 2 lags (values in brackets are those of their linear counterpart)

The diagnostic tests for the Markov-switching model for 2 regimes and 2 lags are given in Table 21. The model with higher log likelihood is preferred to that with lower, whilst the

²⁴Cointegrated systems with Markovian regime shifts can be characterized as non-Gaussian cointegrated VARs of infinite order. This property of cointegrated MS-VAR processes allows for the cointegration analysis of such data generating processes on procedures available for infinite order VARs (Krolzig, 1996).

model with lower information criteria is preferred to those higher. \succ is used to indicate 'is preferred to.' and \prec indicates 'less preferred to.'

† the linearity test is not implemented for the MSxAx process.

** significant using the corresponding χ test with the corresponding degrees of freedom.

The Linearity test compares the nonlinear MSVECM to a linear VECM, sometimes evoking the Upperbound of Davies (1977, 1987).

The AIC and HQ criteria agree that the best model is the MSMH, whilst the Log Likelihood criteria has the fully specified MSIAH perform best (and also performing best in comparison to their linear counterpart). Hence from the class of 2 regimes and 2 lags, the MSMH performs best for the Thai data³⁴.

Since the autoregressive parameters are the same between the two regimes, the probabilities of the crises periods are the mirror images of those of the periods of confidence in the currency. This is not the case with the MSxAx, where the autoregressive parameters are regime dependent.

The fit for fundamentals is better than that of the nominal exchange rate.

As the reader can see the two-regime does not tell us very much, namely, the tool only signals whether to stay in Baht or out of the domestic currency (switch to Dollar). With the introduction of a middle regime, the normal (or calm) period, the currency trader is able to just leave the assets in the domestic currency, and the duration of such position is also determined by the model. As far as the currency holding is concerned, the estimates from the Markov switching error correction model are on the conservative side (and even too

³⁴The software is developed by Hans-Martin Krolzig at Kent University and associate researcher at Nuffield College, Oxford. The working paper associated with this software development is Krolzig (1998).

Model	Log-Likelihood	AIC	HQ	SC	Linearity Test
	(vs linear)	(vs linear)	(vs. linear)	(vs linear)	
MSH	-350.1533	9.2538	9.4926	9.8493	13.2534 ²⁵
	(γ -356.7800)	(γ 9.2945)	(\prec 9.4736)	(\prec 9.7411)	
MSI	-351.4443	9.2611	9.4879	9.8268	10.6714 ²⁶
	(γ -356.7800)	(γ 9.2945)	(\prec 9.4736)	(\prec 9.7411)	
MSIH	-345.4143	9.1854	9.4480	9.8404	22.7313 ²⁷
	(γ -356.7800)	(γ 9.2945)	(γ 9.4736)	(\prec 9.7411)	
MSM	-351.4199	9.2605	9.4873	9.8262	10.7202 ²⁸
	(γ -356.7800)	(γ 9.2945)	(\prec 9.4736)	(\prec 9.7411)	
MSMH	-344.7305	9.1683	9.4309	9.8233	24.0989 ²⁹
	(γ -356.7800)	(γ 9.2945)	(γ 9.4736)	(\prec 9.7411)	
MSA	-347.8197	9.3705	9.6928	10.1744	17.9205 ³⁰
	(γ -356.7800)	(\prec 9.2945)	(\prec 9.4736)	(\prec 9.7411)	
MSIA†	-345.7729	9.3693	9.7155	10.2328	22.0141† ³¹
	(γ -356.7800)	(\prec 9.2945)	(\prec 9.4736)	(\prec 9.7411)	
MSAH†	-345.9099	9.3977	9.7559	10.2910	21.7400† ³²
	(γ -356.7800)	(\prec 9.2945)	(\prec 9.4736)	(\prec 9.7411)	
MSIAH†	-336.3480	9.2087	9.5907	10.1615	40.8640† ³³
	(γ -356.7800)	(γ 9.2945)	(\prec 9.4736)	(\prec 9.7411)	

Table 19: Model selection: 2-regime case

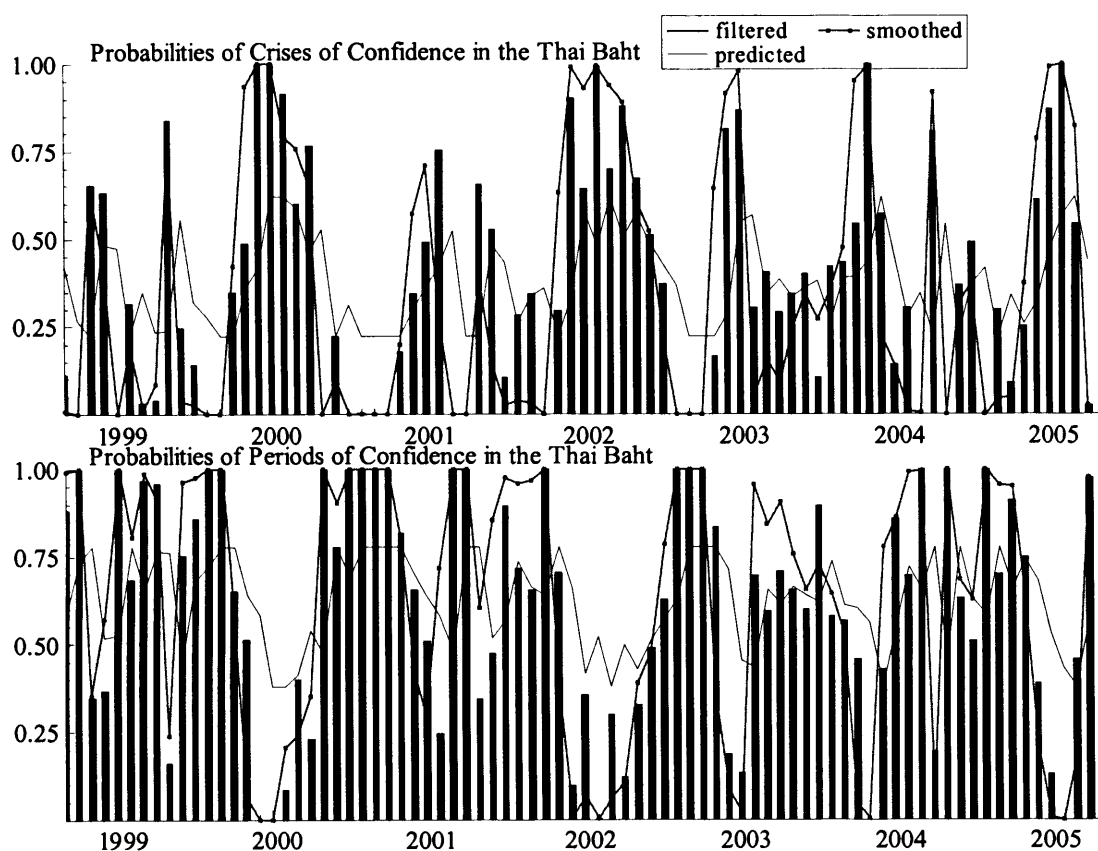


Figure 8: The best performance in detecting a two-regime market has a switch in both the mean and the heteroskedasticity

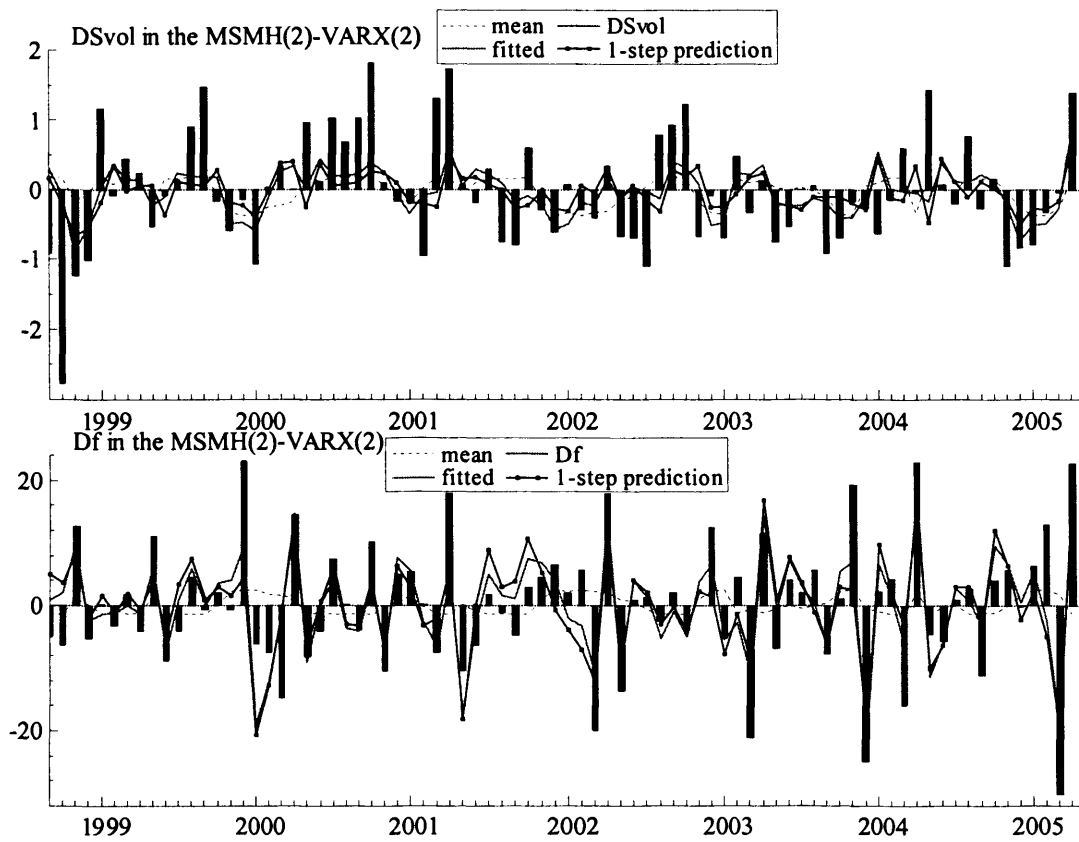


Figure 9: The mean, fitted, and 1-step prediction for the MSMH model

conservative in the two-regime specification). For those reasons we now turn to consider the three-regime Markov switching models.

For 3 regimes and 2 lags (values in brackets are those of their linear counterpart)

The model selection criteria from the three-regime estimation is in the table immediately below. In the three-regime case, the best performer is the fully specified model, with the intercept, the autoregressive parameters and the heteroskedasticity depending on the state or regime (where the ‘switch’ occurs).

Note The best performing model for the two-regime case did not solve for the three-regime one as the decomposition failed in the `invertsylm` and in `choleski` functions.

‡ contemporaneous correlation failed.

** significant using the corresponding χ test with the corresponding degrees of freedom.

Model	Log-Likelihood	AIC	HQ	SC	Linearity Test
	(vs linear)	(vs linear)	(vs linear)	(vs linear)	
MSH	-338.5659	9.1391	9.4615	9.9431	36.4282 ³⁵
	(γ -356.7800)	(γ 9.2945)	(γ 9.4736)	(γ 9.7411)	
MSI	-344.1448	9.2286	9.5271	9.9730	25.2703 ³⁶
	(γ -356.7800)	(γ 9.2945)	(γ 9.4736)	(γ 9.7411)	
MSIH	-331.9137	9.0728	9.4429	9.9959	49.7324 ³⁷
	(γ -356.7800)	(γ 9.2945)	(γ 9.4736)	(γ 9.7411)	
MSM	-344.7259	9.2431	9.5416	9.9875	24.1081 ³⁸
	(γ -356.7800)	(γ 9.2945)	(γ 9.4736)	(γ 9.7411)	
MSA	-328.3680	9.2342	9.7237	10.4550	56.8238 ³⁹
	(γ -356.7800)	(γ 9.2945)	(γ 9.4736)	(γ 9.7411)	
MSIA	-331.8350	9.4209	9.9581	10.7608	49.8899 ⁴⁰
	(γ -356.7800)	(γ 9.2945)	(γ 9.4736)	(γ 9.7411)	
MSAH‡	-308.7691	8.8942	9.4553	10.2937	96.0217 ⁴¹
	(γ -356.7800)	(γ 9.2945)	(γ 9.4736)	(γ 9.7411)	
MSIAH	-281.0461	8.3012	8.9100	9.8197	151.4678⁴²
	(γ -356.7800)	(γ 9.2945)	(γ 9.4736)	(γ 9.7411)	

Table 20: Model selection: 3-regime case

The results from fitting the MSIAH-VARX is as follows:

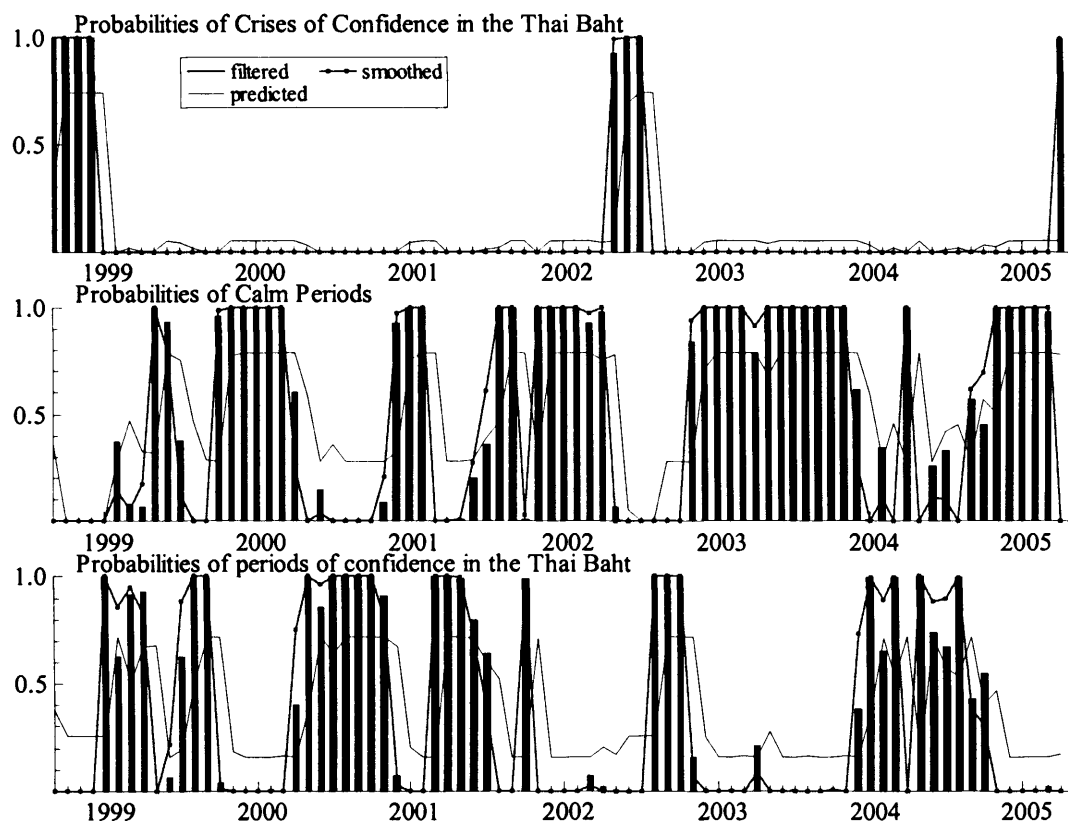


Figure 10: The best performing model for the three-state market is the fully specified MSIAH model

This multivariate result dates the crisis to be very close to that defined by the International Monetary Fund, namely, at the beginning of the sample period. Additional crisis periods are dated as occurring between May-July 2002 and in April 2005, the last period saw a hike in world petrol prices which also contributed to the weakening of the Baht against the Dollar. A look back at the Bank of Thailand's bimonthly Economic and Monetary report in May 1997 and July 1997 showed that there was no concern about the economy in general and the value of the Baht in particular, the Baht actually *strengthened* towards the end of

June 1997—and that there was a false alarm in our detection mechanism.

In the three states (regimes), all criteria are unanimous in the fully specified model being the best performer. This decision is supported by Psaradakis and Spagnolo's (2003) Monte Carlo analysis which reveals that such procedures⁴³ estimate the state dimension correctly, provided that the parameter changes are not too small and the hidden Markov chain is fairly persistent.

The results from fitting the MSIAH-VARX is as follows:

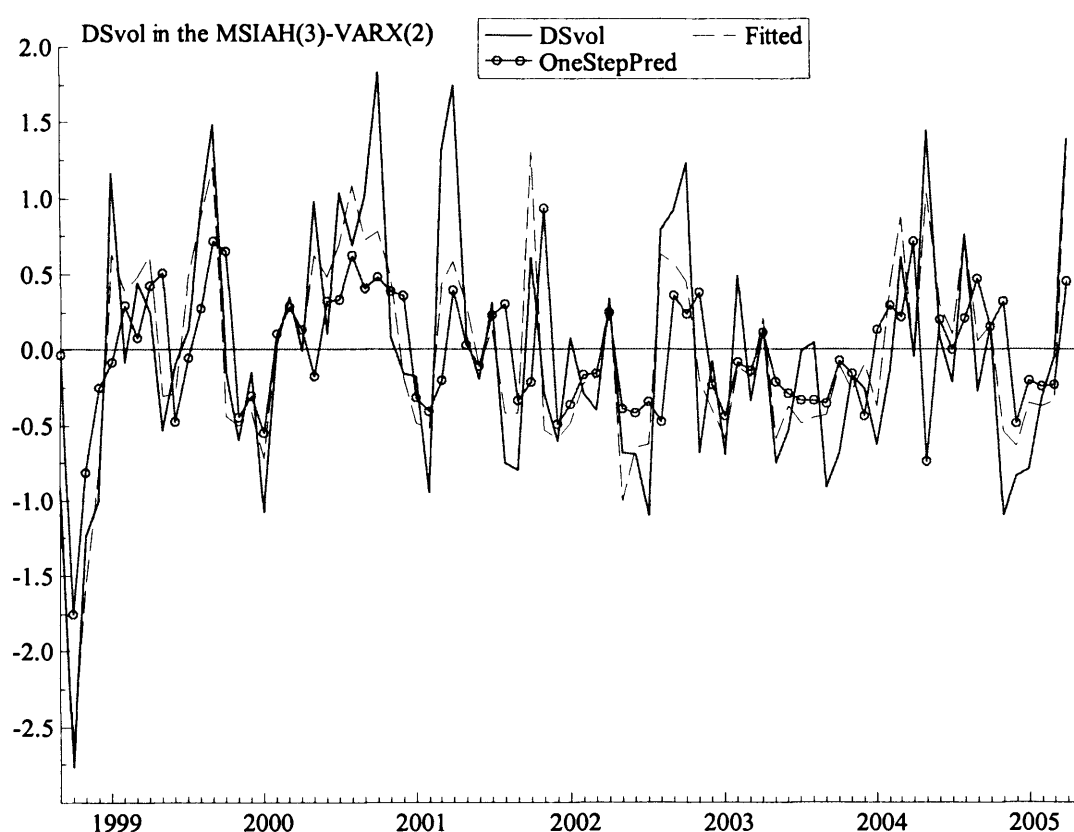


Figure 11: The first dependent variable DSvol in the multivariate Markov-switching, error-correcting model

⁴³ARMA representation which Markov-switching processes admit, as well as procedures that are based on optimization of complexity-penalized likelihood measures.

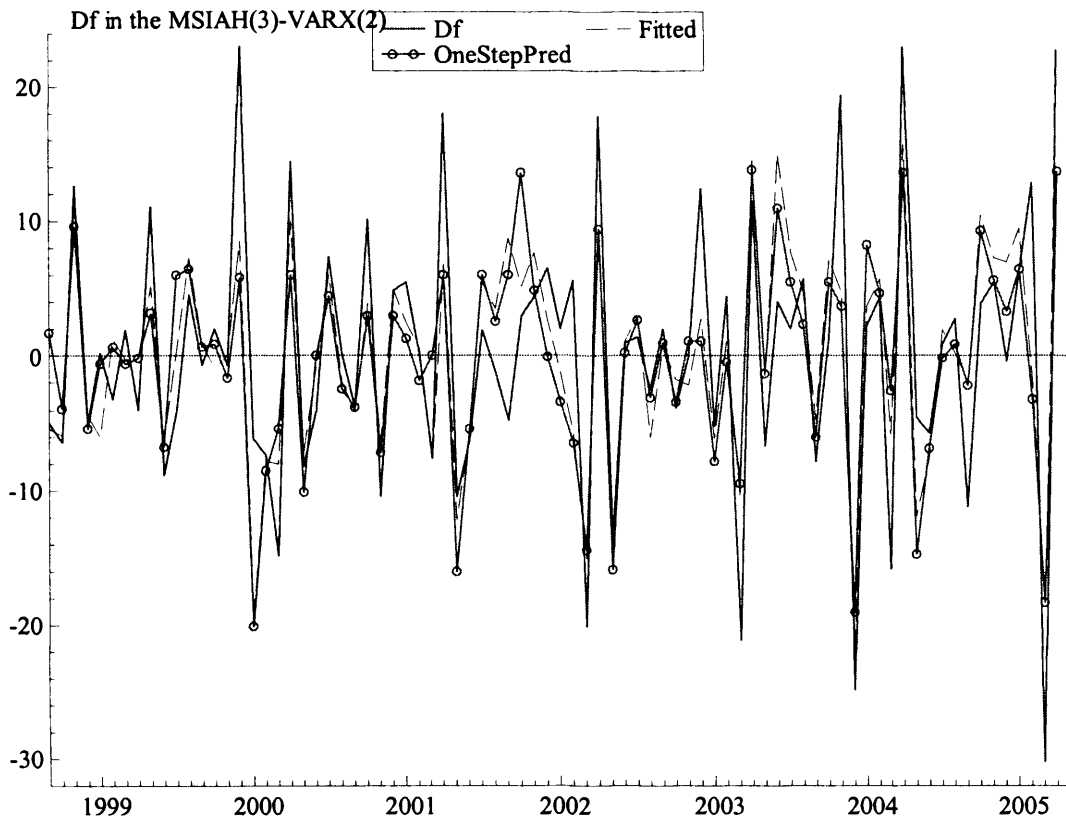


Figure 12: The second multivariate dependent variable Df , in the Markov-switching, error-correcting model

$$\text{Transition matrix} = \begin{matrix} & \begin{matrix} \text{Regime 1} & \text{Regime 2} & \text{Regime 3} \end{matrix} \\ \begin{matrix} \text{Regime 1} \\ \text{Regime 2} \\ \text{Regime 3} \end{matrix} & \begin{pmatrix} 0.7415 & 0.0000 & 0.2585 \\ 0.04943 & 0.7906 & 0.1599 \\ 0.0000 & 0.2814 & 0.7186 \end{pmatrix} \end{matrix}$$

Note: $p[i][j] = \Pr\{s(t+1) = j | s(t) = i\}$

The transition matrix allows us to observe the asymmetry of the currency crisis (a fall in a value of the currency in greater magnitude than a rise in value of the same currency), if the autoregressive parameters had been state-dependent, the asymmetry test results would

have been shown here. Since we know that each state travels to the next depending on the attractor, a low-probability state always moves to that of a higher probability state. By looking at the magnitude of each element in the transition matrix, one can then deduce that each state is persistent, 70% of the time, the market stays in the same state. 25% of the time the market jumps from a favourable state to a crisis state. If the market is calm, then it stays calm with nearly 80% probability. If it starts off in crisis then it will switch to a calm state and stays there. If the market starts off favourable, then it can either move to a calm market (28%) or stays in the favourable state (71%).

	No. of Obs.	Probability	Duration
<i>Regime 1</i>	8.0	0.0988	3.87
<i>Regime 2</i>	41.4	0.5167	4.78
<i>Regime 3</i>	30.6	0.3845	3.55

Table 21: The number of occurring regime, the probability of that happening and how long it lasts

The probability of the Baht facing the crises of confidence is 9.88%, with the investors panicking 8 times, lasting 3.87 months in total. The probability of calm markets is more than half of the time (51.67%), with 41 occurrences, lasting 4.78 months (just over 19 weeks) in total. The probability of favourable markets when the investors are confident in the Baht is over one thirds of the time (38.45%), for approximately as long a duration as the crises periods. Note that the overall degree of persistence in the Markov-switching model depends on the autoregressive parameters *and* the transition probabilities, thus, if the autoregressive parameter of regime 1 is greater than that of regime 2 *and* the transition

probability from state 1 to state 1 (in our case from a crisis to another), p_{11} , is large, the process will tend to remain in the regime with substantial autoregressive persistence. If the transition probability from state 2 to state 2 (from a calm market to another) is small, the system will have a tendency to switch into regime 1 from regime 2 in the two-state case, and in our 3-regime case, from the transitional probability matrix, the system is likely or has a tendency to switch from state 2 to 1, state 3 to 2, and state 2 to 3 (state with larger probability being a relatively more globally optimal and acts as an attractor). In other words, as our autoregressive parameter for the nominal exchange rate is larger in Regime 1 (crisis state) -0.008 (see Table below) and the transition probability from one crisis to another is very large (93.75%), by this Hamilton (1989) Markov-switching setup, the system has a tendency to switch into a crisis state from a high volatility state (2 to 1), calm to high volatility (3 to 2), and high volatility to calm (2 to 3), but not otherwise (not, for example, from a calm state to a crisis or 3 to 1, or from a crisis to a high volatility state where currency appreciates in value straight after a currency crash). Similarly for the monetary fundamental autoregressive parameter below, the mean in Regime 1 (crisis state) is large and the transitional probability from crisis to crisis very large (97%), the system is likely to find the monetary fundamentals being attracted to a crisis state, with the movements in and out of states having the same directions (2 to 1, 3 to 2, and 2 to 3) as in the same transitional probability matrix as that of the nominal exchange rate.

The Maximum Likelihood estimation results are as follow (significant statistics at 95% in bold⁴⁴):

The adjustment coefficient represents the mean reverting or error-correcting to the long-

⁴⁴where the t -value for our 80 samples is 1.99.

	MSIAH(3)-VAR(2)	
	$\Delta Svol$	Δf
Regime-dependent intercepts		
ν_1	-2.3708	-12.9735
	(0.2196)	(0.7380)
ν_2	-0.3016	0.5611
	(0.0603)	(1.2700)
ν_3	0.6141	-2.1990
	(0.1148)	(0.8752)
Adjustment coefficients		
α	0.1096	-4.0450
t -values	(-0.1454)	(-0.2392)
Regime 1: Variance		
$\Delta Svol$	0.0639	
Δf		0.7218
Regime 2: Variance		
$\Delta Svol$	0.1056	
Δf		55.0490
Regime 3: Variance		
$\Delta Svol$	0.2796	
Δf		18.2679

Table 22: MSIAH(3)-VAR(2) Maximum Likelihood estimation results

run equilibrium of the system, it is not significant, signifying that the nominal exchange rate is rather persistent and not fast mean-reverting.

<i>Regime 1: Autoregressive coefficients</i>	$\Delta Svol$	Δf
$\Delta Svol_{t-1}$	-0.8143	-8.0064
	(0.2065)	(0.6941)
$\Delta Svol_{t-2}$	-0.6670	-4.2452
	(0.1007)	(0.3384)
Δf_{t-1}	0.1039	-0.3657
	(0.0322)	(0.1083)
Δf_{t-2}	-0.0843	-0.7374
	(0.0163)	(0.0549)
cri_1	-0.3720	-1.5621
	(0.0536)	(0.1802)

Table 23: The Autoregressive coefficients for Regime 1

All coefficients in the crisis state are significant, indicating that both the nominal exchange rates and monetary fundamentals adjust to restore equilibria when the market is extremely uncertain. Lagged variables in the crisis state are also highly significant. In other words, they play an important part in helping the adjustment short-run dynamics.

Only the first lag of the monetary fundamentals adjust to restore the fundamentals disequilibrium in calm/normal currency markets. The sentiment (exogenously determined *cri*-lagged by one period (one month)- by the Markov chain where history of a variable does not matter) drives the changes in the nominal exchange rate and in the monetary

<i>Regime 1: t-values</i>		
	$\Delta Svol$	Δf
Constant	-10.7983	-17.5803
$\Delta Svol_{t-1}$	-3.9428	-11.5346
$\Delta Svol_{t-2}$	-6.6247	-12.5455
Δf_{t-1}	3.2249	-3.3769
Δf_{t-2}	-5.1626	-13.4388
cri_1	-6.9378	-8.6683

Table 24: The t-values for Regime 1

<i>Regime 2: Autoregressive coefficients</i>	$\Delta Svol$	Δf
$\Delta Svol_{t-1}$	-0.0026	-3.0734
	(0.1093)	(2.1294)
$\Delta Svol_{t-2}$	-0.0106	-3.7181
	(0.0958)	(2.0812)
Δf_{t-1}	-0.0144	-1.1562
	(0.0083)	(0.1787)
Δf_{t-2}	-0.0118	0.2830
	(0.0096)	(0.2168)
cri_1	-0.0297	1.3034
	(0.0118)	(0.2662)

Table 25: The Autoregressive coefficients for Regime 2

<i>Regime 2:t-values</i>		
	$\Delta Svol$	Δf
Constant	-5.0027	0.4418
$\Delta Svol_{t-1}$	-0.0238	-1.4433
$\Delta Svol_{t-2}$	-0.1104	-1.7865
Δf_{t-1}	-1.7464	-6.4711
Δf_{t-2}	-1.2251	1.3056
cri_1	-2.5258	4.8970

Table 26: The t-values for Regime 2

fundamentals.

t -value significant at 5% (two-tailed) for 80 samples = 1.99.

In the buoyant currency market, it is the monetary fundamentals that move to restore the short-run (2 months) disequilibria, as evident by both of the Δf_{t-1} and Δf_{t-2} being significant when each affects Δf statistically.

Both the two lags of the fundamentals adjust to restore their own disequilibria in favourable/buoy markets for Baht/USD. The exogenously determined crisis variable highly significantly determine both of our dependent variables, $\Delta Svol$ and Δf . The volatility (variance) in fundamentals are much greater than that of the nominal exchange rate, and, unusually, least volatile in the crisis state. Within the variable across regimes, the volatility in crisis state is the least for the nominal exchange rate, over and above the calm and the favourable states, where the rate appreciates in value.

In Regime 1 (panic)—where normal indicators prove unreliable—the contemporaneous cor-

<i>Regime 3: Autoregressive coefficients</i>	$\Delta Svol$	Δf
$\Delta Svol_{t-1}$	-0.0300	2.2123
	(0.1403)	(1.1164)
$\Delta Svol_{t-2}$	-0.1399	-0.8306
	(0.1363)	(1.0852)
Δf_{t-1}	-0.0332	-1.0404
	(0.0201)	(0.1538)
Δf_{t-2}	0.0275	-0.3532
	(0.0173)	(0.1364)
cri_1	0.1209	0.6505
	(0.0414)	(0.3167)

Table 27: The Autoregressive coefficients for Regime 3

<i>Regime 3:t-values</i>		
	$\Delta Svol$	Δf
Constant	5.3469	-2.5126
$\Delta Svol_{t-1}$	0.2136	1.9817
$\Delta Svol_{t-2}$	-1.0262	-0.7654
Δf_{t-1}	-1.6515	-6.7638
Δf_{t-2}	1.5877	-2.5905
cri_1	2.9224	2.0541

Table 28: The t-values for Regime 3

	<i>Regime 1</i>			<i>Regime 2</i>			<i>Regime 3</i>	
	Ds	Df		Ds	Df		Ds	Df
Ds	1.0000	0.9995	Ds	1.0000	0.1499	Ds	1.0000	0.6433
Df	0.9995	1.0000	Df	0.1499	1.0000	Df	0.6433	1.0000

Table 29: MSMH(3)-VECM(2) Contemporaneous Correlation Table

relation show the right sign, we would expect the hike in *Svol* or the crash in the currency value to go with the sudden drop in fundamentals. In the crisis currency market, there is significant evidence that the two variables comove, 99.95% move together in panic/herd-like behaviour, where only 14.99% and 64.33% move together in normal and buoyant markets respectively.

Regime Classification for the MSIAH(3)-VECM(2) model for Thai Data

At the beginning of the sample period, the Baht was in the crisis of confidence (this period is defined as a crisis period). Then the Baht was going from a favourable period of confidence to a calm, normal market, except in the three months of 2002 and in April 2005, our last period in the sample. What accounted for the last crisis of confidence is most likely to be the oil price rise, which reached the record high post-sample in August 2005.

The Markov-switching methodology software (MSVAR130.h, and MSVAR130.oxo) is written by Hans-Martin Krolzig, now at Kent University. It gave regime classification for the fully specified model for the Thai economy. One of our particular interest is that of the crisis scenario (regime 1), and interestingly the model detects two other crises states post the Asian crisis, one is between May-July 2002, and the other recently in April 2005, the latter could be due to the rising oil prices which greatly affected the domestic economy.

Regime 1: Crisis	Regime 2: Calm	Regime 3: Confidence
[probability]	[probability]	[probability]
1998:9 - 1998:12 [1.0000]	1999:5 - 1999:6 [0.8925]	1999:1 - 1999:4 [0.9075]
2002:5 - 2002:7 [0.9984]	1999:10 - 2000:3 [0.9973]	1999:7 - 1999:9 [0.9604]
2005:4 - 2005:4 [0.9972]	2000:12 - 2001:2 [0.9907]	2000:4 - 2000:11 [0.9381]
	2001:7 - 2001:9 [0.8687]	2001:3 - 2001:6 [0.9296]
	2001:11 - 2002:4 [0.9954]	2001:10 - 2001:10 [0.9717]
	2002:11 - 2003:11 [0.9878]	2002:8 - 2002:10 [0.9999]
	2004:4 - 2004:4 [1.0000]	2003:12 - 2004:3 [0.9047]
	2004:9 - 2005:3 [0.9022]	2004:5 - 2004:8 [0.9447]

Table 30: Regime Classification for the MSMH(3)-VECM(2) model describing post-1997

Thai data

The relative forecast performance of the regime-switching models depends on the regime present at the time the forecast is made (Clements and Smith (1999), Pesaran and Potter (1997)). Krolzig's (2004) theory predicts that the differences between the optimal and the linear forecasting rules are strongest if the forecasts are made in the regime which is unlikely to prevail (in his example being during the US recessions). There is a marked improvement in the forecasts with the introduction of a third regime and a regime-dependent error variance (MSIAH(3)-VECM(2)).

From Figures 11 and 12, the overall performance of a 1-step forecast is better for Df than for $DSvol$, especially in the first and last periods of the sample and elsewhere where the volatility is acute. The statistical properties of the smoothed and predicted errors are visualized in Figure 13, where the normality of the standardized or smoothed errors are shown. The predicted errors show non-normality, which is assumed in the MS-VECM. Also there is no strong autocorrelation left in the errors.

2.5 *Part I: conclusion*

In Part I the author asked a question 'What happened to the Thai Baht?' and found the following. Firstly the driving force behind the nominal exchange rate was established and this background story is provided by Frankel (1979). Strong evidence for the Frankel's RID is found for the Thai data post 1997 crisis. In addition, by nesting the Frankel model within a non-linear detection tool, the author is able to describe the state of the Thai markets into three different scenarios, one of the crises of confidence in the Baht, one of the calm market, and lastly one of the confidence in the domestic currency, each regime/state/condition of the Thai-Dollar market being persistent and stable, 70-80% of the time. By applying the

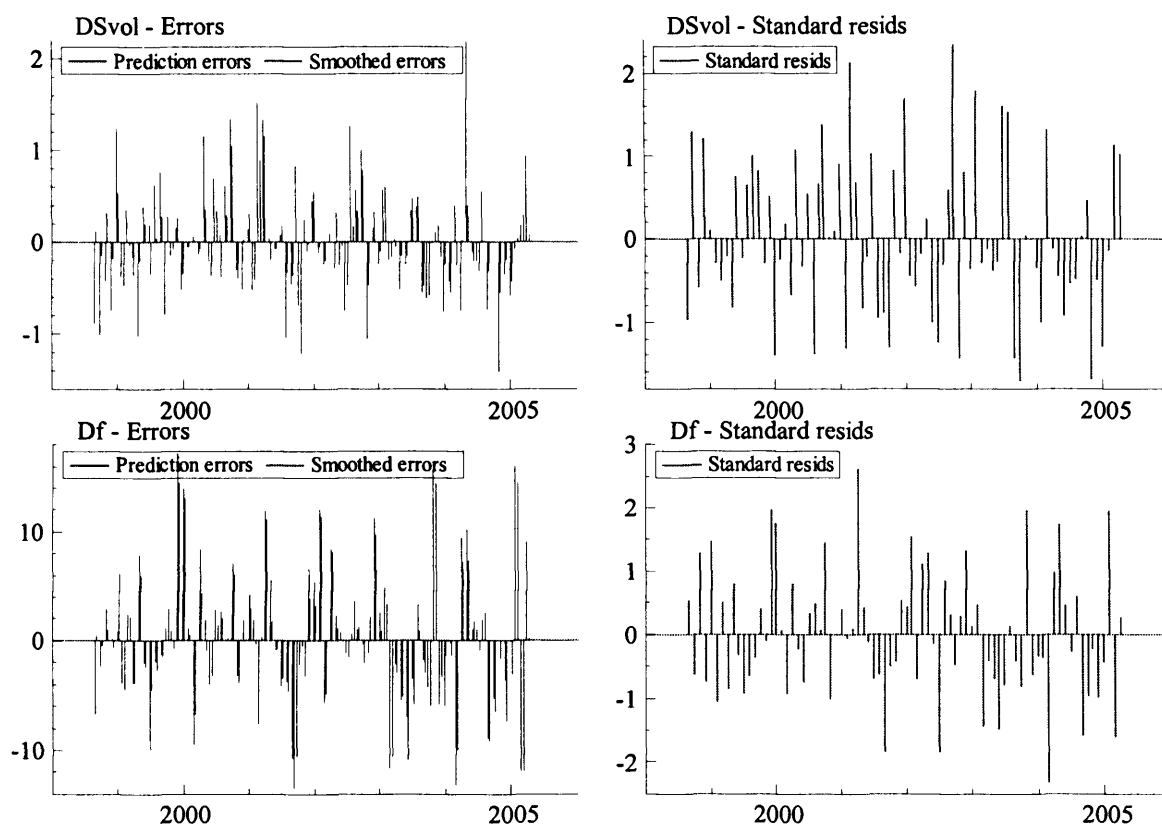


Figure 13: The errors and residuals of the dependent variables DSvol and Df from the MSIAH(3)-VECM(2) model

methodology traditionally used for the business cycle, two other episodes of crises (in addition to the Thai currency crisis of 1997-1998, the beginning of our sample period) are detected, one falsely, and the last correctly.

Secondly, when investors lose confidence in the Thai Baht against the US Dollar, the nominal exchange rates and the monetary fundamentals both move together to restore the equilibrium both in short and the long run. Only the first lag of the monetary fundamentals adjust to restore the fundamentals disequilibrium in calm/normal currency markets. In the buoyant currency market, it is the monetary fundamentals that move to restore the short-run (2 months) disequilibria. It is also possible to verify the directions that the nominal exchange rate and the fundamentals are taking in terms of states, namely, the nominal exchange rate system, less than 30% of the time, switch into a crisis state from a calm state, crisis to calm, calm to favourable /confident market.

With a simple set of RID fundamentals, the fully specified model (MSIAH-VECM) allows the mean and the variance of the disturbance to vary over time *and* subject to Markovian shifts (where only the *current* values of fundamentals count), we are able to determine with high accuracy what kind of market the Baht found itself in. This information is useful for investors and policymakers. What's more, the technique has been successfully applied to other aspects of policymaking (such as terrorist attacks, securities trading etc.) using variables that are of major importance to the researcher that are known to be determined by a number of factors which are also available at similar frequency but do not appear to be linked directly. Hamilton's tool, generalized by Krolzig, allows us to visualize and, to a less effective degree, predict the currency market state. So in the Thai Baht against the US Dollar case, there is significant evidence that the mean of the equilibrium-correcting

mechanism varies, and the variance of the disturbance is heteroskedastic and time-varying.

Further research, with more data becoming available, could include oil prices as an explanatory variable, as well as current accounts. The general markov switching model has already been applied by Enders and Sandler (2004). in accounting for casualties in the low and high states of terrorism alert.

In the first part of this thesis I have provided significant evidence that the nominal exchange rate for Thailand was driven by monetary factors. In particular, the real interest rate differential between the two trading partners proved significant. In addition, by nesting the real interest rate differential model in the regime switching, error-correcting structure, I am able to capture two further episodes of crises of confidence in the Baht. Although, the second crisis of confidence was not supported by the history of the Baht *ex-post*, the detection of the possible third crisis was backed up by the recent weakening of the Baht. Evidence from the Markov-switching model also gave description about the dynamics of the nominal exchange rate and monetary fundamentals movement, that both adjust to restore an equilibrium.

2.6 *Part I*: Policy Implication and marker for further research

In *Part I*, I applied a tool normally associated with the business cycle prediction to be used with the nominal exchange rate markets. As is often the case with the Markov-switching models, the tool is much better used to explain what happened to the Baht much better than it can predict, but our ability to develop on prediction is limited by the relatively small data compared to the number of variables used. It would be of great interest to be able to include such variables as the current account into our analysis.

3 *Part II: On the Real Exchange Rate Determination*

3.1 The Productivity Bias Hypothesis

3.1.1 Introduction In the short run, nominal exchange rates depend primarily on financial market variables and expectations; and, if the prices of goods and services are slow to change, nominal exchange rate movements will be reflected immediately in real exchange rate changes. Over the longer horizon, economic theory suggests real-side variables increasingly affect the real exchange rate. In particular, assuming that financial capital is relatively free to move internationally, and that trade in goods is relatively unhindered by tariffs and quotas, a country's real exchange rate is determined by how efficient labour and capital are in producing tradable goods compared to producing nontradable goods. We can think of traded goods as 'manufactured goods' and nontraded goods as 'services'

According to a traditional model—the Balassa-Samuelson model—if the productivity of a country's workers in producing manufactured goods relative to their productivity in producing services grows faster than abroad, then the country's currency will appreciate in real terms; i.e., the rate of exchange of domestic for foreign goods rises. Conversely, if the relative productivity growth of manufacturing goods workers is lower than abroad, the currency depreciates. In the third part of the thesis, having found that real interest rate differentials matter for two trading countries, an investigation into the comparative productivity seems appropriate. A question arises as to how one would deflate the nominal exchange rate: in terms of Consumer Price Index, or Producer Price Index? After looking at the existing literature, we first investigate the definition of the real exchange rate and the options available in order to undertake this project in *Part II*.

3.1.2 The Productivity Bias Literature Review The Productivity Bias hypothesis seems to explain Japan well. Outside Japan, however, it is rather hard to find strong evidence that fast-growing countries have experienced significant real exchange rate appreciation (Devereux, 1999). Isard and Symansky (1997) find some evidence of the Balassa-Samuelson hypothesis in the real exchange rate behaviour of Japan, Korea and Taiwan, but no evidence for other Asian countries such as Indonesia, Thailand, and Malaysia. Bahmani-Oskooee (1992) and Dibooglu (1996) used cointegration analysis and tested this hypothesis over the period 1960-1988 for the advanced countries against the USA. The results showed that *the real exchange rate and the productivity differentials were cointegrated*, supporting the productivity-bias hypothesis. Similarly, Bahmani-Oskooee and Rhee (1996) supported the hypothesis in the cases of advanced countries against Korea. Recent studies (Engel (1996), Canzoneri et al.(1996), Isard and Symansky (1997), Chinn (2000)) have shown that real exchange rates are driven more by differences in price levels across countries, particularly in traded goods, rather than by differences in movements in the relative price of nontraded goods. Isard and Symansky show that, for fast growing East Asian countries, there is *little evidence for real appreciation* relative to Japan or the US (even before the 1997 Asian currency crisis). They also show that, even at low frequencies, almost all the *trends in real exchange rates are driven by movements across countries in the relative prices of traded goods*, rather than by different trends in the relative price of nontraded goods within countries. It would seem that these findings present a puzzle, since they indicate both a *departure from the Balassa-Samuelson hypothesis*, but also substantial and persistent *deviation from the law of one price in traded goods* across countries. Devereux (1999) explores a mechanism for long-run real exchange rate determination as an alternative to the Balassa-Samuelson model,

but which includes the Balassa-Samuelson model as a special case. Devereux's model seeks to explain the tendency for long-run exchange rates to be dominated by differentials in traded goods prices, and the tendency for many faster-growing Asian economies to experience real exchange rate depreciation against Japan and the US.

Time-series work on the theory include Hsieh (1982), Edison and Klován (1987), Rogoff (1992). These authors test whether the real exchange rates can be explained by relative productivity. Bahmani-Oskooee (1992) and Bahmani-Oskooee and Rhee (1996) are the only studies that find some success in uncovering such a relationship. De Gregorio et al. (1994) and Asea and Mendoza (1994) find more positive results using annual sectoral OECD data. By using disaggregate data, these authors are able to calculate both relative prices and productivities of nontradable goods, as well as real exchange rates. While they find that relative prices are explained by real productivities, it is unclear whether real exchange rates can be explained by relative productivity. The Balassa-Samuelson hypothesis is examined by testing for cointegration between the relative prices of nontradables and real output. DeLoach (2001) follows De Gregorio et al. (1994) and Asea and Mendoza (1994) in using relative prices of nontradables. In addition, he uses Johansen and Juselius's (1990) Maximum Likelihood test for cointegration and concentrates on estimating long-run relationship. Like Rogoff (1992), real oil prices are additionally considered as an additional permanent supply shock. The main contribution of DeLoach (2001) is that *relative prices are significantly affected by permanent innovations in real output and real oil prices*.

Canzoneri et al. (1999) test the Balassa-Samuelson model's two assumptions using a panel of OECD countries. Their results suggest that *relative prices generally reflect relative labour productivities in the long run*. The reason for this investigation is that changes in

real exchange rate have been so persistent that they question the notion of purchasing power parity. These authors report that, for a wide class of technologies, the ratio of marginal costs is proportional to the ratio of average labour products in the two sectors.

Using sectoral output and employment pre-1997 Asian data, Chinn (2000) calculated relative prices and relative productivities for China, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand. There time series regressions of the real exchange rate on relative prices indicate a role for relative prices for Indonesia, Japan and Korea. Nonetheless, the examination of real exchange rates and relative productivity ratios, reveals a relationship for only three countries: Japan, Malaysia, the Philippines. Only when augmenting the regressions with real oil prices are significant relationships obtained for Indonesia and Korea. Panel regression results are slightly more supportive of a relative price view of real exchange rates. However, the panel regressions incorporating productivity variables, as well as other demand side factors⁴⁵, are less encouraging, except for a small subset of countries (Indonesia, Japan, Korea, Malaysia and the Philippines).

The data on long run real exchange rates typically consist of 20-30 years of data on any pair of country, and unit root tests have low power in small samples to distinguish between series that are non-stationary and series that are stationary but highly persistent. Hakkio (1984) is the first to exploit the benefit of pooling when examining PPP. Recently developed techniques allow the possibilities to deal with nonstationary data in heterogeneous panels. Canzoneri et al. (1999) are able to confirm the existence of a long run or cointegrating

⁴⁵Chinn (1997)'s surprise result was that government spending does not appear to be a determinant of real exchange rates in the region, something that lends support to our assumption (that government spending does not affect welfare in general) in our fully-fledged RBC model for Thailand in last section.

relationship between the relative price of non-tradeables and the ratio of average labour products. They argue that *the problems with the Balassa-Samuelson hypothesis lie in the failure of PPP to explain traded goods prices*, especially for the US dollar. Using panel data, they are able to establish the existence of an appropriate long run (or cointegrating) relationship, but unlike the first component estimate, the second PPP component parameter estimates are not close to the values implied by PPP. Canzoneri et al. (1999) contribute the failure of PPP to hold for traded goods to be *a US dollar phenomenon*, in that their large and persistent deviations from PPP in traded goods dominate US dollar real exchange rate movements and it is therefore difficult to explain those movements with differences in sectoral productivities. The results are more favourable when the DM is used as a reference currency.

MacDonald and Ricci (2001, 2003) investigate the impact of the distribution sector on the real exchange rate, controlling for the Balassa-Samuelson effect, as well as other macro variables. They estimate long-run coefficients using a panel dynamic OLS estimator. Their main result is that *an increase in the productivity and competitiveness of the distribution sector with respect to foreign countries leads to an appreciation of the real exchange rate*⁴⁶, similarly to what a relative increase in the domestic productivity of tradables does. This contrasts with the result that one would expect by considering the distribution sector as belonging to the non-tradable sector. One explanation may lie in the use of the services from the distribution sector in the tradable sector. MacDonald and Ricci's results also contribute to explaining the so-called PPP puzzle.

⁴⁶This is the aspect of the hypothesis that will be tested in a medium-sized open economy with real business cycles in the last section.

Rogers and Jenkins (1995), Engel (1999), Obstfeld (2001) and Chari, Kehoe and McGrattan (2002) show that *fluctuations in the relative price of nontraded goods account for less than 10% of the fluctuations of real exchange rate* in variance decompositions of US bilateral real exchange rates with a number of OECD countries. These variance decompositions imply that not only are there large deviations from the law of one price for traded goods, but that these deviations are as large as, or almost as large as, the corresponding deviations of nontraded goods. Rogers and Jenkins (1995) in particular show that, on average, 81% of the variance of the real CPI exchange rate is explained by changes in the relative price of *traded* goods, rather than the relative price of non-traded goods. This is consistent with Engel's (1993) results that, among the possible variances for the G7 countries, 93.75% have smaller within-country variance than the cross-country ones for the same good. Such results lend support to sticky-price models (Dornbusch (1976) and Giovannini (1988)). This body of evidence supports the view that, in the presence of sticky prices, nominal exchange rate movements are the key source of real exchange rate volatility.

3.1.3 Empirical Test on the Productivity Bias Hypothesis

Constructing the bilateral real exchange rate Following Betts and Kehoe (2004c), the author calculates the bilateral real exchange rate between the US and country i as:

$$RER_{th,us,t} = NER_{th,us,t} \frac{P_{us,t}}{P_{th,t}}, \quad (68)$$

$NER_{th,us,t}$ denotes the nominal exchange rate in terms of country i currency units per USD at date t ,

$P_{us,t}$ is a price deflator or index for the basket of goods consumed or produced in the United States, and

$P_{th,t}$ is a price deflator or index for the comparable basket of goods in country i .

In traditional real exchange rate theory, aggregate price levels are thought of as functions of the prices of both traded and nontraded goods. Denote $P_{i,t}^T$ as a price inflator or a price index for traded goods in country i , multiplying and dividing the previous equation by the ratio of traded goods prices gives:

$$RER_{th,us,t} = \left(NER_{th,us,t} \frac{P_{us,t}^T}{P_{th,t}^T} \right) \left(\frac{P_{th,t}^T}{P_{th,t}} / \frac{P_{us,t}^T}{P_{us,t}} \right) \quad (69)$$

The first term in brackets on the right hand side denotes the bilateral real exchange rate of traded goods, henceforth denoted as $RER_{th,us,t}^T$. $RER_{th,us,t}^T$ measures deviations from the law of one price for traded goods. It also captures the effect for the real exchange rate of traded goods of any differences in the compositions of the baskets of traded goods across the two countries. The second term is a ratio of internal relative prices (Betts and Kehoe, 2004c), denoted as $RER_{th,us,t}^N$. $RER_{th,us,t}^N$ is the ratio of a function of the relative price of nontraded goods to traded goods in Thailand to that in the United States. This expression is referred to as the (bilateral) relative price of nontraded (to traded) goods. Generally, the real exchange rate can be decomposed into these two components when supplied with data on traded goods price deflators (or price indices), and aggregate price deflators (or price indices).

The second term from Equation 69 is a ratio of internal relative prices:

$$RER_{th,us,t}^N = \frac{\left(\frac{P_{th,t}^T}{P_i(P_{th,t}^T, P_{th,t}^N)} \right)}{\left(\frac{P_{us,t}^T}{P_{us}(P_{us,t}^T, P_{us,t}^N)} \right)}. \quad (70)$$

$RER_{th,us,t}^N$ is used to measure the prices of nontraded goods. It avoids the need to assume a functional form for aggregate price measures.

70 can be rewritten as:

$$RER_{th,us,t} = RER_{th,us,t}^T \times RER_{th,us,t}^N \quad (71)$$

which, in logs, is:

$$rer_{th,us,t} = rer_{th,us,t}^T + rer_{th,us,t}^N \quad (72)$$

Equation 72 is a simple decomposition of the real exchange rate into two components, one due to the failure of the law of one price and effects due to differences in the compositions of traded goods output, the other due to cross-country fluctuations in the relative prices of nontraded to traded goods.

Some authors, Imbs et al. (2005) among them, argue that there is significant bias in constructing the aggregate price indices. In addition, they suggest that the bias is larger for traded goods sectors than for nontraded goods sectors.

Three data series are needed:

- 1a. A nominal exchange rate series between Thailand and trade partner i ;
- 2a. An aggregate price level measure for Thailand;
- 3a. A comparable aggregate price level measure for country i .

There are three types of aggregate price levels to choose from:

- 1b. The Gross Output Deflator (GO Deflator);
- 2b. The Consumer Price Index (CPI);
- 3b. The Personal Consumption Deflator (PC Deflator).

1b. and 3b. are Deflators, whilst 2b. is the fixed weight price index. 2b. and 3b. measure the price of consumption of a basket of goods and not goods and services (like 1b.). 2b. includes the price of traded-imported goods and also the prices of nontraded wholesale, distribution and retail services.

The GO Deflator is computed as the ratio of nominal gross output summed over all sectors to real gross output summed over all sectors. The underlying gross output data by sector are available only at the annual frequency. As Betts and Kehoe (2004c) report, it is relatively difficult to find GO Deflator data for a large number of countries. Gross output data are normally found in the publications of national statistical agencies that are responsible for computing the input-output matrices for a country. The GO Deflator is the sum of the values of nominal gross output over all relatively traded goods sectors to generate P_i^T for any trade partner i . This is why it is called a traded goods price deflator.

The CPI is a non-geometric base-year quantity weighted average of the prices of a basket of goods and services consumed within a country. As a consumption-based aggregate price measure, the CPI measures the price of a basket of goods and services *consumed* in a country, rather than measuring a price of the goods and services produced within a country as the Gross Output Deflator does. As mentioned earlier, the CPI for a country includes the prices of traded import goods. It also includes the prices of nontraded wholesale, distribution and retail services embodied in the final consumer prices of otherwise traded goods. The CPI

for country i at date t is measured as:

$$CPI_{it} = \sum_j \alpha_{ij} p_{ijt}^C \quad (73)$$

where p_{ijt}^C is the price paid for good or service j by consumers in country i at date t .

α_{ij} is a base-period expenditure weight on good j . The primary advantage of using the CPI is that it is readily available for all of the countries in our sample at the monthly, quarterly, and annual frequencies.

The PC Deflator is computed as the ratio of nominal personal consumption expenditure to real personal consumption expenditure⁴⁷. Like the CPI, the PC Deflator measures the price of a consumption basket of goods and services, rather than measuring a price of the goods and services produced by a country.

Thailand's major trading partners are listed in the table below⁴⁸:

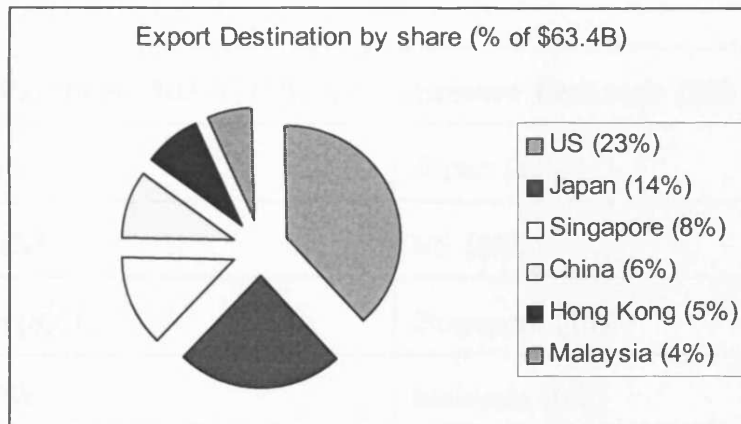


Figure 14: Thailand's export destination by share of GDP

⁴⁷Personal consumption expenditure is defined as in the national income and product accounts.

⁴⁸Data from the Council of State Governments: Eastern Regional Conference (<http://www.csgeast.org>)

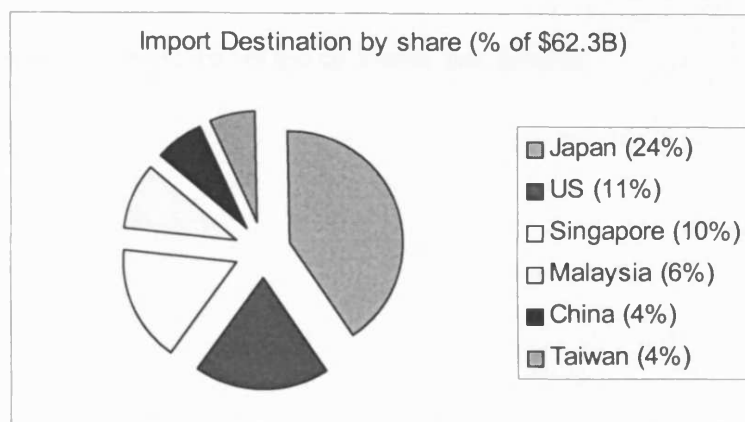


Figure 15: Thailand's import destination by share of GDP

Export Partners (\$63.36 Billions†)	Import Partners (\$62.3 billions†)
US (23%)	Japan (24%)
Japan (14%)	US (11%)
Singapore (8%)	Singapore (10%)
China (6%)	Malaysia (6%)
Hong Kong (5%)	China (4%)
Malaysia (4%)	Taiwan (4%)

Table 31: Thailand's major trading partners (2001 estimate)

† 2001 estimate. As the United States is Thailand's biggest export partner and second biggest import partner country, the United States Dollar is used as the foreign currency. The exchange rate is expressed in terms of Bahts per Dollar.

3.1.4 The Data *Data Sources*

The Data for *Part II* is quarterly and are taken from four sources. First, Thomson's *Datastream Advance*⁴⁹, second, the Bank of Thailand website, third the US Department of Labour website, and lastly the US Bureau of Economic Analysis's National Economic Accounts webpage⁵⁰

Exchange rates

Thailand The nominal exchange rates per US Dollar are the Global Trade Information Service (GTIS⁵¹) rates and are the only available series for the period of study. The real exchange rate is the nominal deflated by the Thai GDP deflator.

Prices

Thailand The tradeable and nontradable price indices are constructed from the Bank of Thailand's Consumer Price Index by Group (Table 77⁵²), rebased to the annual average of 2002=100 for cross-sectional comparison.

The US Traded and nontraded price indices are constructed using the US Department of Labour's Bureau of Labour Statistics's Table 1. Consumer Price Index for All Urban Consumers (CPI-U): U. S. City Average, by expenditure category and commodity and service group. The base year is recalculated to be 2002 = 100.

⁴⁹<http://www.datastream.com>

⁵⁰<http://www.bea.gov/bea/dn1.htm>.

⁵¹<http://www.gtis.com>

⁵²<http://www.bot.or.th/bothomepage/databank/EconData/EconFinance/tab77e.asp>

Output

Thailand Sectoral GDP are calculated from The Bank of Thailand's Gross quarterly GNP at 1988 prices (Table 86) Sectoral Real GDP is deflated using each sector's own price index.

The US Sectoral GDP are calculated from the US Department of Commerce's Bureau of Economic Analysis⁵³'s National Income without capital consumption by industry (Table 6.1C for 1993-2000 and Table 6.1D for 2001-2005).

Sectoral Real GDP is deflated using each sector's own price index, calculated by the same weighted method as the CPI. The traded price index is called TPI and is a weighted index of each subsector's contribution towards the overall traded index and likewise for the nontraded index, hereby called NPI. From 2001, services were split into Professional and business services, Educational services, health care, and social assistance, Arts, entertainment, recreation, accommodation, and food services and Other services, except government and thus were recalculated together for the consistency of the time series data.

Employment

Thailand Sectoral employment data are calculated from the Thai Labour Force Survey done by the National Statistical Office and downloaded from the Bank of Thailand website. The missing employment data were replaced by the arithmetic average of the two nearest neighbours.

⁵³<http://www.bea.doc.gov/>

The US Sectoral employment are compiled from the US Department of Labor's Bureau of Labor Statistics' Labour Force Statistics from the current population survey.

3.1.5 Data Construction The author follows De Gregorio et al. (1994) and Stockman and Tesar (1995) in the following classification. Additions in each category are added to each due to the availability of the Thai data⁵⁴

1. *Traded goods*: agriculture; manufacturing; mining; retail and transportation. These take up 70% of Thai GDP.

2. *Nontraded goods*: electricity; gas, water; finance; insurance and real estate; private and government services. They take up 30% of Thai GDP.

The traded and nontraded indices are constructed from the quarterly Gross National Product using The Bank of Thailand Table 86:⁵⁵. I constructed the traded and nontraded⁵⁶ price indices based the categories in the table below, using a simplifying assumption that each enters the index with equal weights.

Each sector's overall contribution to GDP is as depicted in the pie chart below:

Compared to that of the US:

Comparing the traded sector, the picture for the Thai traded sector looks like this:

Thailand's nontraded sector,

Compared to the US:

⁵⁴All Tha data from the Bank of Thailand website

<http://www.bot.or.th/bothomepage/databank/EconData/EconFinance/index04e.htm>

⁵⁵<http://www.bot.or.th/bothomepage/databank/EconData/EconFinance/tab86e.asp>

⁵⁶The majority of vegetable and fruits are consumed within the country and are highly perishable in the heat and thus regarded as nontraded between Thailand and the United States. Non-alcoholic beverages in Thailand consist largely of perishable fruit juices, iced coffee, and local water and is considered nontraded.

Traded	Nontraded
1. Agriculture	1. Amenities: Electric, Gas, Water
2. Mining and quarrying	2. Finance
3. Manufacturing	3. Insurance
4. Wholesale and retail	4. Real Estate or Construction
5. Transport and communications	5. Private and Government Services

Table 32: Subsectors of Traded and Nontraded Sectors

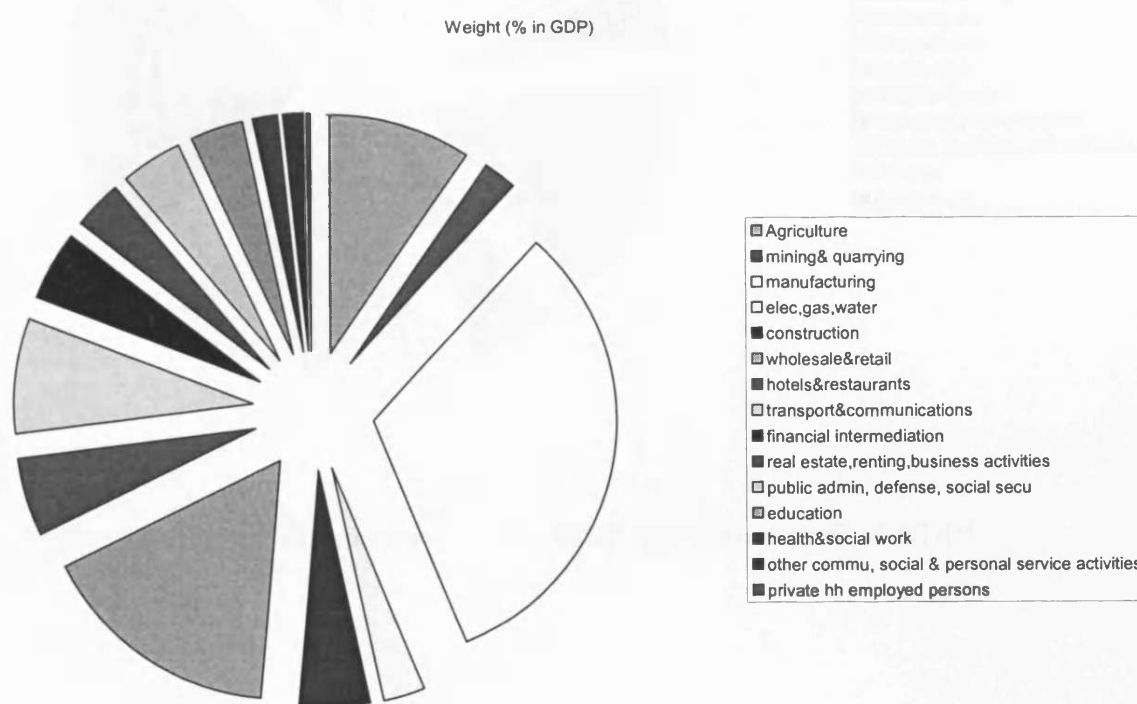


Figure 16: Thailand's composition of GDP (all sectors as % of GDP)

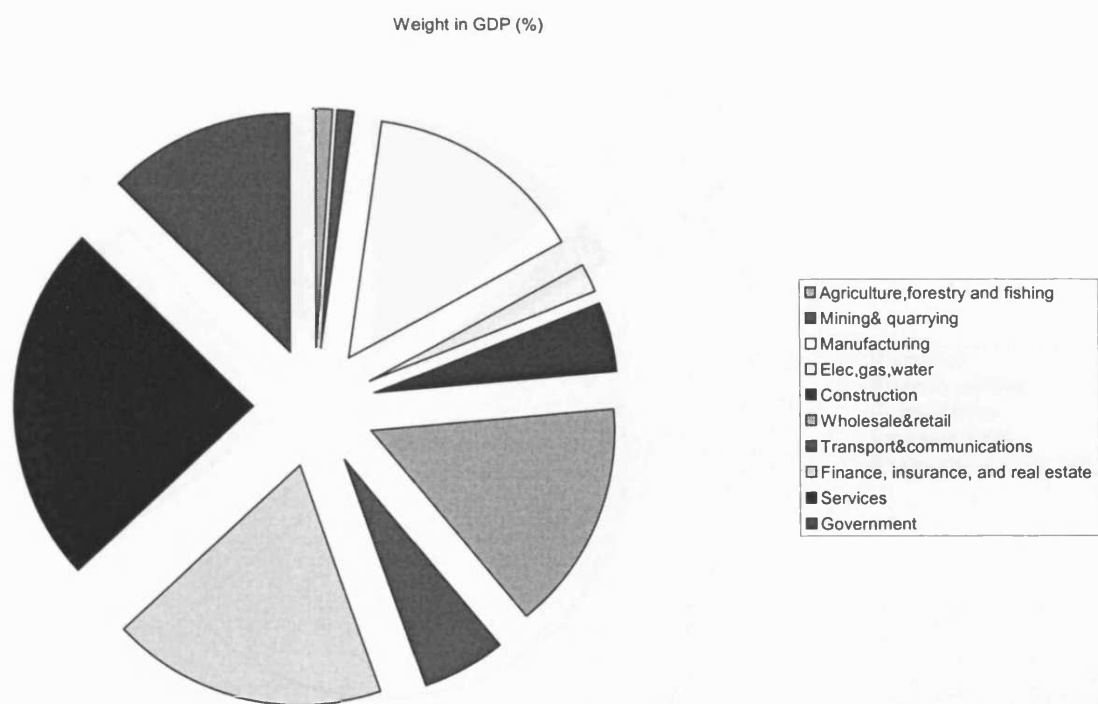


Figure 17: The US composition of the GDP (all sectors as % of GDP)

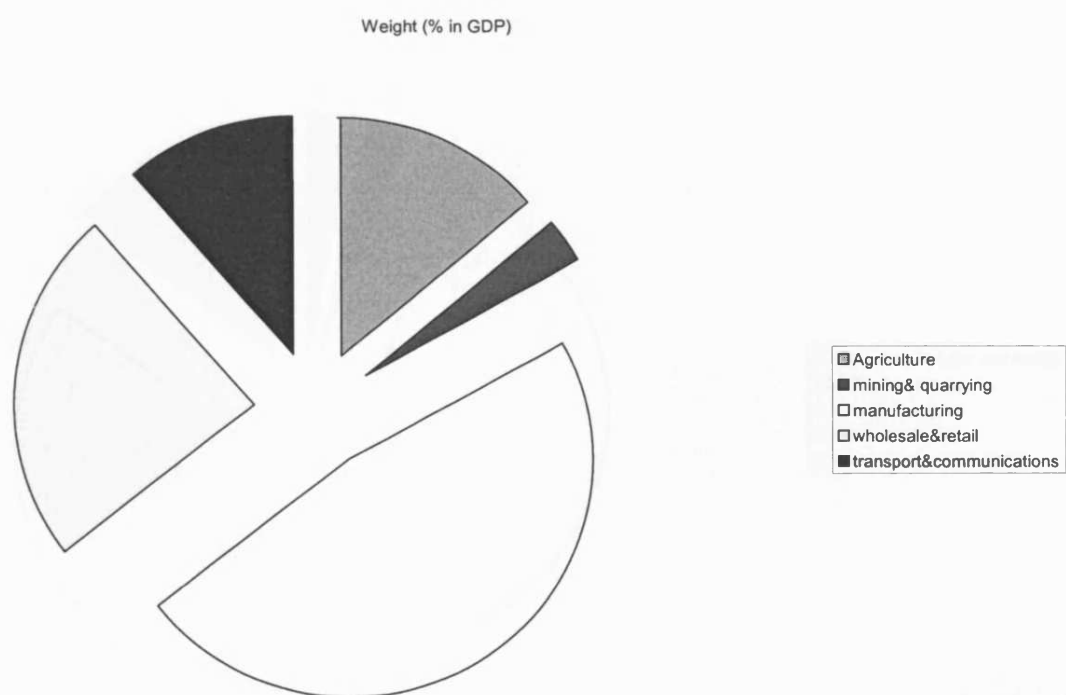


Figure 18: Thai traded sector weight in GDP

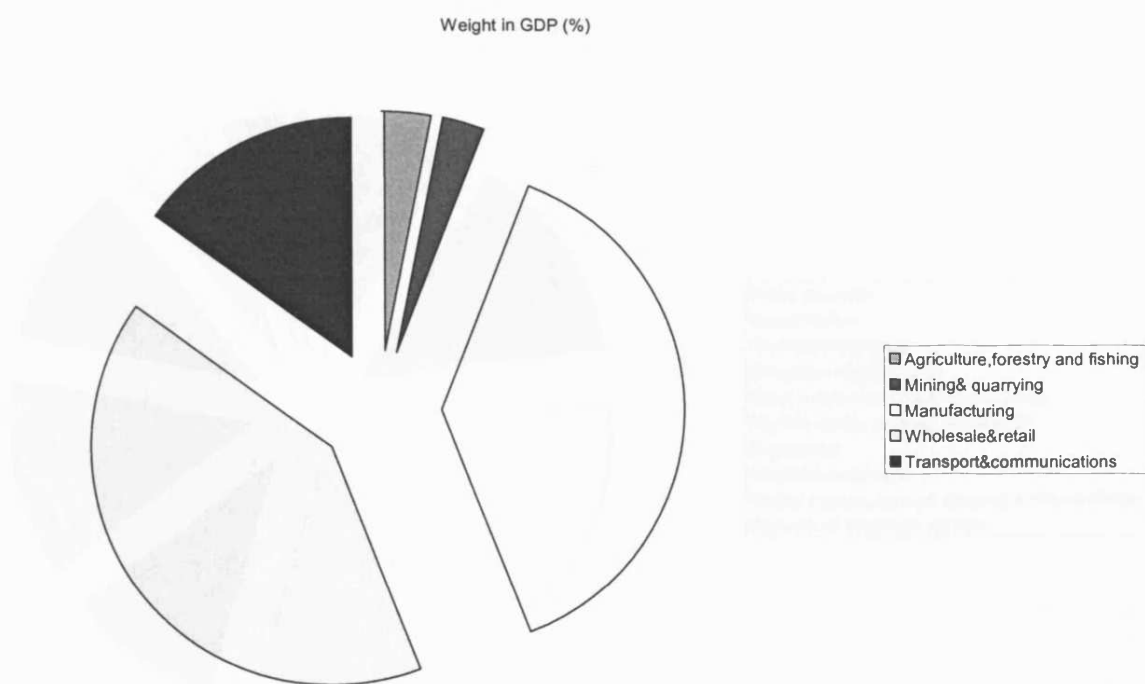


Figure 19: The US traded sector weight in GDP

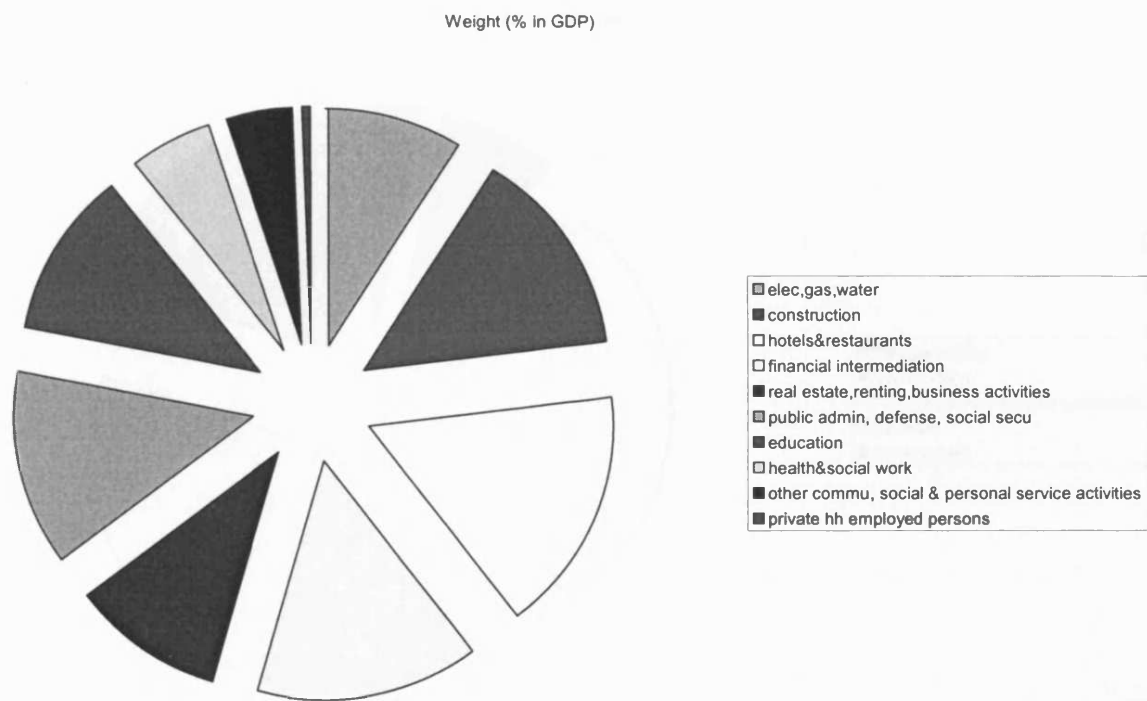


Figure 20: Thailand's nontraded sector weight in GDP

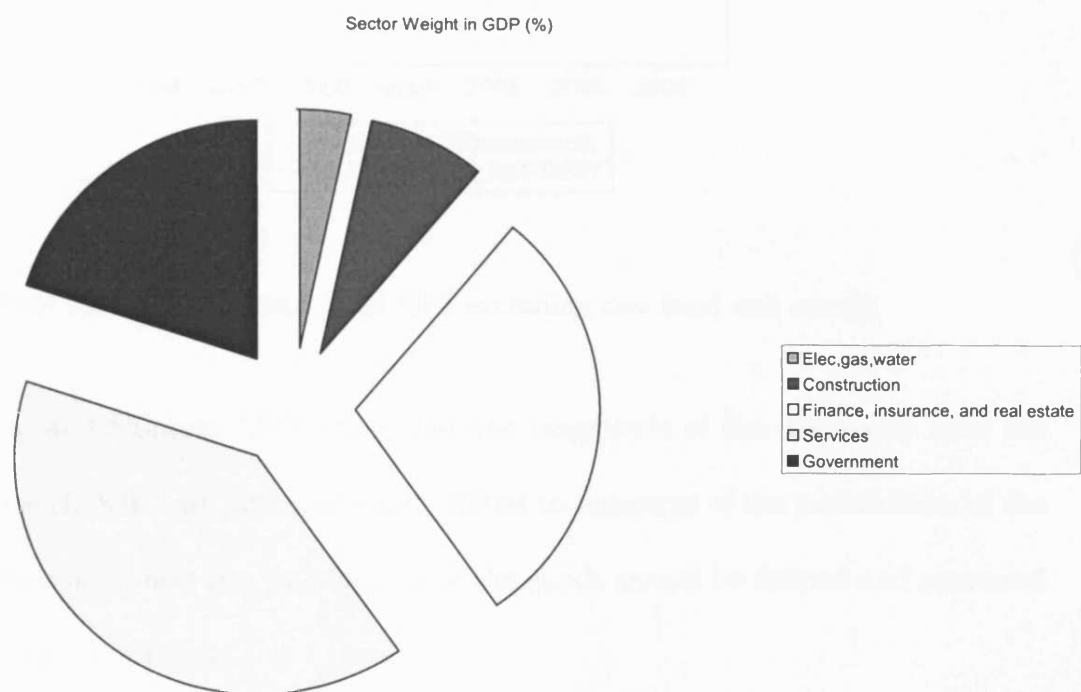


Figure 21: The US nontraded sector weight in GDP

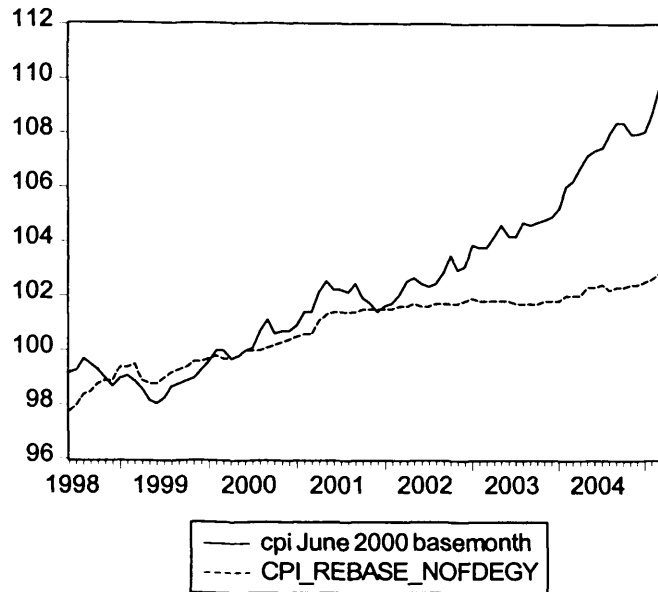


Figure 22: Thai CPI and Thai CPI excluding raw food and energy

Since Crucini and Shintani (2002) find that the magnitude of the deviations from the Law of One Price (LOOP) are systematically related to measures of the tradabilities of the goods, the decision as to how the tradabilities of the goods should be defined and measured is of particular relevance to us.

By taking raw food and energy off the normal Thai CPI, the difference between normal CPI and CPI with less non-tradables are dramatic. A country's price level is increasing in the prices of both tradables and nontradables. Hence, international productivity differences can have implications for relative international price levels, namely, for real exchange rates. Balassa (1964), Samuelson (1964) and Harrod (1933) used this observation to explain the international pattern of deviations from the purchasing power parity (the first part of the Balassa-Samuelson decomposition of the real exchange rate). The Harrod-Balassa-Samuelson effect (hereafter the Balassa-Samuelson hypothesis) is a tendency for countries

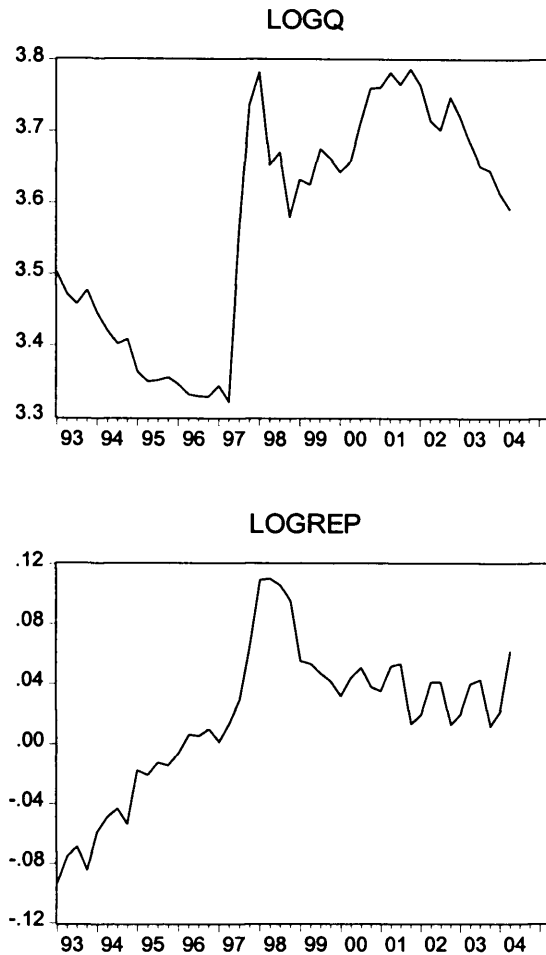


Figure 23: The Log of real exchange rate and the relative prices

with higher productivity in tradables (typically Japan) compared with nontradables to have higher price levels. The relative overall (tradables and nontradables) Thai price to the US price plotted against the real exchange rate reveals a shared trend upwards. So it seems that the higher the relative price is in Thailand, the cheaper the Thai baht becomes.

Again the unrestricted cointegration rank test in Eviews 5.0 shows there is no evidence for the long run relationship between the two variables.

Table 28 shows the results from the unrestricted cointegration rank test:

Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None	0.1368	10.8613	15.49	0.2202
At most 1 *	0.0949	4.3896	3.76	0.0362

Table 33: The unrestricted cointegration rank test between the log of real exchange rate and the relative price indices

There is no evidence at 5% of a long run relationship between the all-sector real exchange rate and the overall relative prices.

Sectoral Price Indices, Sectoral Output and the Real Sectoral Exchange Rates

The real exchange rate is defined as the relative price of national outputs.

$$q_t = \frac{P}{EP^*} \quad (74)$$

which looks a different story to the nominal rates (data in Baht per USD)

In our case, it is the relative price of the US to the Thai producer goods (that is, the product of the Baht per Dollar nominal exchange rate and the US producer price index, divided by the Thai producer price index). In other words, the real exchange rate is a measure of one country's overall price level relative to another, and is often associated with the price of nontraded goods relative to traded goods.

The productivity bias hypothesis states that a **relatively more productive country should experience a real appreciation of its currency** (Bahmani-Oskooee and Nasir, 2004). The theory describes long-run deviations from purchasing power parity to differences

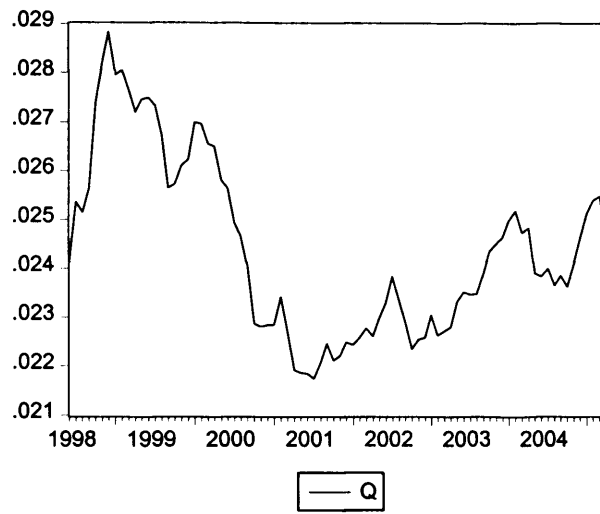


Figure 24: The Thai real exchange rate

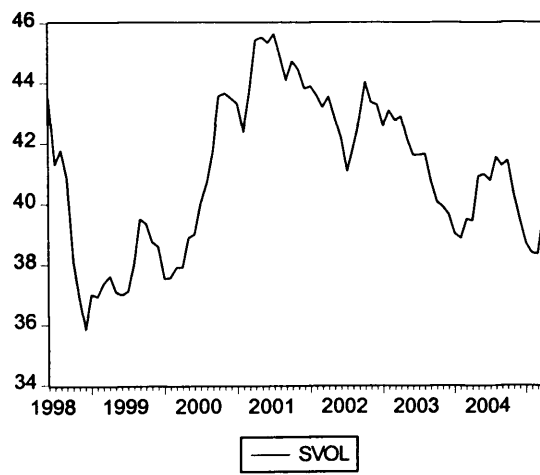


Figure 25: The Thai nominal exchange rate

in rates of growth of productivity in traded goods industries (Balassa, 1964; Samuelson, 1963; Asea and Mendoza, 1994). According to this hypothesis, faster-growing countries will have relatively higher growth rates of productivity in traded goods. This will generate persistent real exchange rate appreciation through a rate of growth of nontraded goods prices that is higher than that of slower-growing countries.

The Harrod-Balassa-Samuelson hypothesis consists two parts: the first is that relative prices of traded to nontraded goods should determine, in a large part, real exchange rates (Isard and Symansky (1997) for the APEC countries). The second part of the HBS hypothesis lies in the assumption of the Purchasing Power Parity of traded goods.

Let the log aggregate price index be given as a weighted average of log price indices of traded (T) and nontraded (N) goods,

$$p_t = (1 - \alpha) p_t^T + \alpha p_t^N \quad (75)$$

where

α is the share of nontraded goods in the price index. The foreign country's aggregate price index p^* is constructed using the same weight for nontraded goods. If we define the real exchange rate, in logs, to be

$$q_t \equiv (s_t + p_t^* - p_t), \quad (76)$$

where s is the log of the domestic currency price of foreign currency, then the following expression holds:

$$q_t = (s_t - p_t^T + p_t^{T*}) - \alpha [(p_t^N - p_t^T) - (p_t^{N*} - p_t^{T*})] \quad (77)$$

$$q_t = q_t^T - \alpha \tilde{p}_t. \quad (78)$$

If sticky-prices explain the time series behaviour of CPI-based real exchange rates, then q_t and q_t^T (all in logs) should be cointegrated (not at 5% but at 10%), since \tilde{p}_t should be stationary (it isn't). However, if the Balassa-Samuelson model is correct, q_t and \tilde{p}_t should be cointegrated (not at 5%) and q_t^T stationary (it is). So we can conclude that although the evidence for the Productivity Bias (Balassa-Samuelson) is not conclusive, the data seem to suggest that there is more consistent evidence of the productivity bias than the sticky-price explanation.

The 2 tables immediately below show no cointegration between the all-sector real exchange rate and the traded sector-only real exchange rate at 5% (although there would be a rejection at 10%).

Table ... shows the evidence of nonstationarity of order 1 in the \tilde{p}_t series, which is the traded-nontraded prices

The first term on the right hand side is the common currency relative price of home and foreign tradables (q_t^T). It is assumed to be zero by Purchasing Power Parity although the time series plot of the series is given above. The second term on the right hand side is considered of particular relevance since many economic models consider it as the determinant of the real exchange rate (Chinn, 2000). Hence, applying the Purchasing Power Parity, the real exchange rate becomes:

Sample (adjusted): 1993Q3 2004Q2				
Included observations: 44 after adjustments				
Trend assumption: Linear deterministic trend				
Series: LOGQ LOGQT				
Lags interval (in first differences): 1 to 1			0.05	
Trace Test for the number of coint equation		Trace	Critical	
Hypothesized No. of CE(s)	Eigenvalue	Statistic	Value	Prob.**
None	0.2528	13.8142	15.4947	0.0882
At most 1	0.0223	0.9937	3.8415	0.3188
<i>No cointegration at the 0.05 level</i>				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) <i>p</i> -values				

Table 34: The trace test between the log of real exchange rate and the relative price indices

Max Eigenvalue Rank Test		Max-Eigen	0.05 Critical	
Hypothesized No. of CE(s)	Eigenvalue	Statistic	Value	Prob.**
None	0.2528	12.8205	14.2646	0.0835
At most 1	0.0223	0.9937	3.8415	0.3188
<i>No cointegration at the 0.05 level</i>				
* denotes rejection of the hypothesis at the 0.05 level				

Table 35: The max eigenvalue test between the log of real exchange rate and the relative price indices

Null Hypothesis	D(PCURLY) has a unit root	
Exogenous: Constant		
Bandwidth:	2 (Newey-West using Bartlett kernel)	
	Adj. <i>t</i> -Stat	Prob.*
Phillips-Perron test statistic	-5.4180	0.0000
Test critical values:	1% level	-3.5777
	5% level	-2.9252
	10% level	-2.6007
*MacKinnon (1996) one-sided <i>p</i> -values		
Residual variance (no correction)	0.0002	
HAC corrected variance (Bartlett kernel)	0.0001	

Table 36: Evidence of nonstationarity in the relative trade-nontrade price series

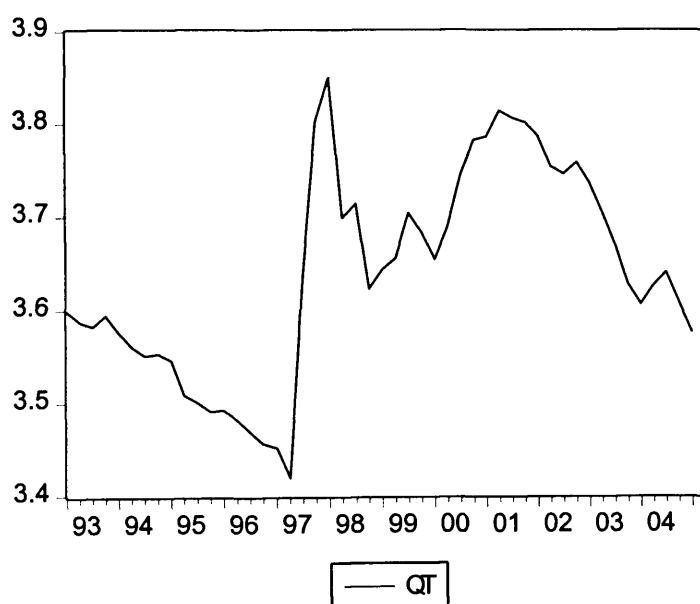


Figure 26: The Thai real exchange rate based only on the traded goods sector (in logs)

$$q_t = -\alpha \tilde{p}_t \quad (79)$$

α represents the share of nontraded goods.

The author tests q_t^T and finds no evidence of a unit root, so the Thai q_t^T is $I(0)$ with the results from Eviews 5 using the Phillips-Perron test statistic given in the table below:

Null Hypothesis: q^T has a unit root		
Exogenous: Constant		
Bandwidth: 4		
(Newey-West using Bartlett kernel)	Adj. t -Stat	Prob.*
Phillips-Perron test statistic	-1.7733	0.3890
Test critical values: 1% level	-3.5744	
5% level	-2.9238	
10% level	-2.5999	
*MacKinnon (1996) one-sided p -values		
Residual variance (no correction)	0.0026	
HAC corrected variance (Bartlett kernel)	0.0032	

Table 37: The real Baht-Dollar exchange rate is stationary

From here on, most researchers assume that q_t^T is stationary ($I(0)$) and that q_t is non-stationary of the order 1 ($I(1)$). By such an assumption, a cointegrating relationship:

$$q_t = -\alpha [(p_t^N - p_t^T) - (p_t^{N*} - p_t^{T*})] \quad (80)$$

Let us define $[(p_t^N - p_t^T) - (p_t^{N*} - p_t^{T*})]$ as \tilde{p} .

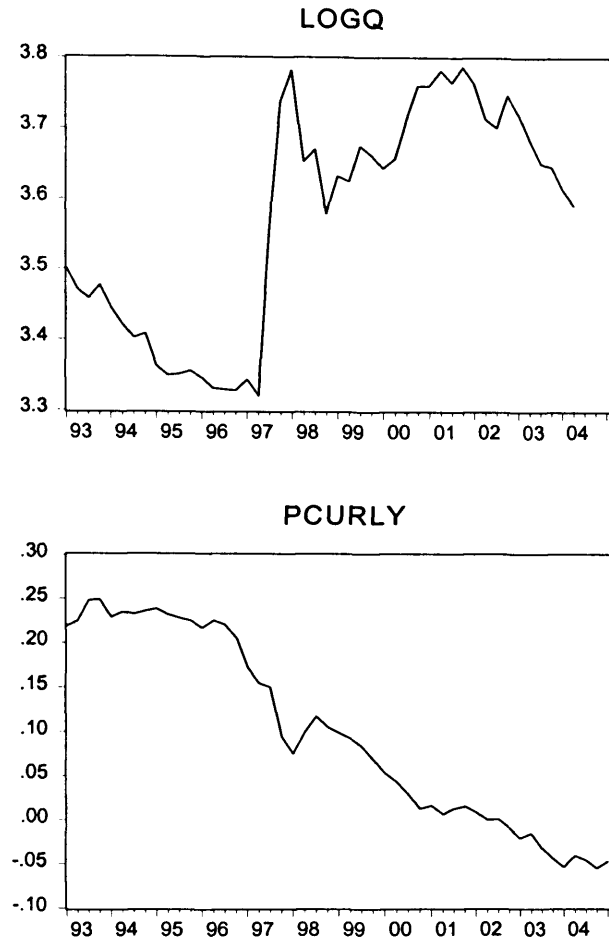


Figure 27: Thai Real Exchange Rate and Sectoral Traded-nontraded Price Differential

By constructing the weighted sum of tradables and nontradables price indices, and using cointegration techniques, Chinn (1996) found no evidence that relative prices of tradables and nontradables explain the Thai real exchange rate. Following Chinn (1996), we have the following results.

From the time series observation, pre- and post-crisis (from 2002 onward, as defined by the Markov-switching technique in *Part I* of the thesis, and also the IMF Economic Outlook), the real exchange rate (Baht/USD) seemed to be moving with the relative price, \tilde{p} .

Sample (adjusted): 1993Q3 2004Q2				
Included observations: 44 after adjustments				
Trend assumption: Linear deterministic trend				
Series: LOGQ PCURLY				
Lags interval (in first differences): 1 to 1				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None	0.2194	11.0830	15.4947	0.2065
At most 1	0.0041	0.1818	3.8415	0.6699
No cointegration at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p -values				

Table 38: No cointegration between the log of real Baht-Dollar and the relative trade-nontrade prices

No cointegration was reported between the real Baht-Dollar exchange rate and the relative nontrade-trade price indices.

The relative prices of nontradables and tradables are hereby determined solely by productivity differentials, under two assumptions. Firstly, capital is perfectly mobile internationally. Secondly, factors of production are free to move between sectors. By substituting for relative prices, another cointegration relation is obtained:

$$q_t = -\alpha [(a_t^T - a_t^N) - (a_t^{T*} - a_t^{N*})] \equiv -\alpha \tilde{a}_t \quad (81)$$

where a^i is total factor productivity (*TFP*) in sector i , and the sectoral production functions are assumed identical. As in Chinn (2000), the last two equations are the focus of our empirical investigation.

Again pre- and post-crisis (from 2002 onwards), the real exchange rate seemed to be moving with the relative productivity. The cointegration results of the real exchange rate and the relative productivity are reported below:

Again there is no evidence of cointegration between the real exchange rate and the relative traded-nontraded within and across the borders. Previous attempts to test the Harrod-Balassa-Samuelson hypothesis regarding the Thai productivity level were hampered by the lack of sectoral productivity data. Following Bahmani-Oskooee and Rhee (1996) and Chinn (2000), this is the equation to be estimated:

$$q_t = \kappa_0 + \kappa_1 (a_t - a_t^*) + u_t \quad (82)$$

The above equation implicitly *assumes that the economy-wide* productivity level, a , and

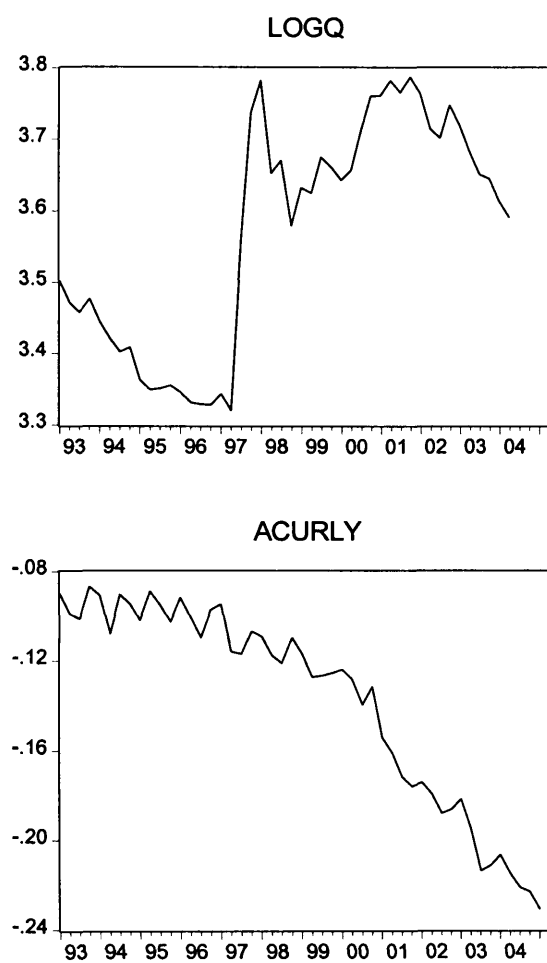


Figure 28: The Thai real exchange rate and relative sectoral traded-nontraded productivity

Sample (adjusted): 1993Q3 2004Q2				
Included observations: 44 after adjustments				
Trend assumption: Linear deterministic trend				
Series: LOGQ ACURLY				
Lags interval (in first differences): 1 to 1				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None	0.1406	6.6752	15.4947	0.6157
At most 1	0.0002	0.0100	3.8415	0.9199
No cointegration at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) <i>p</i> -values				

Table 39: The trace test for long run relationship between the real exchange rate and the relative sectoral productivity

the difference of the sectoral a 's are cointegrated. In the simplest case:

$$a_t = \omega a_t^T - \omega a_t^N \quad (83)$$

In the above equation ($q_t \equiv -\alpha \tilde{a}_t$), α is not identified. We can only estimate the product $\kappa = \omega\alpha$. If the coefficients of the sectoral a are not the same, then an omitted variable might lead to no evidence of cointegration, even if $q_t \equiv -\alpha \tilde{a}_t$ holds.

Recent literature, such as De Gregorio et al. (1994) and Chinn and Johnston (1996), has often focused on total factor productivity (TFP). This reflects an interest in *assessing the relative importance of supply shocks*, as proxied by total factor productivity, and demand shocks, as proxied by government expenditures, etc. in explaining real exchange rate movements. Hsieh (1982) and Marston (1987) use average products of labour, which have an advantage of implicitly allowing both supply and demand shocks to affect real exchange rates. Following Chinn (2000), the average labour productivity is taken as the proxy for the sectoral total factor productivity. The average labour productivity is calculated by dividing real output in sector i by labour employment⁵⁷ in sector i :

$$A_i^L \equiv \frac{Y_i}{N_i} \quad (84)$$

So we have, for the tradable sector (represented by the Thai Producer Price Index, which includes agriculture, mining and manufacturing),

$$A_T^L \equiv \frac{Y_T}{N_T} \quad (85)$$

⁵⁷Employment is classified by International Standard Industrial Classification ,Revision 3 (1989), United Nations.

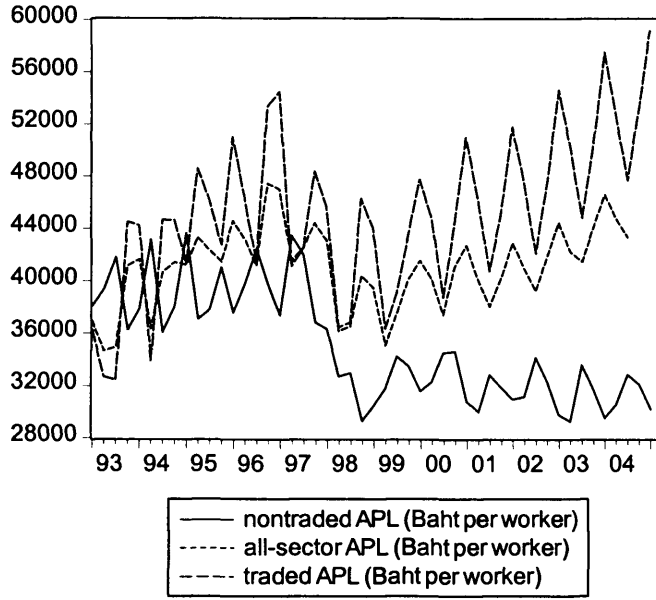


Figure 29: The Thai Overall and Sectoral Productivity

Similarly, for the services or the nontradable sector,

$$A_N^L \equiv \frac{Y_N}{N_N} \quad (86)$$

Once the sectoral indices are constructed, the real sectoral GDPs (Y_T , and Y_N) can be found. And once the real sectoral GDPs are found, the average product of labour for each sector can be found. The diagram below shows the all-sector APL (A^L), traded sector APL (A_T^L), and the nontraded sector APL (A_N^L).

So now we can substitute out, for Thailand

$$a_t = 0.7a_t^T - 0.3a_t^N \text{ (Thai coefficients calculated from the data)}$$

and the United States

$$a_t^* = 0.4a_t^{T*} - 0.6a_t^{N*}$$

Hence, from $q_t = \kappa_0 + \kappa_1(a_t - a_t^*) + u_t$, we have now found $(a_t - a_t^*)$, and observed the

spot nominal exchange rates. The real exchange rates q_t are expressed in terms of GDP deflators (rather than the CPIs which tend to have traded goods in them) and so the BS hypothesis for Thailand can now be tested, using the Johansen-Juselius cointegration test. The results indicate one cointegrating relation at 10%, but no evidence at 5%.

Sample (adjusted): 1993Q4 2004Q2				
Included observations: 43 after adjustments				
Trend assumption: Linear deterministic trend				
Series: LOGQ ADIFF				
Lags interval (in first differences): 1 to 2				
The Trace Test		Trace	0.05 Critical	
Hypothesized No. of CE(s)	Eigenvalue	Statistic	Value	Prob.**
None	0.2672	13.4826	15.4947	0.0983
At most 1	0.0027	0.1161	3.8415	0.7332
No cointegration at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Table 40: The trace test for the Productivity Bias following Bahmani-Oskooee and Rhee (1996) and Chinn (2000)

Since the rejection lies between 5-10%, there is no evidence for the Thai-US productivity bias. If it were possible to take out the entire readjustment of the value of the Baht then we might just have the evidence for the productivity bias hypothesis. But this is of course

Max Eigenvalue Rank Test		Max-Eigen	0.05 Critical	
Hypothesized No. of CE(s)	Eigenvalue	Statistic	Value	Prob.**
None	0.2672	13.3665	14.2646	0.0689
At most 1	0.0027	0.1161	3.8415	0.7332
No cointegration at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Table 41: The maximum eigenvalue test for the Productivity Bias following Bahmani-Oskooee and Rhee (1996) and Chinn (2000)

only a speculation. To conduct such an experiment would require a whole construction of the entire Thai economy—where there was no crisis to the Baht in the artificial economy. The productivity surge experiment is then performed on such an economy to see if there was evidence of the productivity bias in *Part III*.

3.1.6 Demand-side factors and their influence on the real exchange rate Although productivity is our main focus, other factors can also influence relative prices, notably from the demand side such as government spending. While government consumption falls mainly on nontradable goods (services among them), government spending should raise the relative price of nontradable goods and thus appreciate the domestic currency. This conclusion, as observed by Balvers and Bergstrand (1997), is derived from the assumption that public and private consumption are *substitutes* in each representative agent's utility function. If they were *complements*, however, this effect could be reversed.

The attempt to add more variables such as real oil prices and government spending and the terms of trade is hampered by the small sample. Future research on this topic would benefit from such additional variables.

3.2 Empirical Conclusion

The Balassa-Samuelson explanation of real exchange rate movements is that—given perfect labour mobility—changes in relative productivity across sectors lead to changes in relative prices. Since technological innovation is most likely to be concentrated in the tradable-goods sector, countries with higher long-run growth rates should have higher relative prices of nontradable goods as well as higher-valued currencies. The investigation in *Part II* also failed to uncover any such relationship, mainly because of the severe readjustment of the value of the Baht in the 1997-98, the impact of which led to a severe contraction of the Thai economy as well as dramatic capital outflows. By using an artificially constructed model of the entire Thai economy, it is possible to see the impact of a productivity surge to the domestic economy whether it would indeed lead to real exchange rate appreciation as hypothesized by the Harrod-Balassa-Samuelson hypothesis.

3.2.1 Policy implications from *Part II*

Deregulation A fall in fixed costs of entry to the distribution sector, according to Devereux's (1999) model above, must lead to a fall in P and a real depreciation. Thus, deregulation will tend to reduce the real exchange rate. In Devereux's model, this happens instantaneously. The trend path of the real exchange rate will be permanently lower and there are no dynamic implications for expenditure or the current account.

Fiscal Policy The impact of a rise in government spending and/or government debt in Devereux's model is as follows. The nested Balassa-Samuelson model implies that the real exchange rate is unaffected by the size of government spending and is determined solely

by technology factors. This is consistent with the Real Business Cycle assumption and model outlined and tested in our later chapter. Empirical evidence such as De Gregorio et al. (1994), however, indicate that a higher share of government spending leads to a higher (more appreciated) real exchange rate.

3.2.2 A note on evidence of deviations from PPP Throughout this thesis a rather strong assumption of Purchasing Power Parity is assumed to hold. Before we proceed to *Part III* of the thesis, it is worth noting that there are two conflicting approaches in recent studies of PPP. The oldest–absolute version of PPP–approach by Cassel (1918) postulates that relative prices (in different countries and locations) of a common basket of goods will be equalized when quoted in the same currency. The relative version of PPP, with the emphasis across time rather than space, is that the exchange rate will adjust to offset inflation differentials between countries. In Cassel’s view, whilst the exchange rate might temporarily diverge from PPP, such deviations are, to him, of minor importance. Modern versions of PPP recognizes the importance of slow speeds of adjustment, define PPP as reversion of the real exchange rate to a constant mean.

Balassa (1964) and Samuelson (1964) draw on Ricardo’s and Harrod’s ideas and turn their attention on the fact that *divergent international productivity levels could–via their effect on wages and home good prices–lead to permanent deviations from Cassel’s absolute version of PPP*. They independently make a link between PPP, exchange rates and intercountry real-income comparisons, arguing that the absolute version of PPP is flawed as a theory of exchange rates. Assuming that PPP holds for traded goods, their argument is based on the fact that **productivity differentials between countries determine the domestic relative prices of nontradables, leading to trend deviations from PPP in the long run**. Obstfeld (1993) uses these ideas to develop a model in which real exchange rates contained a pronounced deterministic trend.

Increasingly, the contrasting views of these two approaches in recent studies of PPP are becoming apparent. Modern research on PPP, taking into account the possibility of slow

speeds of reversion, finds evidence of PPP if the unit root null can be rejected in favour of a stationary alternative for real exchange rates. It remains to be discussed whether the stationary alternative should be level stationarity, reversion to a constant mean, or trend stationary alternative for real exchange rates. Papell and Prodan (2003) use conventional tests and find evidence of some variant of PPP for 9 of the 16 countries. With more restricted tests, there is evidence for 5 additional countries. The Cassel (absolute) version of PPP is supported for 10 countries and the Balassa-Samuelson version is supported for 4 countries.

3.2.3 Persistence Imbs et al. (2005) show the importance of a dynamic aggregation bias and prove that established time series and panel methods substantially exaggerate the persistence of real exchange rates because of heterogeneity in the dynamics of disaggregated relative prices. Their estimates of the real exchange rate half life fall dramatically to little more than one year—significantly below the ‘consensus view’ of Rogoff’s 3-5 years when heterogeneity is properly taken into account. The authors claim that their corrected estimates are consistent with plausible nominal rigidities and thus claim to have solved the PPP puzzle.

Frankel and Rose (1996) and Lothian (1997) report that deviations from PPP are temporary points to a half life of 4-5 years. Canzoneri et al.’s (1999) results provide favourable support for the hypothesis of purchasing power parity in traded goods, especially when the DM is the reference currency. There nominal exchange rates and PPP exchange rates appear to be cointegrated. Canzoneri et al. (1999)’s estimates suggest that the slopes of the cointegrating relationships are far from the hypothesized value of unity when the dollar is used as the reference currency but nominal and PPP exchange rates are nearly proportional when the DM is used as the reference currency.

3.3 *Part II: Conclusion*

The logic of the Balassa-Samuelson model flows from several assumptions. The first is that domestic workers' wages are equalized by competition between the tradables and nontradables sectors. This implies that if the productivity of workers and capital in the sector producing traded goods grows faster than that of their counterparts in the sector producing nontraded goods, then the price of nontraded goods relative to traded goods should rise. Thus the price of haircuts and restaurant meals become more expensive relative to televisions and cars. The second is that traded goods prices in different countries are tied together by international arbitrage activities, so that the price (in a common currency such as the dollar) of a traded commodity is the same in Korea or the U.S. (ignoring the effects of tariff barriers and transportation costs). Since a country's overall price level consists of the prices of both traded and nontraded goods and the prices of traded goods are (more or less) equalized across countries, it follows that the overall price level will tend to rise faster in countries where nontraded goods prices are rising faster, i.e., with relatively high productivity growth in the manufacturing sector (as compared to the service sector). In turn, this implies that countries with relatively high manufacturing productivity growth will have growing real purchasing power over foreign goods, and their currencies will appreciate in real terms.

At first glance, the model's conclusions would appear to suggest that it is desirable to have relatively low service sector productivity growth and consequently an appreciating strong currency; but that would represent an incorrect view, equating an appreciating currency with a higher level of economic welfare. In general, there is no straightforward link between how

well an economy is doing and the real exchange rate. Consider the fact that society is usually made better, not worse, off by higher productivity in services (as well as in manufacturing). In order to see how well the Thai economy is doing, our attention now turns to exploring the other aspects of the Thai-like economy by employing the use of a fully-specified open economy representative agent model, comprising of the Government, Household, Industry, and Foreign Sectors and their respective utility specification. The model exhibits cyclical patterns and responds to shocks like the real economy does⁵⁸.

⁵⁸For analytical simplicity no more than 2 shocks are applied at once.

4 *Part III*: What *will* happen to the Baht if a real shock is sent to an artificial Thai economy?

4.1 A Medium Open Economy Real Business Cycle model

The monetary model is a useful first approximation in fixing our intuition about exchange rate dynamics, even though it fails to explain the data on many dimensions. Because purchasing power parity is assumed to hold as an exact relationship, the model cannot explain the dynamics of the real exchange rate. The main reason to study nominal exchange rate behaviour is if we think that nominal exchange rate movements are correlated with real exchange rate changes, so that they have real consequences. In *Part I*, we have shown the dynamics of the nominal exchange rate using a Business Cycle computation technique. In *Part II*, we failed to provide the empirical evidence for the productivity bias. In *Part III*, then, it is appropriate to see the whole economy at work, both providing the dynamics for the real exchange rate and providing the evidence for the productivity bias, something that we were not able to do in *Part II* by simply estimating the long run relationship over time. In this section, the whole economy is specified based on a real business cycle model.

4.2 The Lucas Model

Kydland and Prescott (1982), Long and Plosser (1983) pioneered the outgrowth of the equilibrium strategy for business cycle analysis initiated by Lucas (1972, 1975, 1976) and extended by Barro (1976, 1981), but their approach differ from the previous literature in two ways. Firstly, the Real Business Cycles (hereafter, RBC) models place more emphasis on cycle propagation mechanisms, namely how the effects of a shock spread over time. Sec-

only, in the RBC models shocks that initiate the business cycles are emphasized as real (as opposed to monetary) in origin.

Conventional view of the impact of a productivity shock on an economy is that a spurt in productivity leads to an expansion of output, if this extra output has to be sold in the world markets the price of the good must fall i.e. the higher the world supply of the good the lower the relative price. The country should then experience real exchange rate depreciation and the worsening of the term of trade.. However, this contrasts with the empirical findings of currency appreciation after a productivity surge. The most notable example is the US productivity surge of the latter half of the 1990s, which led to the continuous dollar appreciation against other currencies throughout the period.

According to Sofat, Minford, Nowell and Meenagh (2005), a 1% deterministic productivity growth shock shows real exchange rate appreciation followed by a return to the equilibrium or what they also regard as a business cycle. They show that *the real business cycle alone can reproduce the univariate properties of the real exchange rate without the need to introduce the nominal rigidity.*

Models relying on nominal rigidity (with a high but implicit elasticity of output to shocks) have difficulty in reproducing the high real exchange rate volatility. The deterministic simulation is performed in order to establish the magnitude and shape of the response function of the real exchange rate to the RBC technology shock (which is a workhorse for a typical real business cycle model). In the RBC world, the 'shock' is a burst of unanticipated productivity growth that raises the productivity level in steady state well above its previous path.

Productivity surge raises permanent income, stimulating investment streams, raising cap-

ital stock. Extra labour and capital is needed to expand real output but both factors of production is slow to arrive (job search and capital delivery as well as capital installation and labour training take time). Real interest rate must rise to reduce demand to the available supply. The rising real interest rate violates the real uncovered interest parity, which links the domestic to the rest of world economy. This must be compensated by a rise in the real exchange rate relative to its expected future value. This rise is possible by the expectation of falling real exchange rates, thus enabling the URIP to be re-established, consistent with the new, higher real interest rate. With the arrival of the additional & required labour and capital, real interest rate falls, and the real exchange rate moves back to equilibrium. The new equilibrium is a real depreciation from the previous steady state, since output is now higher and must be sold on world markets at a discounted price.

To demonstrate the consistency of the model with the facts, Sofat et. al. (2005) ask whether the model could have generated the real exchange rate patterns found in the actual data. The steps are then taken to calibrate the model to the Thai data, and derive from calibration the behaviour of the productivity and preference shocks. Then the sampling variability is generated within the model by bootstrapping⁵⁹.

Alquist and Chinn (2002) find that the real exchange rate is cointegrated with a broad productivity differential. They find that each 1% increase in the US-Euro area productivity differential results in between 4-5% appreciation in the dollar/euro exchange rate.

⁵⁹The bootstrapping is a simple non-parametric, distribution-free statistical analysis technique which resamples with replacement of a given sample (for example, average waiting time per simulation run). It does not assume a specific distribution for the response of interest.

4.3 The Sofat-Minford-Nowell-Meenagh (SMNM) model

The model fitted for Thailand is taken from the work developed by Prakriti Sofat and Patrick Minford at the Cardiff Business School, it is extended from the work of the Liverpool Research Group⁶⁰ and computed by Eric Nowell and David Meenagh. It is a medium-sized open economy with the domestic economy clearly specified, taking the world economy as given. Although the given world economy is a small economy assumption, the Sofat-Minford-Nowell-Meenagh medium-sized open economy model has varying real exchange rates and the domestic economy interacting with the rest of the world via the Uncovered Interest Parity (UIP) assumption and micro-founded current account. The model is for an economy with identical infinitely lived agents who produce a single good as their output and use the good both for consumption and investment. There is no population growth and all variables are per capita. It is also assumed that there are no market imperfections such as frictions of transactions costs.

At the beginning of each period t , the representative agent chooses the commodity bundle for consumption during the period. She also chooses the total amount of leisure that she would like to enjoy during the period. Finally, the agent chooses the total amount of factor inputs necessary to carry out production during the period. The three choices are constrained by the fixed amount of time available and the aggregate resource constraints faced. During the period t , the economy is influenced by various random shocks. Instead of trading goods in a normal open economy setup, here for simplicity goods are only exchanged as final goods and do not enter in the production function. The consumption C_t in the utility

⁶⁰Special thanks go to the authors themselves, and Eric Nowell and David Meenagh for computing assistance.

function is the composite per capita consumption, which consists of agents' consumption of domestic goods, C_t^d , and their consumption of imported goods, C_t^f .

We define σ as the elasticity of substitution and assume Constant Elasticity of Substitution (CES). As such, the composite consumption function for Thailand is given by an Armington aggregator of the form:

$$C_t = \left[\omega (C_t^d)^{-\rho} + (1 - \omega) (C_t^f)^{-\rho} \right]^{\frac{-1}{\rho}}, \quad (87)$$

ω is the weight of home goods in the consumption function.

The US's composite consumption function is hereby represented as C_t^F (not to be confused with C_t^f , which denotes the domestic country's foreign goods consumption, or imports).

The consumption-based price index P_t is defined as the minimum expenditure necessary to buy one unit of the composite good C_t , given the price of the domestic good and foreign good. The index that corresponds to the above specification of preference is derived as:

$$P_t = \left[\omega^{\frac{1}{1+\rho}} (P_t^d)^{\frac{\rho}{1+\rho}} + (1 - \omega)^{\frac{1}{1+\rho}} (P_t^F)^{\frac{\rho}{1+\rho}} \right] \quad (88)$$

P_t^d is the domestic price level

P_t^F is the foreign price level in domestic currency.

$P_t^F = S_t P_t^f$, where S_t is the nominal exchange rate and P_t^f is the foreign price level in foreign prices, thus P_t^F is the foreign price level in domestic prices. Agent's demand for home and foreign goods is a function of their respective relative price and composite consumption.

$$C_t^d = \left(\frac{P_t^d}{\omega P_t} \right)^{-\left(\frac{1}{1+\rho}\right)} C_t \quad (89)$$

and

$$C_t^f = \left(\frac{P_t^F}{(1-\omega) P_t} \right)^{-\left(\frac{1}{1+\rho}\right)} C_t \quad (90)$$

A consumer is expected to maximize her expected utility subject to her budget constraint.

Each agent's preferences are given by:

$$U = \max E_0 \left[\sum_{t=0}^{\infty} \beta^t u(C_t, L_t) \right], \quad 0 < \beta < 1. \quad (91)$$

β is the discount factor, C_t is consumption in period t , L_t is the amount of leisure time consumed in period t , and E_0 is the mathematical expectations operator. The agent's tastes are assumed constant over time, and not influenced by exogenous stochastic shocks. The preference ordering of consumption subsequences $[(C_t, L_t), (C_{t+1}, L_{t+1}), \dots]$ does not depend on t or on consumption prior to time t . It is assumed that $u(C, L)$ is increasing in (C, L) and concave:

$$u'(C, L) > 0, \quad u''(C, L) < 0.$$

We also assume that $u(C, L)$ satisfies Inada-type conditions⁶¹:

$$u'(C, L) \rightarrow \infty \text{ as } c \rightarrow 0,$$

and

$$u'(C, L) \rightarrow 0 \text{ as } c \rightarrow \infty,$$

$$u'(C, L) \rightarrow \infty \text{ as } l \rightarrow 0 \text{ and}$$

$$u'(C, L) \rightarrow 0 \text{ as } l \rightarrow \infty.$$

Here the government has no role since we assume complete markets and no externality.

⁶¹Inada (1963).

The government collects tax and spends it to provide public goods. This introduces the demand side disturbance to the basic model, which is otherwise governed by supply side disturbance. The model follows Lucas (1980, 1987) in assuming that money has value in exchange. In the Sofat et al. (2005) model, trading is introduced in decentralised markets. The use of money is motivated by the use of the cash-in-advance (CIA) model, namely a subset of consumption goods must be paid for with currency acquired in advance. This type of an RBC model is extended from the representative agent framework by Bennett McCallum (McCallum (1989)).

4.3.1 The Household Sector The model economy is assumed to have a large number of identical households. Each household makes consumption, investment, and labour supply decisions over time. Sofat et. al. (2005) assume the following time-separable utility function of the form:

$$U(C_t, 1 - N_t) = \theta_0 (1 - \rho_0)^{-1} C_t^{(1-\rho_0)} + (1 - \theta_0) (1 - \rho_2)^{-1} (1 - N_t)^{(1-\rho_2)}, \quad (92)$$

where $0 < \theta_0 < 1$, and $\rho_0, \rho_2 > 0$ are the substitution parameters. This type of functional form follows McCallum and Nelson (1999) and has the advantage of not being too restrictive in that the specification does not force the elasticity of substitution between consumption and leisure to unity. When $\rho_0 = \rho_2$, the Constant Elasticity of Substitution (CES) utility function simplifies to the Cobb-Douglas version. Each agent plays a dynamic stochastic game, with changes in expectations about future events generally affecting current decisions. Each decision at a given point in time is influenced by what agents believe would be their available opportunity set in the future. Each agent in the Sofat et al. (2005) model is

endowed with a fixed amount of time which is spent on leisure L_t and/or work N_t . If the total endowment of time H_t is normalized to unity, it then follows that:

$$N_t + L_t = 1 \text{ or } L_t = 1 - N_t \quad (93)$$

If \bar{l} is the normal amount of leisure necessary for an agent to sustain her productivity over a period of time, an agent who prefers more than normal amount of leisure time—say U_t —is assumed to be unemployed:

$$U_t = (1 - N_t) - \bar{l}. \quad (94)$$

As there are no unemployment benefits (μ) for the Thai economy, the consumer real wage (v_t) is greater than zero (as opposed to greater than the benefits) to create an incentive to work (as opposed to just consume leisure or doing nothing). Where there are unemployment benefits, the degree of substitution between work and leisure is higher. In the general case the representative agents budget constraint is:

$$\begin{aligned} (1 + \phi_t) C_t + \frac{b_{t+1}}{1 + r_t} + \frac{Q_t b_{t+1}^f}{(1 + r_t^f)} + \frac{p_t S_t^P}{P_t} \\ = (1 - \tau_{t-1}) v_{t-1} N_{t-1} + \mu_{t-1} [(1 - N_{t-1}) - \bar{l}] + b_t + Q_t b_t^f + \left(\frac{(p_t + d_t) S_t^P}{P_t} \right) \end{aligned} \quad (95)$$

The representative agents budget constraint for Thailand is:

$$(1 + \phi_t) C_t + \frac{b_{t+1}}{1 + r_t} + \frac{Q_t b_{t+1}^f}{(1 + r_t^f)} + \frac{p_t S_t^P}{P_t} = (1 - \tau_{t-1}) v_{t-1} N_{t-1} + b_t + Q_t b_t^f + \left(\frac{(p_t + d_t) S_t^P}{P_t} \right) \quad (96)$$

where:

ϕ_t represents consumption tax, this is assumed to follow a stochastic process.

τ_t represents labour income tax, this is also assumed to follow a stochastic process.

d_t is dividends, which is obtained from an individual's investment in shares,

$$d_t = \left(\frac{p_t + d_t}{P_t} \right) S_t^P. \quad (97)$$

L_t denotes Labour (time spent at work).

p_t denotes the present value of shares.

Q_t denotes the real exchange rate.

v_t denotes the real consumer wage,

$$v_t = \frac{W_t}{P_t}. \quad (98)$$

Consumers take into account domestic and foreign prices while evaluating their real wages but producers do not since they do not use imported intermediate goods. The consumer real wage is greater than zero since Thailand has no unemployment benefits. But for the sake of clarity and generality, μ and the terms associated with μ remain in the text, with $\mu = 0$ in the coded Fortran program when the Thai data are used.

The representative agent's real demand for domestic money is equal to consumption of domestic goods inclusive of sales tax. Similarly the agent's real demand for foreign money is equal to consumption of foreign goods inclusive of sales tax:

$$(1 + \phi_t) C_t^f = \frac{M_t^{Fp}}{P_t^F}, \quad (99)$$

where:

$$M_t^{F_p} = S_t M_t^{f_p} \quad (100)$$

Consumption is treated as a *cash* good, i.e. the cash-in-advance constraint is binding only in the case of consumption. Investment is a *credit* good. The household's budget constraint is divided into two subperiods. In the first subperiod, the household receives labour income (net-of-tax) $(1 - \tau_{t-1}) v_{t-1} N_{t-1}$, domestic bond income from previous period b_t , foreign bond income $Q_t b_t^f$, unemployment benefits (if any, in Thailand's case this is zero), and dividends d_t from the number of shares invested (S_t^P). In the second subperiod, the representative household buys goods with the currency carried forward from the first subperiod and purchases shares and government bonds.

In this stochastic environment the representative agent maximizes her expected discounted stream of utility subject to her budget constraint. The Lagrangian associated with this problem is:

$$U = \max E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\theta_0 (1 - \rho_0)^{-1} C_t^{(1-\rho_0)} + (1 - \theta_0) (1 - \rho_2)^{-1} (1 - N_t)^{(1-\rho_2)} \right] \right\} \\ + \lambda_t \left\{ \begin{aligned} &(1 - \tau_{t-1}) v_{t-1} N_{t-1} + \mu_{t-1} [(1 - N_{t-1}) - \bar{l}] + b_t + Q_t b_t^f + \\ &\frac{(p_t + d_t) S_t^P}{P_t} - (1 + \phi_t) C_t - \frac{b_{t+1}}{1+r_t} - \frac{Q_t b_{t+1}^f}{(1+r_t^f)(1-r_p)} - \frac{p_t S_t^P}{P_t} \end{aligned} \right\} \quad (101)$$

λ is the Lagrangian multiplier, $0 < \beta < 1$ is the discount factor, and $E(\cdot)$ is the mathematical expectations operator. The first order conditions are listed below.

With respect to C_t , the marginal utility of domestic consumption equals the shadow price of output, taking account of the sales or consumption tax (ϕ_t).

$$(1 - \rho_0) \theta_0 (1 - \rho_0)^{-1} C_t^{-\rho_0} = \lambda_t (1 + \phi_t) \quad (102)$$

With respect to N_t , the marginal disutility of labour equals labour's marginal product, the real wage, which is affected by income tax (tax on labour) (and the unemployment benefit, if existed):

$$(1 - \rho_2) (1 - \theta_0) (1 - \rho_2)^{-1} (1 - N_t)^{-\rho_2} = \beta E_t \lambda_{t+1} [(1 - \tau_t) v_t - \mu_t]. \quad (103)$$

The supply of labour is positively related to the net-of-tax real wage (and negatively related to the unemployment benefits, if any).

With respect to b_t , $\frac{\lambda_t}{1+r_t} = \beta E_t \lambda_{t+1}$.

With respect to b_t^f , $\frac{\lambda_t Q_t}{(1+r_t^f)} = \beta E_t \lambda_{t+1} Q_{t+1}$.

With respect to S_t^p , $\frac{\lambda_t p_t}{P_t} = \beta E_t \lambda_{t+1} \left(\frac{p_{t+1} + d_{t+1}}{P_{t+1}} \right)$. All of these conditions characterize the expected behaviour of the economy and determine the time path of the values of labour, consumption, and investment in financial assets. To prevent each household from borrowing an unlimited amount at the current interest rate, each household's decision rule is subject to a transversality condition:

$$Y_{T-1} - r_T D_T - \phi_T C_T - \tau_T v_T N_T^s - T_T = C_T. \quad (104)$$

Substituting the transversality condition into the first order condition for consumption, we get the present value per share. Using the arbitrage condition and forward substitution,

the present value per share⁶² can be written as:

$$p_t = \sum_{i=1}^{\infty} \frac{d_{t+i}}{(1+r_t)^i} \left(\frac{P_t}{P_{t+i}} \right). \quad (105)$$

Sofat et al. (2005) argue that their medium economy setup (a rather small to medium size in that the domestic economy has no effect on the world rate, is affected by the world rate exogenously, but the exogenous world rate shock is large enough for the domestic interest rate to deviate from the world rate and thus resulting in the constantly varying real exchange rates). When the representative agent's demand for home goods is substituted into the Representative Household's Lagrangian, the Uncovered Real Interest Parity (URIP) is obtained by logging the simplified outcome:

$$\left(\frac{1+r_t}{1+r_t^f} \right) = \frac{Q_{t+1}}{Q_t} \quad (106)$$

to get:

$$r_t = r_t^f + E_t \Delta \log Q_{t+1}, \quad (107)$$

with both domestic and foreign interest rates in real terms.

4.3.2 The Government Sector It is assumed that the government spends less than the nation's output, $G_t \leq Y_t$, for all t . Here in the equilibrium business cycle models with rational expectations, output is always at its 'desired' levels. Given the information set, agents are maximizing their welfare subject to constraints. In this set-up there are no distortions, and thus government expenditures might not improve the agent's welfare and are subsequently

⁶²The present value per share is discounted future dividends.

dropped from the agent's utility function. There are no unemployment benefits in Thailand and therefore to increase their consumption, agents have to work more hours and thus have to cut down on the amount of leisure. Without the unemployment benefits the substitution effect is lower than economies with welfare state such as the UK.

The government collects income tax τ_t and consumption tax ϕ_t to finance its expenditure (which by our assumption does not affect welfare). Both income and consumption taxes are assumed to be stochastic processes. Additionally, the government issues debt (bonds, b_t) in each period. Each bond pays a return in the next period. The government then collects seigniorage $\frac{M_{t+1}^d - M_t^d}{P_t^d}$, which acts as a lump-sum tax and is assumed to be a stochastic process, leaving real asset prices and allocation unchanged. The labour income tax reduces the take-home pay, and thus reduces the opportunity cost of leisure, and there is thus an increase in substituting leisure for work.. This substitution effect decreases labour supply. The tax simultaneously reduces the representative agent's income. Given that leisure is a normal good, the loss in income leads to a reduction in leisure consumption, other things being equal. The income effect induces an individual agent to work more. The relative strength of the income and substitution effects would ultimately determine whether an agent would work more or less hours.

Consumption tax is imposed by the State on flows in the production of current output (the sales of business firms) whilst income tax is imposed on the net income received by agents. The consumption or sales tax is imposed by the State or Government on the sales of each representative firm or business.

The Government budget constraint is therefore given by:

$$G_t + b_t + \mu_t [(1 - N_t) - \bar{l}] = \tau_{t-1} v_{t-1} N_{t-1} + \phi_{t-1} C_{t-1} + \frac{b_{t+1}}{1 + r_t} + \frac{M_{t+1}^d - M_t^d}{P_t^d}, \quad (108)$$

b_t are real bonds

P_t^d is the domestic price level.

The total tax revenue that the Government collect is $\tau_{t-1} v_{t-1} N_{t-1} + \phi_{t-1} C_{t-1}$. The Government also has to produce cash prior to making the purchase (they also face a cash-in-advance constraint):

$$P_t^d G_t \leq M_t^{dg}, \quad (109)$$

where M_t^{dg} is the Government's demand for domestic money. The Government is hereby assumed to have *home bias*, namely, they consume only domestic goods.

4.3.3 The Industrial Sector Here a constant-returns-to-scale production function is assumed:

$$Y_t = Z_t N_t^\alpha K_t^{1-\alpha} \quad (110)$$

where $0 \leq \alpha \leq 1$.

Y_t is the aggregate output per capita.

K_t is capital carried over from previous period $(t - 1)$,

Z_t represents the state of technology.

The government budget constraint:

$$G_t + b_t = \tau_{t-1}v_{t-1}N_{t-1} + \phi_{t-1}C_{t-1} + \frac{b_{t+1}}{1+r_t} + \frac{M_{t+1}^d - M_t^d}{P_t^d}, \quad (111)$$

b_t is real bonds, and P_t^d is the domestic price level. The total tax revenue collected by the state is $\tau_{t-1}v_{t-1}N_{t-1} + \phi_{t-1}C_{t-1}$. The government also faces a cash-in-advance constraint:

$$P_t^d G_t \leq M_t^{dg}. \quad (112)$$

M_t^{dg} is the government's demand for domestic money. It is assumed here that the Government also has home bias and consumes only domestic goods.

4.3.4 The Foreign Sector In a stochastic environment, a representative agent maximizes his/her expected discounted streams of utility subject to his/her budget constraint. The agent's consumption constraint is:

$$P_t C_t^{63} = P_t^d C_t^d + P_t^F C_t^f \quad (113)$$

The utility-based price index corresponding to the above consumption function is of the form:

$$P_t = \left[\omega^{\frac{1}{1+\rho}} (P_t^d)^{\frac{\rho}{1+\rho}} + (1-\omega)^{\frac{1}{1+\rho}} (P_t^F)^{\frac{\rho}{1+\rho}} \right]. \quad (114)$$

⁶³From previously, the consumption function is an Armington aggregator of the form $C_t = \left[\omega (C_t^d)^{-\rho} + (1-\omega) (C_t^f)^{-\rho} \right]^{\left(\frac{-1}{\rho}\right)}$, where C_t is complete per capita consumption, made up of C_t^d (agent's consumption of domestic good) and C_t^f (agent's consumption of foreign or imported goods). ω is the weight of home goods in the consumption function.

The Lagrangian for agent's maximization, subject to both the budget and consumption constraints, is:

$$U = \max E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\theta_0 (1 - \rho_0)^{-1} C_t^{(1-\rho_0)} + (1 - \theta_0) (1 - \rho_2)^{-1} (1 - N_t)^{(1-\rho_2)} \right] \right\} +$$

$$\lambda_t \left\{ (1 - \tau_{t-1}) v_{t-1} N_{t-1} + b_t + Q_t b_t^f + \frac{(p_t + d_t) S_t^p}{P_t} - (1 + \phi) C_t - \frac{b_{t+1}}{1+r_t} - \frac{Q_t b_{t+1}^f}{(1+r_t^f)(1-r_p)} \right.$$

$$\left. - \frac{p_t S_t^p}{P_t} \right\} + \lambda_t^c \left\{ P_t^d C_t^d + P_t^F C_t^f - P_t C_t \right\}. \quad (115)$$

The first order conditions with respect to C_t^d and C_t^f are $\theta_0 C_t^{-\rho_0} \frac{\partial C_t}{\partial C_t^d} - \lambda_t (1 + \phi_t) \frac{\partial C_t}{\partial C_t^d} - \lambda_t^c P_t^d + \lambda_t^c P_t \frac{\partial C_t}{\partial C_t^d}$ and $\theta_0 C_t^{-\rho_0} \frac{\partial C_t}{\partial C_t^f} - \lambda_t (1 + \phi_t) \frac{\partial C_t}{\partial C_t^f} - \lambda_t^c P_t^F + \lambda_t^c P_t \frac{\partial C_t}{\partial C_t^f}$.

From Backus, Kehoe and Kydland (1994), the equilibrium terms of trade can be computed from the intra-temporal marginal rate of substitution between goods in the Armington aggregator function. The slope of the indifference curve or the marginal rate of substitution is given by:

$$\frac{P_t^F}{P_t^d} = \frac{\frac{\partial C_t}{\partial C_t^f}}{\frac{\partial C_t}{\partial C_t^d}} = \left(\frac{1 - \omega}{\omega} \right) \left(\frac{C_t^d}{C_t^f} \right)^{1+\rho}. \quad (116)$$

Knowing this, the first condition with respect to C_t^f is divided by that of C_t^d to obtain:

$$\frac{P_t^F}{P_t^d} = \frac{\frac{\partial C_t}{\partial C_t^f}}{\frac{\partial C_t}{\partial C_t^d}} \quad (117)$$

or

$$\frac{P_t^F}{P_t^d} = \left(\frac{1 - \omega}{\omega} \right) \left(\frac{C_t^d}{C_t^f} \right)^{1+\rho} \quad (118)$$

which can be rewritten as:

$$Q_t = \left(\frac{1 - \omega}{\omega} \right) (F)^{(1+\rho)}; \quad (119)$$

where $Q_t = \frac{P_t^F}{P_t^d}$ and $F = \frac{C_t^d}{C_t^f}$.

The elasticity of substitution between home and imported goods is given by:

$$\sigma = \left(\frac{\partial F}{\partial Q} \right) \left(\frac{Q}{F} \right) = \frac{1}{1 + \rho}. \quad (120)$$

Substituting the above equation in the equation for Q_t , we have the real exchange rate:

$$Q_t = \left(\frac{1 - \omega}{\omega} \right) \left(\frac{C_t^d}{C_t^f} \right)^{\left(\frac{1}{\sigma} \right)}, \quad (121)$$

σ is never zero since the goods are assumed to be substitutable but not perfectly substitutable and thus σ will not take the infinite value and will remain some finite value. The lower the estimated σ , the less the substitution between the two goods. In other words, the greater degree of product differentiation, the smaller the elasticity of substitution between the products.

Thailand's import equation can be derived from the real exchange rate equation. Taking logs of the real exchange rate equation yields:

$$\log IM_t^{64} = \sigma \log \left(\frac{1 - \omega}{\omega} \right) + \log (C_t^d) - \sigma \log Q_t. \quad (122)$$

But the import function requires imports to be described by the overall consumption, which is related to the domestic good consumption in the following way:

⁶⁴Since $IM_t = C_t^f$.

$$C_t^d = \left(\frac{P_t^d}{\omega P_t} \right)^{-\frac{1}{1+\rho}} C_t. \quad (123)$$

Taking logs of the domestic good consumption equation gives:

$$\log C_t^d = \sigma \log \omega + \sigma \log P_t - \sigma \log P_t^d + \log C_t. \quad (124)$$

Substituting $\log C_t^d$ back into the import equation to arrive at the import function:

$$\log IM_t = \sigma \log (1 - \omega) + \log C_t - \sigma A \log Q_t, \quad (125)$$

$$A = \frac{\omega^{\frac{1}{1+\rho}}}{\omega^{\frac{1}{1+\rho}} + (1 - \omega)^{\frac{1}{1+\rho}}}, \quad (126)$$

which states that Thailand's imports are positively correlated to the total consumption and negatively related to the real exchange rate. As Q_t increases (or the Thai Baht depreciates), import demand falls.

Similarly for the US (or any other foreign trading partner country), the Armington aggregator consumption function and a corresponding exchange rate equation is:

$$C_t^F = \left[\omega^f \left(C_t^{df} \right)^{-\rho_3} + (1 - \omega^f) \left(C_t^{ff} \right)^{-\rho_3} \right]^{\left(\frac{-1}{\rho_3} \right)}, \quad (127)$$

and

$$Q_t^f = \left(\frac{1 - \omega^f}{\omega^f} \right) \left(\frac{C_t^{df}}{C_t^{ff}} \right)^{\left(\frac{1}{\sigma_1} \right)}, \quad (128)$$

where C_t^F is the composite consumption of the foreign country, C_t^{df} is the foreign country's consumption of her own goods. C_t^{ff} is the foreign country's consumption of domestic

country's goods. ω^f is the weight of foreign country's own goods in her own composite consumption function. Q_t^f is the real exchange rate for the foreign country ($Q_t^f = \frac{1}{Q_t}$) $\sigma_1 = \frac{1}{1+\rho_3}$ is the elasticity of substitution between home goods (home exports) and foreign country's own goods.

Taking logs of Q_t^f , we get:

$$\log EX_t = \sigma_1 \log \left(\frac{1 - \omega^f}{\omega^f} \right) + \log C_t^{df} + \sigma_1 \log Q_t. \quad (129)$$

By definition, $EX_t = C_t^{ff}$ and $Q_t^f = \frac{1}{Q_t}$.

As in the case of the domestic country, the country's export function needs to be described by their overall consumption C_t^F , and thus the need to substitute out for $\log \left(C_t^{df} \right)$.

From the foreign household expenditure minimization,

$$C_t^{df} = \left(\frac{P_t^{df}}{\omega^f P_t^*} \right)^{-\left(\frac{1}{1+\rho_3}\right)} C_t^F, \quad (130)$$

where P_t^* is the consumer price index for the foreign country:

$$P_t^* = \left[(\omega^f)^{\frac{1}{1+\rho_3}} \left(P_t^{df} \right)^{\frac{\rho_3}{1+\rho_3}} + (1 - \omega^f)^{\frac{1}{1+\rho_3}} \left(P_t^D \right)^{\frac{\rho_3}{1+\rho_3}} \right]. \quad (131)$$

P_t^{df} is the foreign country's own price level and P_t^{D65} is the domestic price level in foreign currency.

Taking logs of the foreign consumption of her own goods we get:

$$\log C_t^{df} = \sigma_1 \log \omega^f + \sigma_1 \log P_t^* - \sigma_1 \log P_t^{df} + \log C_t^F. \quad (132)$$

⁶⁵ $P_t^D = \frac{P_t^d}{S_t}$.

Substitute this into the export-in-terms-of- C_t^{df} -and- Q_t equation to get export in terms of C_t^F and Q_t :

$$\log EX_t = \sigma_1 \log (1 - \omega^f) + \log C_t^F + \sigma_1 A^f \log Q_t, \quad (133)$$

where;

$$A^f = \frac{(\omega^f)^{\frac{1}{1+\rho}}}{(\omega^f)^{\frac{1}{1+\rho}} + (1 - \omega^f)^{\frac{1}{1+\rho}}}. \quad (134)$$

The export function equation states that export of the home country are a positive function of the total consumption in the foreign country. It is a positive function of the real exchange rate. If Q_t increases (the home currency depreciates), then export will increase. Both home and foreign representative agents need foreign and home money respectively in order to transact with each other. The US agents need the Thai Baht to buy Thai exports, and get them for imports as well as the Thai purchase of US bonds (the Balance of Payments surplus). This surplus is equal to the home (Thai) agents net demand for foreign money (US Dollar). The Thais (our home agents) obtain the US Dollars from exporting firms to US agents and need the US Dollar for imports and purchases of US bonds. Therefore if home (Thai) agents adjust their sales of foreign bonds then all will be in balance. It is assumed that, in equilibrium, exports equal imports and thus there is no tendency for agents to change their asset position. In disequilibrium, though, the changes between domestic and foreign bonds will depend upon net exports, which is defined as:

$$NX_t \equiv EX_t - IM_t. \quad (135)$$

From our reasoning above, the foreign bonds will evolve over time according to the change in net exports and the current foreign bond holding in the domestic country:

$$b_{t+1}^f = (1 + r_t^f) b_t^f + NX_t. \quad (136)$$

The size of the Thai and US bond markets are as reported in the table below:

	Thailand	US
Size of Bond Market:	47 Bil USD (38% of GDP)	16,324 (156% of GDP)
of which is Government bonds	29 Bil USD (61% of total)	4,537 (28% of GDP)
of which Corporate bonds	7 Bil USD (14% of total)	2,421 (15% of GDP)

Table 42: The size of Thai and US bond markets

Source: *The Bank of International Settlements*⁶⁶

The whole system of 25 equations, 17 terminal conditions (to force the convergence of variables), 25 endogenous and 34 exogenous variables are solved using the Gauss-Siedel (iterative) method in RATXP, a program developed by Matthews (1979) and Minford et. al. (1984).

4.3.5 Behavioural Equations The first order conditions are used to derive how the model behaves. The following lists the model's behavioural equations.

1. C_t is the composite consumption, consisting of a weighted average of the country's domestic goods and foreign goods consumption:

⁶⁶http://www.bis.org/publ/qtrpdf/r_qt0406f.pdf

$$C_t = \left[\omega (C_t^d)^{-\rho} + (1 - \omega) (C_t^f)^{-\rho} \right]^{\left(\frac{-1}{\rho}\right)}. \quad (137)$$

Given consumption C_t , r_t is known:

$$(1 + r_t) = \frac{1}{\beta} \left(\frac{C_t}{E_t [C_{t+1}]} \right)^{-\rho_0} \left(\frac{1 + \phi_{t+1}}{1 + \phi_t} \right) \quad (138)$$

or

$$r_t = \frac{1}{\beta} \left(\frac{C_t}{E_t [C_{t+1}]} \right)^{-\rho_0} \left(\frac{1 + \phi_{t+1}}{1 + \phi_t} \right) - 1, \quad (139)$$

2. Given money supply \bar{M}_t^d , the domestic price level P_t^d is known:

$$\bar{M}_t^d = (1 + \phi_t) C_t^d P_t^d + \bar{G}_t P_t^d \quad (140)$$

or

$$P_t^d = \frac{\bar{M}_t^d}{(1 + \phi_t) C_t^d + \bar{G}_t} \quad (141)$$

Domestic price level P_t^d is a component in the Armington aggregate price level (which is the composite consumption function).

3. Demand for shares implies the price of bonds.

$$S_{t+1}^p = \bar{S}_t; \quad (142)$$

which implies

$$b_{t+1} = b_{t+1}^p. \quad (143)$$

4. The present value of shares, in nominal terms (p_t), is given by the expected income stream from dividend payments:

$$p_t = E_t \sum_{i=1}^{\infty} \frac{d_{t+i}}{(1+r_t)^i} \frac{P_t}{P_{t+i}} \quad (144)$$

5. Production function Y_t is given by:

$$Y_t = Z_t N_t^\alpha K_t^{(1-\alpha)} \quad (145)$$

6. Labour demand:

$$N_t^d = \left(\frac{\alpha Z_t}{w_t} \right)^{\left(\frac{1}{1-\alpha} \right)} K_t \quad (146)$$

7. Capital is related to output:

$$K_t = (1-\alpha) \frac{Y_t}{r_t + \delta} \quad (147)$$

8. From the definition of GDP (our Y_t), C_t is known:

$$Y_t \equiv C_t + I_t + G_t + NX_t \quad (148)$$

9. Investment in the next period is related to the capital available:

$$K_{t+1} = (1+\delta) K_t + I_{t+1} \quad (149)$$

10. Real producer wage w_t :

$$w_t = w_t^* \quad (150)$$

11. Evolution of domestic bond, b_t is found in the Government budget constraint:

$$b_{t+1} = (1 + r_t) b_t + PD_t - \frac{\Delta \bar{M}_t}{P_t}. \quad (151)$$

12. Equilibrium wage w_t^* , w_t^* is derived by equating labour demand N_t^d to the supply of labour N_t^s , where:

$$(1 - N_t^s) = \left\{ \frac{\theta_0 C_t^{-\rho_0} \left[(1 - \tau_t) \exp \left(\log w_t^* - \frac{(1-\omega)^{\frac{1}{1+\rho}}}{\omega^{\frac{1}{1+\rho}} + (1-\omega)^{\frac{1}{1+\rho}}} \log Q_t \right) - \mu_t \right]}{(1 - \theta_0) (1 + \phi_t) (1 + r_t)} \right\}^{\frac{-1}{\rho_2}}, \quad (152)$$

Q_t is the real exchange rate, $(1 - \omega)^{\frac{1}{1+\rho}}$ is the weight of domestic prices in the CPI index.

13. Dividends are defined as surplus corporate cash flow.

$$d_t \bar{S}_t = Y_t - N_t^s w_t - K_t (r_t + \delta) \quad (153)$$

$$d_t = \frac{Y_t - N_t^s w_t - K_t (r_t + \delta)}{\bar{S}_t} \quad (154)$$

14. Primary deficit PD_t :

$$PD_t = G_t + \mu_t (1 - N_t^s - \bar{l}) - \tau_{t-1} v_{t-1} N_{t-1}^s - \phi_{t-1} C_{t-1} - T_{t-1}. \quad (155)$$

15. (Personal Income) Tax T_t :

$$T_t = T_{t-1} + \gamma^G (PD_{t-1} + b_t r_t) + \varepsilon_t \quad (156)$$

16. Exports EX_t :

$$\log EX_t = \sigma_1 \log (1 - \omega^f) + \log C_t^F + \sigma_1 A^f \log Q_t, \quad (157)$$

where

$$A^f = \frac{(\omega^f)^{\frac{1}{1+\rho}}}{(\omega^f)^{\frac{1}{1+\rho}} + (1 - \omega^f)^{\frac{1}{1+\rho}}}. \quad (158)$$

17. Imports IM_t :

$$\log IM_t = \sigma \log (1 - \omega) + \log C_t - \sigma A \log Q_t, \quad (159)$$

where

$$A = \frac{\omega^{\frac{1}{1+\rho}}}{\omega^{\frac{1}{1+\rho}} + (1 - \omega)^{\frac{1}{1+\rho}}}. \quad (160)$$

18. UIP condition:

$$r_t = r_t^f + E_t \Delta \log Q_{t+1} + \varepsilon_{UIP}, \quad (161)$$

r_t^f represents the foreign real interest rate.

19. Net exports:

$$NX_t = EX_t - IM_t. \quad (162)$$

20. Evolution of foreign bonds b_t^f :

$$b_{t+1}^f = (1 + r_t^f) b_t^f + NX_t \quad (163)$$

21. Nominal exchange rate, S_t :

$$\log S_t = \log Q_t - \log P_t^f + \log P_t \quad (164)$$

where

P_t^f is the foreign price and S_t is the nominal exchange rate.

22. Evolution of household debt D_{t+1} :

$$D_{t+1} = (1 + r_t) D_t - Y_{t-1} + (1 + \phi_t) C_t + \tau_t v_t N_t^s + T_t. \quad (165)$$

23. Household transversality condition:

$$Y_{T-1} - r_T D_T - \phi_T C_T - \tau_T v_T N_T^s - T_T = C_T. \quad (166)$$

24. Government transversality condition:

$$G = 0.30. \quad (167)$$

4.3.6 Exogenous Processes The 8 error terms are defined below. The exogenous process that is assumed to drive the change in productivity growth is called $\varepsilon_{1,t}$:

$$\Delta \ln Z_t = \varepsilon_{1,t}. \quad (168)$$

The exogenous process that is assumed to drive the change in the income tax rate is called $\varepsilon_{2,t}$:

$$\Delta \tau_t = \varepsilon_{2,t}. \quad (169)$$

The exogenous process that is assumed to drive the change in the consumption tax rate is called $\varepsilon_{3,t}$:

$$\Delta \phi_t = \varepsilon_{3,t}. \quad (170)$$

The exogenous process that is assumed to drive the change in the unemployment benefits is called $\varepsilon_{4,t}$:

$$\Delta \mu_t = \varepsilon_{4,t}. \quad (171)$$

The exogenous process that is assumed to drive the change in the growth of the long run money supply is called $\varepsilon_{5,t}$:

$$\Delta \ln \bar{M}_t = \varepsilon_{5,t}. \quad (172)$$

The exogenous process that is assumed to drive the change in the growth of the foreign price level is called $\varepsilon_{6,t}$:

$$\Delta \ln P_t^f = \varepsilon_{6,t}. \quad (173)$$

The exogenous process that is assumed to drive the change in the growth of foreign consumption is called $\varepsilon_{7,t}$:

$$\Delta \ln C_t^F = \varepsilon_{7,t}. \quad (174)$$

And finally, the exogenous process that is assumed to drive the change in the growth of foreign interest rate is called $\varepsilon_{8,t}$:

$$\Delta \ln r_t^f = \varepsilon_{8,t}. \quad (175)$$

4.3.7 Steady State Equations The data are calculated according to these identities and definitions:

1. Discount factor

$$\beta = \frac{1}{1 + r_t}. \quad (176)$$

2. Steady state money supply

$$\bar{M} = (1 + \phi) CP + GP. \quad (177)$$

3. Present value of shares

$$p = \frac{d}{1 + r}. \quad (178)$$

4. Production function

$$Y = ZN^\alpha K^{(1-\alpha)}. \quad (179)$$

5. Labour demand

$$N = \frac{\alpha Y}{w^*}. \quad (180)$$

6. Capital

$$K = \frac{(1 - \alpha) Y}{r + \delta}. \quad (181)$$

7. National Income Identity

$$Y \equiv C + I + G + NX. \quad (182)$$

8. Investment

$$I = \delta K. \quad (183)$$

9. Real Producer Wage

$$w = w^* \quad (184)$$

10. Public Finance

$$rb = -PD \quad (185)$$

11. The time path of the economy's values of labour:

$$1 - N = \left(\frac{\theta_0 C^{-\rho_0} [(w^* - (1 - h) Q) (1 - \tau)]}{(1 - \theta_0) (1 + \phi) (1 + r)} \right)^{-\frac{1}{\rho_2}} \quad (186)$$

12. Dividend at steady state:

$$d = \frac{Y - w^* N - (r + \delta) K}{\bar{S}} \quad (187)$$

13. Primary deficit:

$$PD = G - \tau v N - \phi C - T \quad (188)$$

14. Real interest rate:

$$r = r^f \quad (189)$$

15. Net exports at steady state:

$$r^f b^f = NX \quad (190)$$

16. Steady state real exchange rate:

$$\log Q = \log S \quad (191)$$

17. Steady state constraint for household:

$$Y - (1 + \phi) C - \tau v N - T = r D \quad (192)$$

4.3.8 The Data The Thai and US data are from first quarter of 1994 to the last quarter of 2003. Most data are downloaded from Datastream and Datastream Advance terminals and the Bank of Thailand website, except the data for Thailand's Net Export, which is supplied by Asian Development Bank (<http://www.adb.org>).

The Thai wage data since 1993 to 1997 are taken from

<http://www.dol.gov/ilab/media/reports/oiea/wagestudy/FS-Thailand.htm>

Minimum Wage (Baht per day)	April 1994	Oct 1995	July 1996	Oct 1997	Jan 1998
7 High-Cost Provinces†	125	135	145	157	162
7 Lower-Cost Provinces‡	110	118	126	137	140
The Rest (63 Provinces)	102	110	118	128	130

Table 43: Thailand's minimum wage

† Bangkok, Samut Prakarn, Nonthaburi, Pathumthani, Nakornpathom, Samut Sakorn, and Phuket.

‡ Ranong, Pang-Nga, Chonburi, Saraburi, Nakorn Ratchasima, Chiangmai

The average wage data are taken from the Report of the Labor Force Survey, 1999 - 2000, National Statistical Office (<http://www.nso.go.th>)

Real Thai Data are taken from the BoT website, notably the private composite consumption.

Thai Output Data

Implicit GDP Deflator is calculated from Nominal GDP divided by Real GDP

Thai Wage Rates

Implicit GDP Deflator is used to calculate the real (or real producer) wage rate, by discounting the wage rate by the deflator instead of the CPI.

Consumption Data: The BOT has revised the series of the Private Consumption Index (PCI) since January 1993 by changing one component from the estimation of central remitted VAT (Bangkok) deflated by CPI to VAT collection deflated by CPI excluding raw food. As the new component has higher correlation with consumption expenditure.

Thai Capital stock data are annual data provided by the National Economic and Social Development Board (NESDB)⁶⁷.

The Market Dividend Yield (d) is from the Stock Exchange of Thailand⁶⁸.

The demand (and the supply of) shares is represented by the total number of shares outstanding (shares currently owned by the investors). The total number of shares outstanding are the market capitalization divided by the latest closing price/index. Provisional data were also supplied from the NESDB website Detailed data were supplied by

⁶⁷http://www.nesdb.go.th/econSocial/macro/nad/5_stock/onlyTHAILAND.xls.

⁶⁸http://www.set.or.th/static/market/market_u13.html

Amy Ruktanonchai of the Seamico Knight Fund Management Securities Co. Ltd⁶⁹ and their research staff in Bangkok.

The Thai demand and supply of labour is taken from the Bank of Thailand website, using the number of people employed, which was revised in 1996 from 13 years and over to 15 years and over.

The estimate of Thai elasticity of substitution between domestically demanded and imported commodities (the Armington elasticity), σ or $\frac{1}{1+\rho}$, is taken to be $\frac{1}{2}$, thus we assume that ρ equals to unity, a result based on the Armington elasticity estimate for Thai agricultural product by Pisanwanich (2005).

This yields the Thai composite consumption function from Equation

$$C_t = \left[\omega (C_t^d)^{-\rho} + (1 - \omega) (C_t^f)^{-\rho} \right]^{\left(\frac{-1}{\rho}\right)} \quad (193)$$

to be

$$C_t = \left[\omega (C_t^d)^{-1} + (1 - \omega) (C_t^f)^{-1} \right]^{(-1)} \quad (194)$$

$$C_t = \left(\frac{\omega}{C_t^d} + \frac{(1 - \omega)}{C_t^f} \right)^{-1} \quad (195)$$

Consumption of foreign goods is equal to imports by definition:

$$C_t^f = IM_t, \quad (196)$$

and thus

⁶⁹<http://www.skfm.com/home/index.php>.

$$C_t = \left(\frac{\omega}{C_t^d} + \frac{(1-\omega)}{IM_t} \right)^{-1} \quad (197)$$

ω is the weight of home goods in the consumption function and σ is the elasticity of substitution, $\sigma = \frac{1}{1+\rho}$. σ is assumed to be 2, and $\rho = -0.5$. Assuming home bias ω is assumed to be 0.65, a preference of home residents consuming home-produced tradables (relative to foreign-produced tradables) over the foreign consumers.

$$C_t^d = \frac{0.65 C^t IM}{IM - 0.35 C^t} \quad (198)$$

or, given the consumption basket specification, the agent's demand for home and foreign goods is a function of their respective relative price and the composite consumption:

$$C_t^d = \left(\frac{P_t^d}{\omega P_t} \right)^{-\left(\frac{1}{1+\rho}\right)} C_t \quad (199)$$

and

$$C_t^f = \left(\frac{P_t^F}{(1-\omega) P_t} \right)^{-\left(\frac{1}{1+\rho}\right)} C_t. \quad (200)$$

Substituting for ω and ρ in C_t^d we obtain:

$$C_t^d = \left(\frac{P_t^d}{0.65 * P_t} \right)^{-2} C_t \quad (201)$$

The utility-based price index corresponding to the aggregate consumption function is given by:

$$P_t = \left[\omega^{\frac{1}{1+\rho}} (P_t^d)^{\frac{\rho}{1+\rho}} + (1-\omega)^{\frac{1}{1+\rho}} (P_t^F)^{\frac{\rho}{1+\rho}} \right] \quad (202)$$

Substituting the values $\omega = 0.65$, $\frac{1}{1+\rho} = 2$ (and thus $\frac{\rho}{1+\rho} = -1$), and rearranging, we obtain the price of domestic goods consumed, P_t^d :

$$P_t^d = \frac{(0.65)^2 P_t^{F70}}{P_t P_t^F - (0.35)^2} \quad (203)$$

There are two definitions of real wage in the model: supply of labour is determined by the workers' real wage; while the demand for labour is determined by the producers' real wage.

Leisure (free time) of 3.8 hours per day (for participants 10 years and over) is taken from National Statistical Office of Thailand⁷¹, the year is taken to have 365 days. Thus there are $3.8 \times 365 = 1387$ hours of leisure out of possible $24 \times 365 = 8760$ hours. By construction, leisure hours and working hours add up to unity. Leisure hours are thus $\frac{1387}{8760} = 0.158$. Working hours are $1 - 0.158 = 0.842$.

4.3.9 Endogenous Variables r Real interest rate, this variable is called $v(1,1)$ ⁷² in the fortran `rbc_apr2004.f` file.

P Price level is referred to as $v(1,2)$ in the fortran file.

S^p Demand for shares, $v(1,3)$.

p Present value of shares, $v(1,4)$.

Y Output, $v(1,5)$.

N^d Demand for labour, $v(1,6)$.

K Capital, $v(1,7)$.

⁷¹<http://www.nso.go.th/eng/stat/timeuse/timetab15.htm>.

⁷²The first number indicates that the variable is endogenous, the second is the order that the variable appears in the group.

C Composite consumption, $v(1,8)$.

I Investment, $v(1,9)$.

v Consumer real wage, wage rate deflated by the consumer price index, $v(1,10)$.

w Producer real wage, wage rate deflated by the price deflator for GDP at factor cost, $v(1,11)$.

b Domestic bonds, $v(1,12)$.

G Government expenditure, $v(1,13)$.

w^* Equilibrium real wage, $v(1,14)$.

d Dividend per share, $v(1,15)$.

D Household debt, $v(1,16)$.

PD Primary deficit, $v(1,17)$.

T Tax (lump sum), $v(1,18)$.

EX Export, $v(1,19)$.

IM Import, $v(1,20)$.

Q Real exchange rate, $v(1,21)$.

b^f Foreign bonds, $v(1,22)$.

S Nominal exchange rate, $v(1,23)$.

NX Net exports, $v(1,24)$.

4.3.10 Exogenous Variables Z Productivity, $vv(21,1)^{73}$.

τ Labour income tax, $vv(21,2)$.

⁷³The number 21 indicates that this variable is exogenous, the second number in brackets represents the order that that variable appears in the group.

ϕ Consumption tax, vv(21,3).

μ Unemployment benefits, $\mu = 0$ in our empirical section, vv(21,4).

M Money, vv(21,5).

\bar{S} Supply of Shares, vv(21,6).

\bar{l} Leisure, vv(21,7).

\bar{M} A fixed level of money supply, vv(21,8).

ε_1 Error term from the first exogenous variable (vv1, or Z)'s process, vv(21,9).

ε_2 Error term from the second exogenous variable (vv2, or τ)'s process, vv(21,10).

ε_3 Error term from the third exogenous variable (vv3, or ϕ)'s process, vv(21,11).

ε_4 Error term from the fourth exogenous variable (vv4, or μ)'s process, vv(21,12).

ε_5 Error term from the fifth exogenous variable (vv5, or M)'s process, vv(21,13).

ε_6 Error term from the sixth exogenous variable (vv6, or \bar{S})'s process, vv(21,14).

$E_t[C_{t+1}]$ Expected value of consumption in the next period, vv(21,15).

r_base Base value of the real interest rate, vv(21,16).

P_base Base value of price index, vv(21,17).

Y_base Base value of domestic output, vv(21,18).

N_base Base value of labour employed, vv(21,19).

K_base Base value of capital, vv(21,20).

w^*_base Base value of equilibrium real wage, vv(21,21).

d_base Base value of dividend per share, vv(21,22).

PD_base Base value of primary deficit, vv(21,23).

I_base Base value of investment, vv(21,24).

Q_base Base value of the real exchange rate, vv(21,25).

EX_base Base value of exports, $vv(21,26)$.

IM_base Base value of imports, $vv(21,27)$.

G_base Base value of government expenditure, $vv(21,28)$.

P^f Foreign price level, $vv(21,29)$.

POP Population, $vv(21,30)$.

C^F Foreign consumption, $vv(21,31)$.

r^f Foreign interest rate, $vv(21,32)$.

$E[Q]$ expected value of the real exchange rate, $vv(21,33)$.

C_base Base value of consumption, $vv(21,34)$.

The first period's value of an endogenous/exogenous variable is taken to be its initial value.

4.3.11 The Algorithm The complete algorithm can be described in the following steps:

Step 1: Given initial values for the expectational variables, solve the model.

Step 2: Check for convergence.

Step 3: Adjust the expectational variables.

Step 4: Re-solve the model, given the new iterated values of the expectational variables.

4.3.12 Calibration Baseline simulation is a simulation with no change in policy instruments. The endogenous variables are set so that they perfectly track the actual historical values. This is done by adding residuals to each equation. The model's solution is compared with one where one or more exogenous variables are perturbed. Comparing the base and perturbed solution gives an estimate of the policy multiplier if the perturbed exoge-

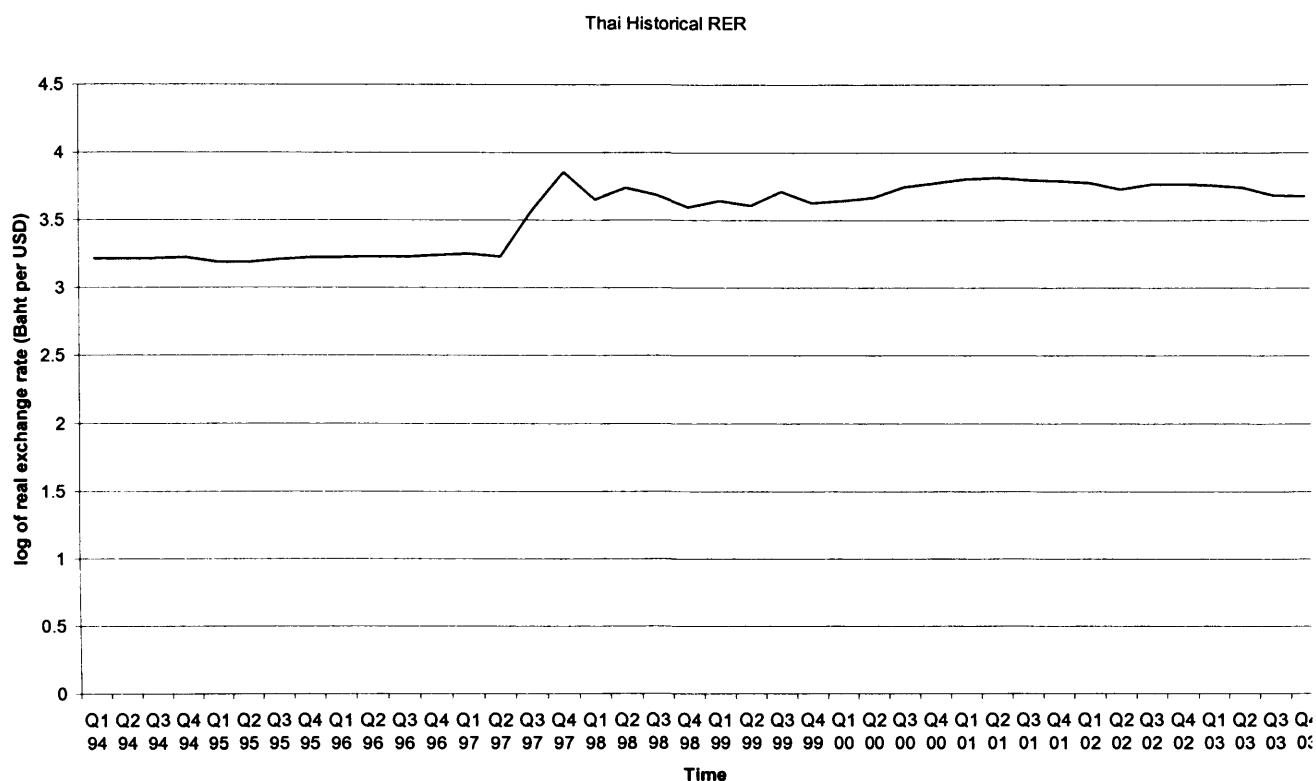
nous variable is a policy instrument. Comparing the results of simulation experiments with those obtained in the base run provides valuable information regarding the effects of policy changes on the economy. The length of the simulation period should be long enough for the effects of changes to work through the model. This is especially important in models which contain long lags or slow rate of adjustment. The terminal date for the simulation should be set sufficiently far in the future so that the simulation is unaffected by the choice of terminal date. Simulating the model over a long period makes it easier to observe the long-run solution of the model (Darby et al., 1999). In order to carry out model simulations, numerical values are assigned to the structural parameters.

4.3.13 Simulation When the money supply (Mbar) and the productivity shock occur at the same time (say 10% each), the real interest rate in the artificial economy reacts as follows. We leave out the pre-forecast period (the first two observations). Prior to July 1997, Thailand had a fixed exchange rate based on a weighted basket of major trading partners' currencies.

The Historical Thai-US Dollar Real Exchange Rate is depicted below:

Policy Parameter	Symbol	Calibrated Value
Output Elasticity of Production	α	0.70
Discount Factor	β	0.97
Depreciation rate	δ	0.0125
Fraction of Elasticity of Goods Substitution	ρ_0	1.20
Money Multiplier	θ_0	0.50
Degree of Seignorage	γ^G	0.05
Fraction of Elasticity of Goods Substitution	ρ_2	1.00
Weight of Home Goods in consumption function	ω	0.70
Fraction of Elasticity of Goods Substitution	ρ	-0.50
Weight of Foreign Goods in consumption function	ω^f	0.70
RER sensitivity to the demand of labour	h	0.80
Fraction of Elasticity of Goods Substitution	ρ_3	-0.50
Elasticity of Import Substitution	σ	2
Elasticity of Export Substitution	σ_1	2

Table 44: Thailand's Policy Parameters and their calibrated values



The historical Thai real exchange rate

After the devaluation and subsequent floating, the data show an exchange rate overshooting to come back to a non-zero mean with no apparent trend. The ADF test in Eviews 4.0 confirms this by providing no evidence of a unit root in the data:

ADF Test Statistic -1.473233	1% Critical Value* -3.6117
	5% Critical Value -2.9399
	10% Critical Value -2.6080

Table 45: ADF Test for the Historical Thai RER

*MacKinnon critical values for rejection of hypothesis of a unit root.

4.3.14 Various shocks and the effects on the artificial economy

The Baseline Simulation Results With the given structure of the whole economy, it is now possible to examine the effects of demand and supply shocks on the behaviour of output, consumption, capital stock, investment, employment, price level, real wage, real interest rate, imports, exports and real exchange rate. This is done by deterministically simulating the calibrated model. For the purpose of this thesis the attention is on the behaviour of the real exchange rate after a shock. The baseline simulation is one where the policy instruments remain unchanged and the endogenous variables' values are set to perfectly track the actual historical values. This is done by adding residuals to each equation. The residuals are computed as if the future expectations of the endogenous variables appeared in the model are equal to the actual values and thus they include the shocks to the equations as well as the forecast errors.

Each variable's simulation starts from the third observation, which is the third quarter of 1994.

The Productivity Surge Experiment Consider a five-year rise in the productivity growth rate, i.e. the technology or the productivity shock is sent to the artificial economy at 1% p.a. in the first year, increasing to 2% in the second, 3% in the third, 4% in the fourth, and staying permanently at 5% above the base from year 5 onwards. At the time of the initial increase, agents had not anticipated it, however, it is assumed that the entire path of the productivity surge is incorporated into each agent's forecast as of the first quarter of the simulation. The model predictions for the case of a productivity surge as described above

are depicted in the diagrams below:

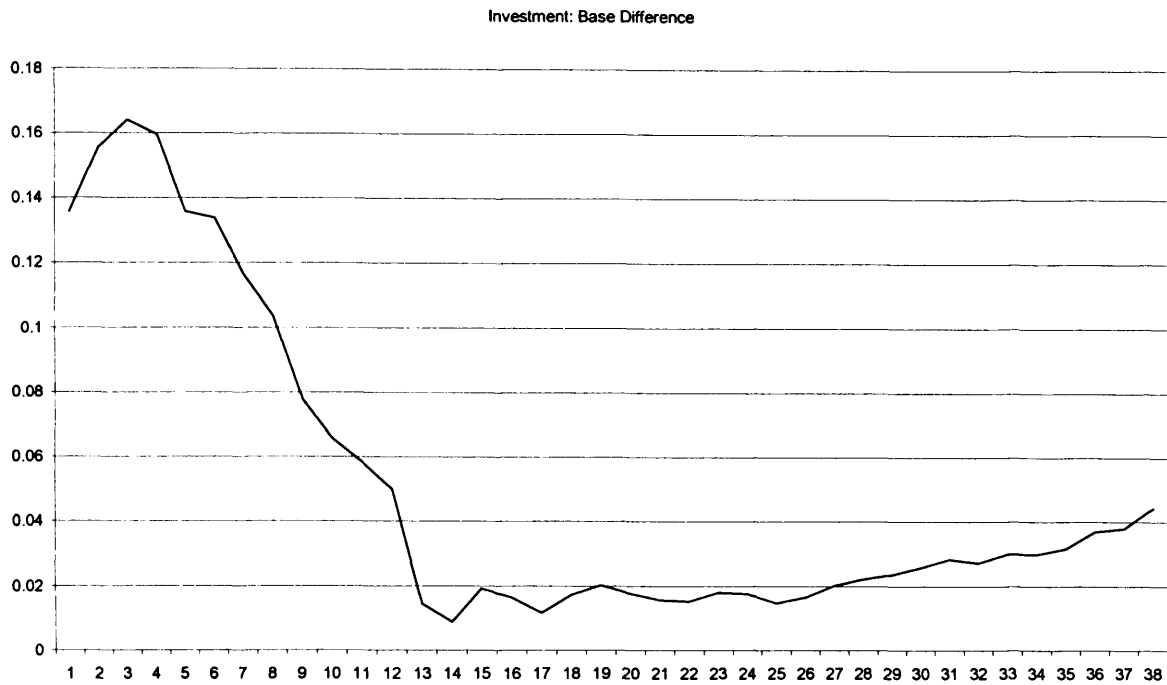


Figure 30: Differences from the base values of investment in the artificial Thai economy following a surge in productivity

As productivity increases, permanent income (output) rises, and more investment is induced in order to generate the additional capital, which is being accumulated in each period until rate of productivity growth is constant.

Capital is slow to arrive, so more labour need to be attracted to work to increase the extra output, this drives up the real wage.

The labour supply rises in respond to the real wage increase. But as more labour arrive, the equilibrium is once again restored with the same number of labour employed as in the previous equilibrium.

The price level and the composite index initially rises and gradually falls back and stays

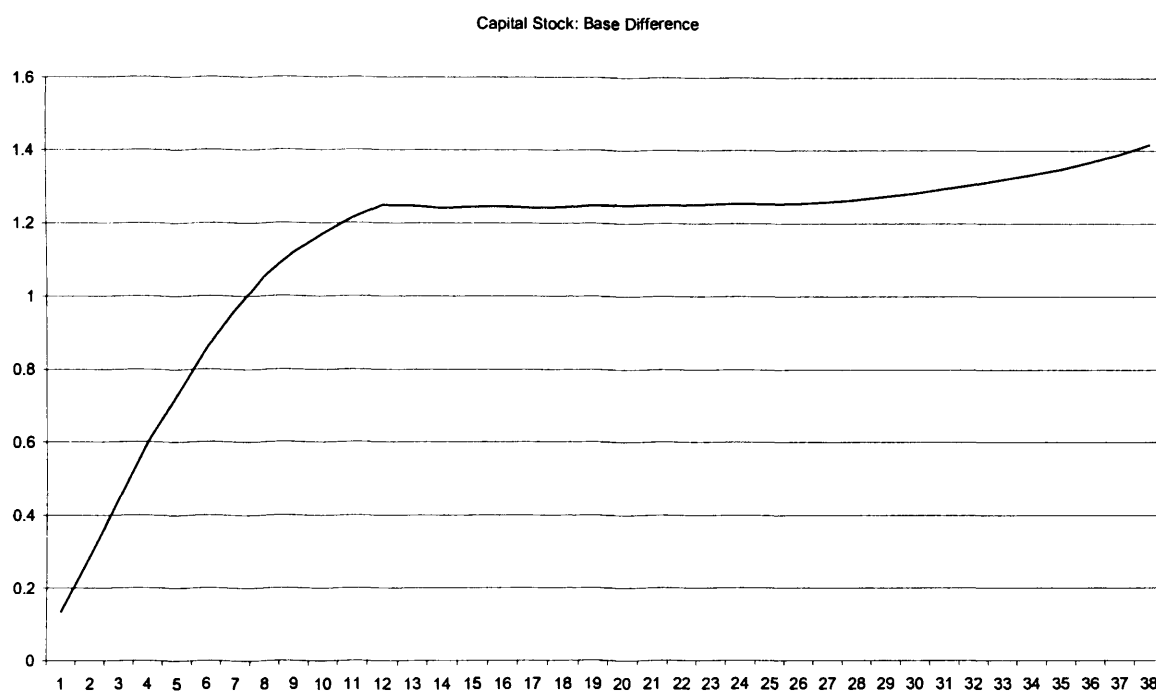


Figure 31: Differences from base values of capital stock in the artificial Thai economy after a surge in productivity

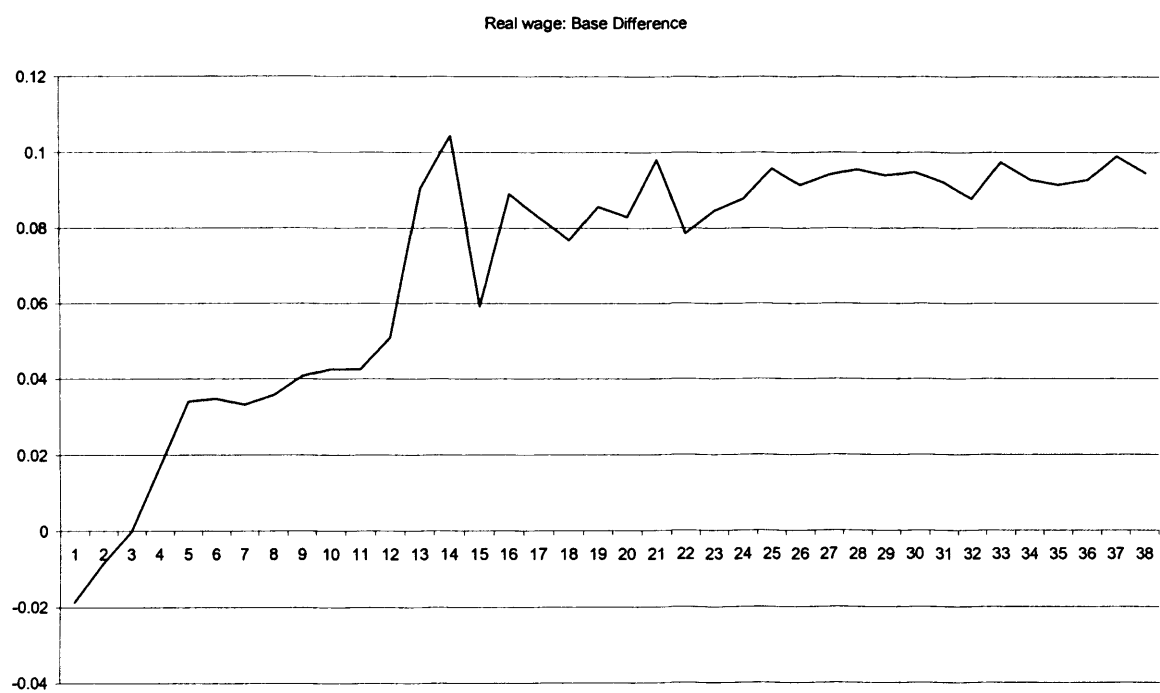


Figure 32: Differences from base values of the Thai real wage following the productivity surge

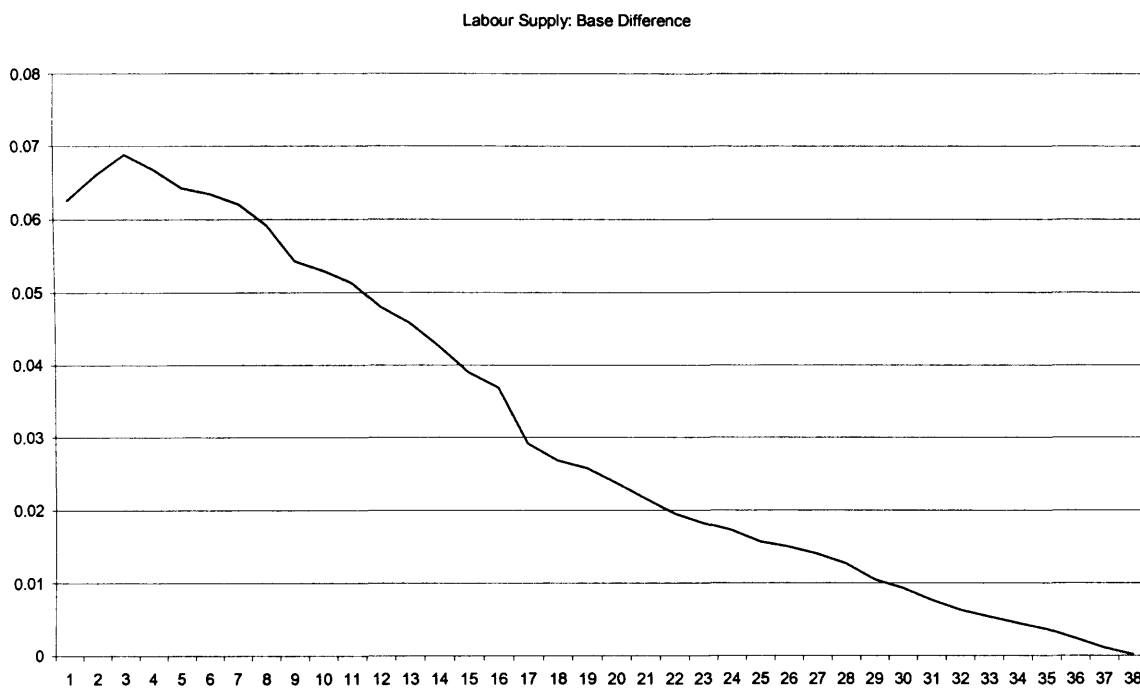


Figure 33: Differences from base values of the Thai labour supply following a surge in the productivity

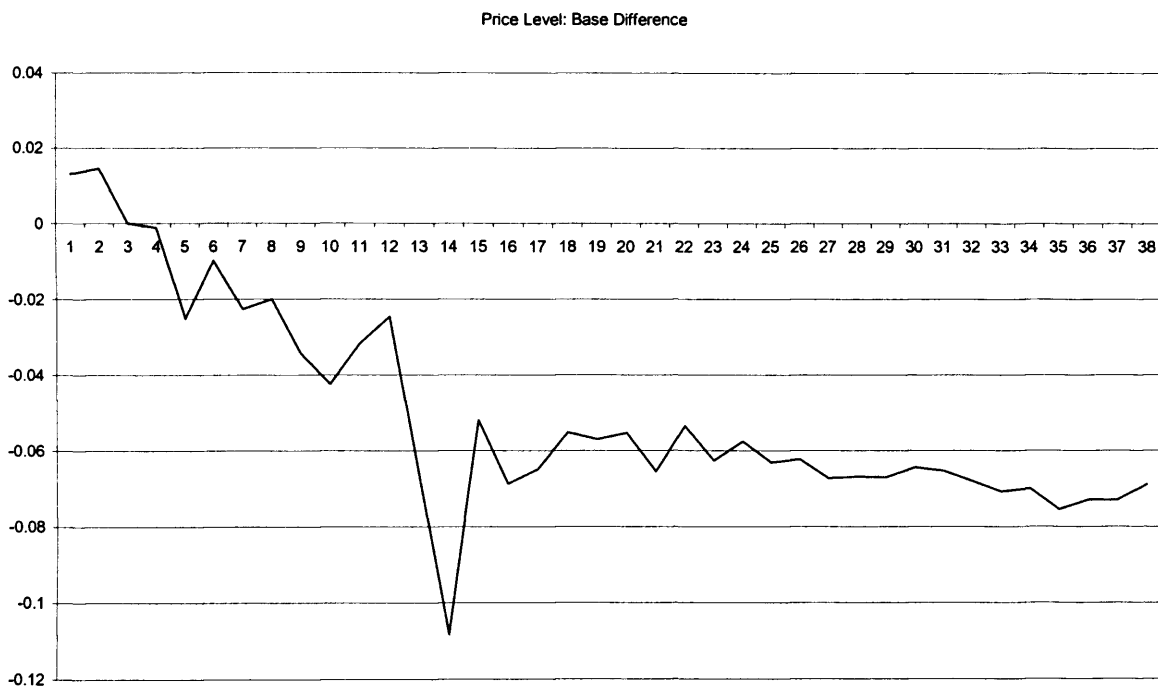


Figure 34: Differences from base values for the price levels in the artificial Thai economy following a productivity surge

lower than the previous equilibrium pre-shock.

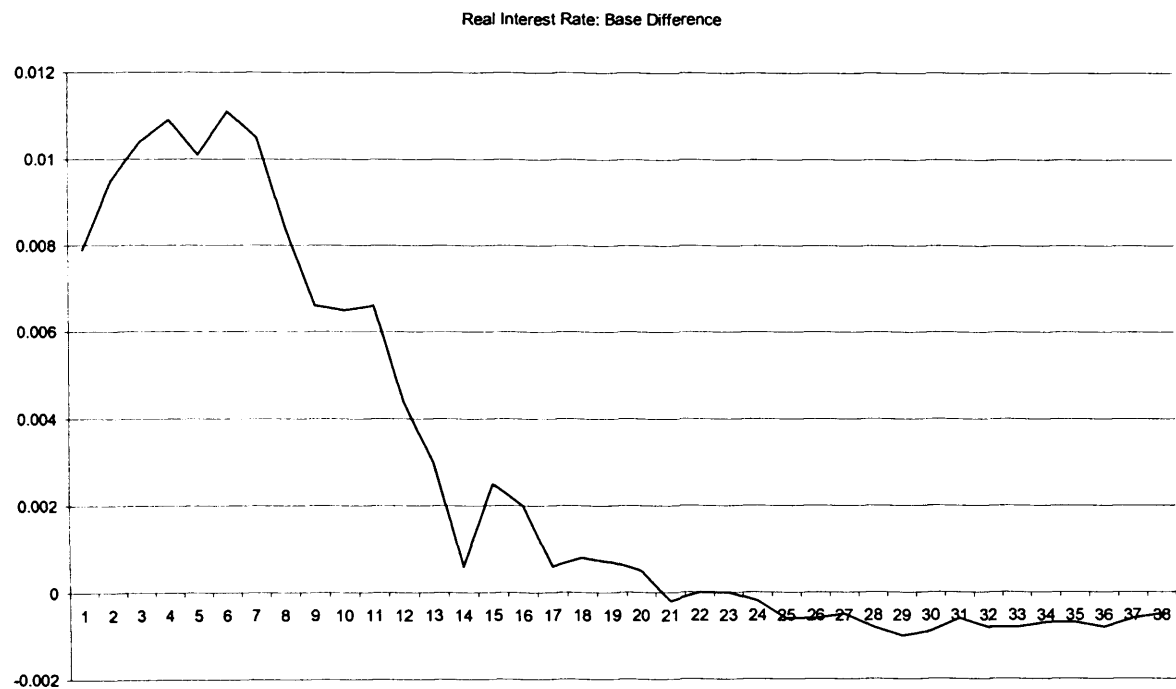


Figure 35: Differences from the base values of the real interest rate following a productivity surge in the artificial Thai economy.

The real interest rate rises to reduce the demand for capital to the available supply, this violates the real uncovered interest parity. Rational agents expect the real exchange rate to fall back steadily and so they have high expectations of the initial rise in the real exchange rate value relative to its expected future value. As real interest rate falls with the arrival of more capital and output, the equilibrium is restored, with a higher real interest rate.

The real exchange rate rises in value initially but as output and capital accumulate and have to be sold in the world market at a lower price, the new equilibrium for the real exchange rate represents a lower value than that prior to the shock.

Consumption increases permanently as more output is being produced at the lower do-

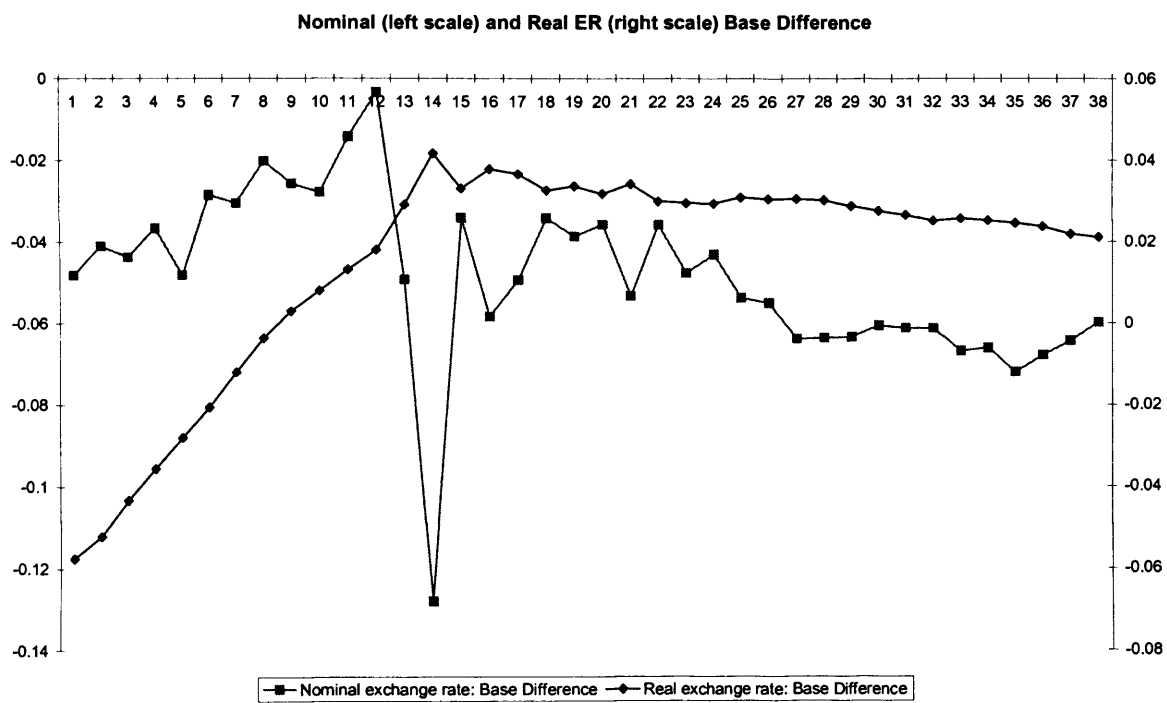


Figure 36: Differences from base values of the nominal and real exchange rates following a productivity surge

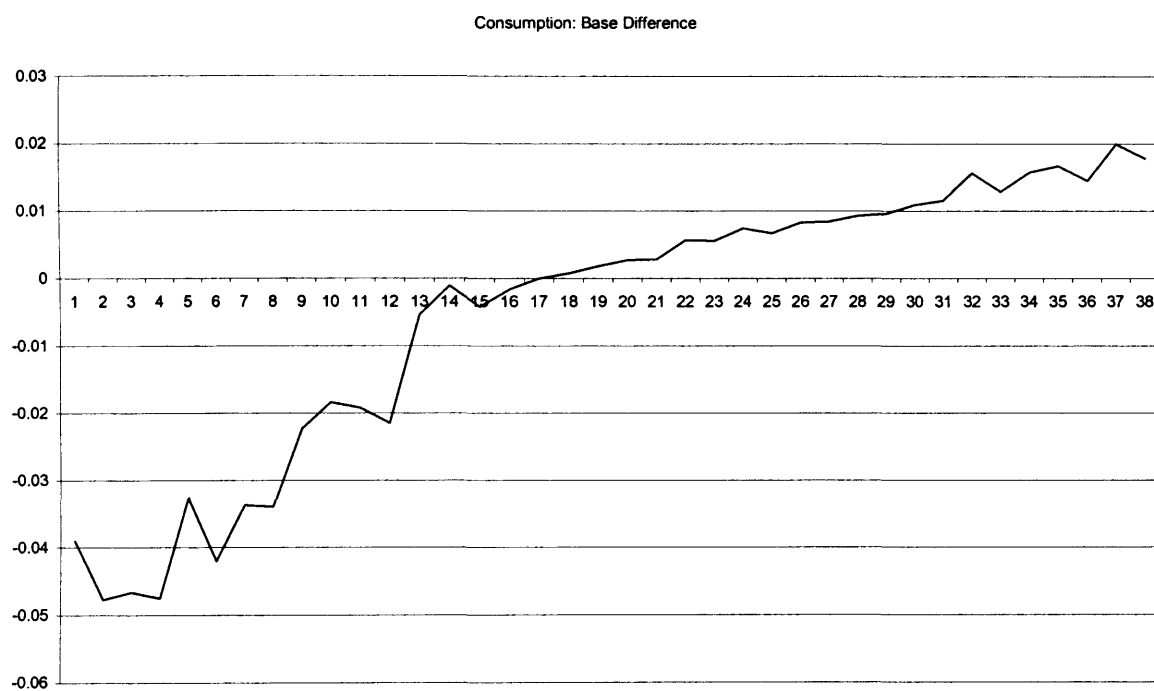


Figure 37: Differences from the base values of consumption in the artificial Thai economy following a productivity surge

mestic price and consumers have home bias and consume more of domestic rather than the foreign counterpart. But since the size of the domestic economy does not influence the world price, the higher world price With the initial rise of the real exchange rate, export falls and then picks up as the interest rate starts to fall to restore the real uncovered interest rate parity. As income rises export rises and since the domestic good is cheaper and foreign good relatively more expensive than the pre-shock level, the Thai income and substitution effects are such that the Thai consumers substituted home for foreign goods as income rises.

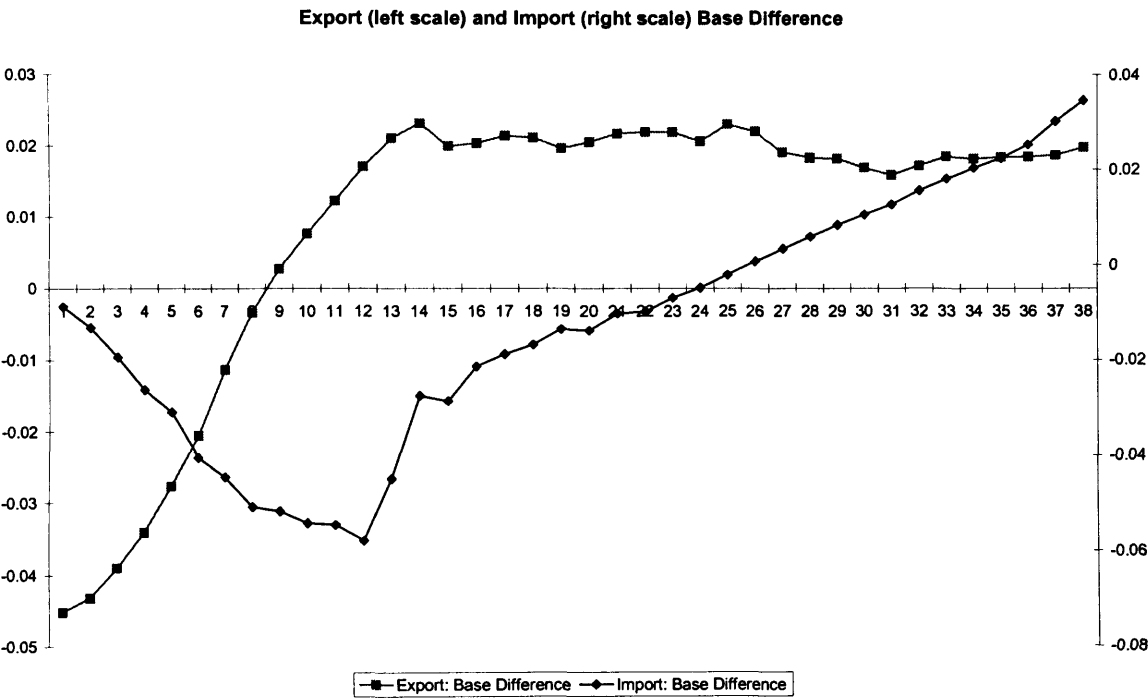


Figure 38: Differences from base values of the exports and imports in the artificial Thai economy following a surge in productivity

With three exceptions of productivity, output and the nominal exchange rate which experienced a slump in value around 13th-14th observation (as the baseline simulation tried to mimick the historical rates around the crisis period), most series behave as we expect them

to⁷⁴. As productivity increases, permanent income (output) rises, this stimulates investments to raise the needed capital stock. Firms need extra labour and capital, this pushes up the real wage. The additional capital is slow to arrive and thus the real interest rate must rise to reduce demand of capital to the available supply. The rising real interest rate violates the uncovered real interest parity (URIP), which must be restored by the expectation that the real exchange rate will steadily fall back, enabling URIP to be established consistently with a higher real interest rate. As real interest rates fall with the arrival of sufficient capital, output and real exchange rates move back to equilibrium, with a higher capital stock than in the previous one. As the agent's demand of home and foreign goods is a function of their respective relative price and the composite function, the initial price rise leads to higher initial fall in the agent's consumption. As the real exchange rate appreciates, the country's export loses competitiveness and initially falls in quantity sold to the US, and the opposite happens to the import of the US goods. As consumption increases, import increases but to a lesser extent than the domestic sales (home bias). Export stabilizes (the US's productivity stays the same compared to that of Thailand) but import keeps on increasing as there is now more money available to the domestic consumers due to the permanently increased income and output.

The convergence paths of productivity, output and nominal exchange rate as well as observations 13th-14th in the price level were interrupted, and thus they did not simply increase and then stabilize. This was signified in the convergence path of the price level,

⁷⁴The slump in the three variables' calculated values may have also contributed to the failure of the model's rolling forecast (see Appendix 3). However, the exact cause of the failure to maintain a smooth simulation path remains unknown.

where around observation 13-14th, there was a drop in value of the currency. This could be due to the fact that the baseline simulation was trying to match the steep drop in value of the historically observed nominal exchange rate, where the Baht suffered around 10% (as signified in the simulation diagram) loss in value after the devaluation announcement on July 2nd, 1997). All other paths of the endogenous variables behave as they should, following a smooth path on the rise and then stabilises after 27th observation. If we were to ignore such abnormality in the convergence path and instead look at the impact of the productivity surge on all variables, the summary of the impact of the baseline simulation will be as follows:

Difference from base results

In most cases, the increase in productivity leads to the corresponding surge or fall in the endogenous variable, depending on how the variable is related. The surge in productivity leads to the initial rise in the real interest rate, output or income, the domestic price level, the demand of labour, investment and initial rise in the immediately-available capital stock. The variable's rise then slows down in the medium term, and then either keeps on increasing in the case of import and capital stock, or in most cases, tapers off. Note that it takes 14 observations (14 quarters = $3\frac{1}{2}$ years) for the real exchange rate to revert back to the new equilibrium.

In *Part III*, the real exchange rate is shown to exhibit a 'business cycle' and is non-linear in nature, something that we have captured earlier in the nominal exchange rate, where the best fit was nonlinear in nature, both along and across (i.e. switches over between) the time span.

Difference from base values	Short Term	Medium Term	Long Term
of system variables	Impact	Impact	Impact
Real interest rate	0.0079	0.0007	-0.0005
Productivity	0.8474	0.6240	0.5969
Output	0.0859	0.0797	0.0678
Price level	0.0131	-0.0638	-0.0689
Labour demand	0.0626	0.0279	0.0002
Capital stock	0.1356	1.2477	1.4163
Consumption	-0.039	0.0016	0.0178
Investment	0.1356	0.0160	0.0444
Real wage	-0.0187	0.0858	0.0946
Export	-0.0452	0.0212	0.0198
Import	-0.0088	-0.0169	0.0346
Nominal exchange rate	-0.0482	-0.0509	-0.0599
Real exchange rate	-0.0575	0.0331	0.0211

Table 46: Base differences from a productivity surge impact on all of the variables in the RBC model

4.4 Part III: Conclusion

The construction of a fully specified macroeconomic model is always useful for the understanding of how a domestic economy operates and reacts to certain policy parameter changes, both within the economy and externally. Sofat et. al. (2005) fully extended the real business cycle model to incorporate the open economy for the UK, which is similar in size to the Thai economy. It is open to outside influences but does not affect the world market because of its medium size. I have adjusted the existing framework based on a medium sized open economy with rational agents to the Thai specification and settings. An experiment is then performed on the artificial Thai economy by sending a productivity shock to it. The result has the real exchange rate appreciating on impact. Hence the author is able to provide in *Part III*, the evidence for the productivity bias that I was not able to do by simply relying on the empirical estimation in *Part II*. In addition, the artificial Thai real exchange rate is shown in the baseline simulation to exhibit a 7 year cycle (3 1/2 year half life).

5 Conclusion to the thesis

From the beginning, the Thai-US nominal exchange rate post 1998 crisis is shown to exhibit nonlinearity along the time span and provides a strong support to the monetarist's camp that the nominal rate is very well explained by the Frankel (1979) real interest rate differential model. By assuming that the history of the nominal rate does not matter, the technique developed and used to explain the business cycles is adapted to the nominal exchange rate markets to see if it can in fact explain the events that we know unfolded *ex-post*. After providing the evidence that the nominal exchange rate and the monetary fundamentals relate in the long run, the nominal exchange rate is shown to mean-revert, although with limited success. Where the nominal exchange rate is allowed to be explained by the three scenarios: in a market where there is a crisis of confidence in the value of the currency, where the market is calm, and where the market is favourable, the Baht is shown to be fully explained by a process where all the intercept, the autoregressive component, and the heteroskedasticity in the disturbance term are allowed to be dependent on the scenario, which is exogenously determined and unobservable by the Markov chain assumption and all vary at the same time. This process uses a great deal of parameters and it will be interesting to see how this model will perform over time. As with other uses and applications of the Markov-switching model in other literature, the model fares better at explaining events than predicting them. In our case in *Part I*, it predicted one crisis too many, but the process also detects the latest loss of confidence in the nominal value of the Baht as well.

In *Part II*, the attention is turned to the *real* value of the exchange rate. Because of the recent and continuous strength of the dollar as a common currency, interest in the rela-

tionship between productivity and exchange rates has grown. Using the Johansen-Juselius cointegration test, the evidence lies controversially between 5% and 10% rejection level. Thus in *Part III*, where many experiments can be performed on the entire artificially constructed Thai economy, a productivity surge experiment is performed, where an unanticipated 1% per annum growth shock to productivity till year five and then 5% permanent increase in the level of productivity relative to the base from the fifth year shows clearly that the real Baht appreciates upon impact. By looking at the baseline simulation result, one is also able to establish that the real Baht has a full life of 7 years. In other words, it takes the Baht three and a half years to return to the new equilibrium upon the impact of such productivity growth.

I have shown in this thesis that money and productivity each affects the exchange rate. This conclusion is drawn from the use of different models, each represents the belief or the conviction of the policymaker, whether the emphasis is on money, or real factors such as productivity. The model in *Part III* can be modified to have money and government spending becoming significant. Such further work is needed to establish the relative importance of the two mechanisms presented here.

5.1 Marker for future research

This thesis provides evidence that the nominal exchange rate is very well explained by the special case of the monetary model stipulated by Frankel (1979). It also shows that the nominal rate performs best where all known components are allowed to vary and many scenarios specified. With time and more data available, this may or may not hold and so the tests for robustness for such complicated models as the fully specified Markov switching

need to be developed. The development of the software that is able to test a methodology usually takes time. Where there are plenty of real-time data available, the Markov-switching model will prove useful. Although the stationarity/nonstationarity of the nominal rate will always be subject to debate and conflicting—usually not clear-cut—evidence, the process of understanding how the nominal rate moves across the different scenarios is valuable. The model may not perform as well in forecasts and could really have done better with explanatory variables that vary as much and as frequently as the exchange rate itself, but it has great potential as an explanatory tool to explain states of alert in other fields of interest and research. With less controversial an explanation, the technique will be used more and more as it gives some visual aid to what is normally a blind alley or a cat and mouse chase. With the Markov-switching tool, the dependent variable can be the number of casualties, and the three states are high terrorist alert, low, and medium alert, for example. The possibilities are endless.

With reference to *Part II*, there is now increasing use of the panel cointegration method, a new development that I have been able to incorporate in the thesis using the latest version of EvIEWS (version 5). It not only provides more explanatory power, it makes more sense to look at different series all at the same time and see how they are related and explained. With greater computing power and methodology developed into software, greater understanding and more correct use of time series and panel data can be achieved by more researchers, no matter which area of interest.

In each medium size economy, there are only a handful of fully developed open macro-economic model for the country. Open communication and cross collaboration across the Thai government agencies and units will result in better models for Thailand with better

results. The Liverpool Research Group has been developing their model for many years and is now reaping the rewards in that it is able to explain the real exchange rate behaviour and inflation persistence for the UK economy. My task now is to compare the results with existing fully specified macroeconomic models in the various government agencies, notably in the Bank of Thailand and the Ministry of Commerce's Department of Business Economics (www.dbe.moc.go.th) and the work done in the Thai universities and research centers, notably Thailand Development Research Institute or TDRI. (www.info.tdri.or.th).

6 References

Acemoglu, D., Johnson, S., Robinson, J., and Y. Thaicharoen (2003), Institutional causes, macroeconomic symptoms: volatility, crises and growth, *Journal of Monetary Economics*, **50**, 49-123.

Alexander, S. (1959), The effects of devaluation: a simplified synthesis of elasticities and absorption approaches, *American Economic Review*, **49**(2), 22-42.

Alquist, R. and M. Chinn (2002), Productivity and the Euro-Dollar exchange rate puzzle, NBER Working Paper, No. 8824, National Bureau of Economic Research.

Arias, G. and U. Erlandsson (2005), Improving early warning systems with a Markov Switching model - an application to South-East Asian crises, mimeo, Centre d'Economie et de Finances Internationales (CEFI), Université de la Méditerranée Aix-Marseille II, Les Milles.

Artis, M., H.-M. Krolzig, and J. Toro, (2004) The European Business Cycle, *Oxford Economic Papers*, **56**, 1-44.

Asea, P. and E. Mendoza (1994), The Balassa-Samuelson model: a general equilibrium appraisal, *Review of International Economics*, **2**, 244-67.

Backus, D., Kehoe, P., and F. Kydland (1994), Relative price movements in dynamic general equilibrium models of international trade, in F. van der Ploeg (ed.) (1994), *Handbook of International Macroeconomics*, Oxford: Basil Blackwell.

Bahmani-Oskooee, M. (1992), A time-series approach to test the productivity bias hypothesis in purchasing power parity, *Kyklos*, **45**, 227-236.

Bahmani-Oskooee, M. and A. Nasir (2004), ARDL approach to test the productivity bias

hypothesis, *Review of Development Economics*, **8**(3), 483-488.

Bahmani-Oskooee, M., and H.-J. Rhee (1996), Time-series support for Balassa's productivity bias hypothesis: evidence from Korea, *Review of International Economics*, **4**, 364-70.

Balassa, B. (1964), The purchasing power parity doctrine: a reappraisal, *Journal of Political Economy*, **72**, 584-96.

Balvers, R. and J. Bergstrand (1997), Equilibrium real exchange rates: closed-form theoretical solutions and some empirical evidence, *Journal of International Money and Finance*, **16**, 345-366.

Bank of Thailand, *Economic and Monetary Report* (bimonthly in Thai only), May and July 1997.

Barro, R. (1976), Rational Expectations and the role of monetary policy, *Journal of Monetary Economics*, **2**, 1-32.

Barro, R. (1981), The equilibrium approach to business cycles, in R. Barro (ed.), *Money, expectations and business cycles*, New York: Academic Press.

Bergin, P., G. Reuven, and A. Taylor (2004), Productivity, Tradability, and the Great Divergence, mimeo, University of California, Davis and NBER, and the Federal Reserve Bank of San Francisco.

Berkowitz, J. and L. Giorgianni (2001), Long-horizon exchange rate predictability?, *Review of Economics and Statistics*, **83**, 81-91.

Betts, C. and T. Kehoe (2004a), Real exchange rate movements and the relative price of nontraded goods, University of Minnesota and University of Southern California.

Betts, C. and T. Kehoe (2004b), Tradability of goods and real exchange rate fluctuations, University of Minnesota and University of Southern California.

Betts, C. and T. Kehoe (2004c), US Real exchange rate fluctuations and relative price fluctuations, The Federal Reserve Bank of Minneapolis Research Department Staff Report, No. 334, March 2004.

Bilson, J. (1978), Rational expectations and the exchange rate, in Frenkel, J. and G. Harry (eds.), *The Economics of Exchange Rates*, Boston: Addison-Wesley.

Black, S. (1973), International money markets and flexible exchange rates, Princeton Studies in International Finance No. 32, New Jersey: Princeton University Press.

Branson, W. (1977), Assets markets and relative prices in exchange rate determination, *Sozialwissenschaftliche Annalen*, **1**, 69-89.

Breitung, J. (2000), The local power of some unit root tests for panel data in B. Baltagi (ed.), *Advances in Econometrics*, Vol. 15: Nonstationary panels, panel cointegration, and dynamic panels, Amsterdam: JAI Press, 161-178.

Broyden, C. (1970), The convergence of a class of double-rank minimization algorithms 2: the new algorithm, *Journal of the Institute for Mathematics and Applications*, **6**, 222-231.

Burnside, C., Eichenbaum, M., and S. Rebelo (2000), Understanding the Korean and Thai currency crises, *Economic Perspectives*, Federal Reserve Bank of Chicago, **3**, pp. 54-60.

Cagan, P. (1956), The monetary dynamics of hyperinflation, in M. Friedman (ed.) (1956), *Studies in the quantity theory of money*, Chicago: University of Chicago Press.

Canzoneri, M., Cumby, R., and D. Behzad (1999), Relative labour productivity and the real exchange rate in the long run: evidence for a panel of OECD countries, National Bureau of Economic Research, Working Paper No. 5676.

Calvo, G. and C. Rodriguez (1977), A model of exchange rate determination under

currency substitution and rational expectations, *Journal of Political Economy*, **85(3)**, 617-625.

Canzoneri, M., Cumby, R. and B. Diba (1996), Relative labour productivity and the real exchange rate in the long run: evidence for a panel of OECD countries, mimeo, Department of Economics, Georgetown University.

Canzoneri, M., Cumby, R., and B. Diba (1999), Relative labor productivity and the real exchange rate in the long run: evidence for a panel of OECD countries, *Journal of International Economics*, **47**, 245-266.

Cassel, G. (1916), The present situation in the foreign exchanges, *Economic Journal*, **26**, 62-65.

Chari, V., Kehoe, P. and E. McGrattan (2002) Can sticky price models generate volatile and persistent real exchange rates?, *Review of Economic Studies*, **69(3)**, 533-563.

Chen, Y. and K. Rogoff (2003), Commodity currencies, *Journal of International Economics*, **60(1)**, 133-160.

Cheung, Y.-W., Chinn, M., and A. Pascual (2002), Empirical exchange rate models of the nineties: are any fit to survive?, NBER Working Paper, No. 9393, National Bureau of Economic Research, forthcoming in *Journal of International Money and Finance*.

Chinn, M. (1999), On the Won: and other East Asian currencies, *International Journal of Finance and Economics*, **4(2)**, 113-127.

Chinn, M. (2000), The usual suspects? Productivity and demand shocks and Asia-Pacific real exchange rates, *Review of International Economics*, **8(1)**, 20-43.

Chinn, M. and L. Johnston (1996), Real exchange rate levels, productivity and demand shocks: evidence from a Panel of 14 Countries, NBER Working Paper No. 5709, National

Bureau of Economic Research.

Chinn, M. and L. Johnston (1999), The impact of productivity differentials on real exchange rates: beyond the Balassa-Samuelson framework, July 1999.

Choi, I. (2001), Unit root tests for panel data, *Journal of International Money and Finance*, **20**, 249-272.

Clarida, R., Sarno. L, Taylor, M. and G. Valente (2003), The out-of-sample success of term structure models as exchange rate predictors: a step beyond, *Journal of International Economics*, **60(1)**, 61-83.

Clements, M. and J. Smith (1999), A Monte Carlo study of the forecasting performance of empirical SETAR models, *Journal of Applied Econometrics*, **14**, 124-141.

Crucini, M. and M. Shintani (2002), Persistence in Law-of-One-Price deviations: evidence from micro-data, mimeo, Department of Economics, Vanderbilt University, Nashville, Tennessee.

Darby, M. (1980), Does purchasing power parity work?, NBER Working Paper No. 607, National Bureau of Economic Research.

Darby, J., Ireland, J., Leith, C., and S. Lewis (1999), COMPACT: a rational expectations, intertemporal model of the United Kingdom economy, *Economic Modelling*, **16**, 1-52.

Davidson, R. and J. MacKinnon (1994), *Estimation and Inference in Econometrics*, Oxford University Press, 329-341.

Davies, R. (1977), Hypothesis testing when a nuisance parameter is present only under the alternative, *Biometrika*, **64**, 247-254.

Davies, R. (1987), Hypothesis testing when a nuisance parameter is present only under the alternative, *Biometrika*, **74**, 33-43.

De Gregorio, J., Giovannini, A. and H. Wolf (1994), International evidence on tradables and nontradables inflation, *European Economic Review*, **38**, 1225-1244.

DeLoach, S. (1997), Do relative prices of non-traded goods determine long-run real exchange rates?, *Canadian Journal of Economics*, **30**, 891-910.

DeLoach, S. (2001), More evidence in favour of the Balassa-Samuelson hypothesis, *Review of International Economics*, **9(2)**, 336-342.

Devereux, M. (1999), Review of international economics. real exchange rate trends and growth: A model of East Asia, UBC Departmental Archives 99-05, UBC Department of Economics, University of British Columbia.

Dempster, A., Laird, N., and D. Rubin (1977), Maximum likelihood estimation from incomplete data via the EM algorithm, *Journal of the Royal Statistical Society*, **39**, Series B, 1-38.

Dixit, A. (1989), Entry and Exit Decisions under Uncertainty, *Journal of Political Economy*, **97**, 620-638.

Dooley, M. and P. Isard (1982), A Portfolio-Balance Rational-Expectations model of the Dollar-Mark exchange rate, *Journal of International Economics*, **12**, 257-276.

Dornbusch, R. (1973), Devaluation, money, and non-traded goods, in Frenkel, J. and H. Johnson (eds.) (1977), *The monetary approach to the balance of payments*, Surrey: Allen & Unwin

Dornbusch, R. (1976), Expectations and exchange rate dynamics, *Journal of Political Economy*, **84**, 1161-1176.

Dornbusch, R. and S. Fischer (1980), Exchange rates and the current account, *American Economic Review*, **70(5)**, 960-971.

Du, J. and S. Wei (2004), Does insider trading raise market volatility?, *Economic Journal*, **27**, 916-942.

Dumas, B. (1992), Partial equilibrium versus general equilibrium models of the international capital market, in F. van de Ploeg (ed.), *Handbook of International Macroeconomics*, Oxford: Basil Blackwell.

Edison, H. and J. Klován (1987), A quantitative reassessment of the Purchasing Power Parity hypothesis, *Journal of Applied Econometrics*, **2**, 309-333.

Ehrmann, M. and M. Fratzscher (2005), Exchange rates and fundamentals: new evidence from real-time data, *Journal of International Money and Finance*, **24**, 317-341.

Eichenbaum, M. and C. Evans (1995), Some empirical evidence on the effects of shocks to monetary policy on exchange rates, *Quarterly Journal of Economics*, **110**(4), 975-1009.

Enders, W. (2004), *Applied Econometric Time Series*, 2nd Edition, International Edition, West Sussex: Wiley.

Enders, W. and T. Sandler (2004), Transnational terrorism 1968-2000: threshold, persistence, and forecasts, mimeo, Department of Economics, Finance and Legal Studies, University of Alabama, and School of International Relations, University of Southern California, Los Angeles.

Engel, C. (1993), Real exchange rates and relative prices: an empirical investigation, *Journal of Monetary Economics*, **32**, 35-50.

Engel, C. (1994), Can the Markov switching model forecast exchange rates, *Journal of International Economics*, **36**, 151-165.

Engel, C. (1999) Accounting for US Real Exchange Rate Changes. *Journal of Political Economy*, **107**, 507-538.

Engel, C. and C. Hakkio (1996), The distribution of exchange rates in the EMS, *International Journal of Finance and Economics*, **1**, 55-67.

Engel, C. and J. Hamilton (1990), Long swings in the Dollar: are they in the data and do markets know it?, *American Economic Review*, **80**, 689-713.

Engel, C. and C. Kim (1999), The long-run US/UK real exchange rate, *Journal of Money, Credit, and Banking*, **31**, 335-356.

Engel, C. and J. Rogers (1996), How wide is the border?, *American Economic Review*, **86**, 1112-1125.

Engel, C. and West (2005), Exchange rates and fundamentals, *Journal of Political Economy*, **113**(3), 485-517.

Engle, R. and C. Granger (1987), Co-integration and error correction representation, estimation and testing, *Econometrica*, **55**, 251-76.

Fair, R. (1970), The estimation of simultaneous equation models with lagged endogenous variables and first order serially correlated errors, *Econometrica*, **38**, 507-516.

Fleming, J. (1962), Domestic financial policies under fixed and under floating exchange rates, *Staff Papers*, International Monetary Fund, **9**, 369-379.

Fletcher, R.(1970), New Approach to Variable-Metric Algorithms, *Computer Journal*, **13**, 317-322.

Flood, R. and N. Marion, (1999), Perspectives on the recent currency crises literature, *International Journal of Finance and Economics*, **4**, 1-26.

Frankel, J. (1979), On the Mark: a theory of floating exchange rates based on real interest differentials, *American Economic Review*, **69**(4), 610-622.

Frankel, J. (1984), Tests of monetary and portfolio balance models of exchange rate de-

termination, in J. Bilson and R. Marston (eds.), *Exchange rate theory and practice*, Chicago: Chicago University Press, 239-260.

Frenkel, J. (1974), Adjustment mechanism and the monetary approach to the balance of payments: a doctrinal perspective, presented at the Third Paris-Dauphine conference on recent issues in international monetary economics.

Frenkel, J. (1976), A monetary approach to the exchange rate: doctrinal aspects and empirical evidence, *Scandinavian Journal of Economics*, **78**, 200-224.

Frenkel, J. and H. Johnson (1977), The monetary approach to the balance of payments: essential concepts and historical origins, in Frenkel, J. and H. Johnson (eds.) (1977), *The monetary approach to the balance of payments*, Surrey: Allen & Unwin.

Frenkel, J. and H. Johnson (eds.) (1977), *The monetary approach to the balance of payments*, Surrey: Allen & Unwin.

Friedman, M. (1953), *Essays in positive economics*, London: University of Chicago Press.

Friedman, M. (1957), *A Theory of the Consumption Function*, New Jersey: Princeton University Press.

Friedman, M. (1959), The demand for money: some theoretical and empirical results, *Journal of Political Economy*, **67**, 327-351.

Friedman, M., (1968), *Money: the Quantity Theory*, International Encyclopedia of the Social Sciences.

Frömmel, M., MacDonald, R., and L. Menkhoff (2002), Markov switching regimes in a monetary exchange rate model, mimeo, University of Hannover, Discussion Paper, No. 266, November.

Froot, K. and K. Rogoff (1995), Perspective on PPP and long-run real exchange rates,

in G. Grossman and K. Rogoff (eds.), *Handbook of International Economics*, Vol. 3, Amsterdam: Elsevier Press, 1648-1684.

Frömmel, M., R. MacDonald, and L. Menkhoff (2002), Markov switching regimes in a monetary exchange rate model, Joint Working Paper, Universität Hannover and University of Strathclyde.

Gelos, R. and S. Wei (2002), Transparency and International Investor Behavior, IMF Working Paper, No. 02/174, International Monetary Fund, Washington, D.C.

Grilli, V. and N. Roubini.(1996), Liquidity models in open economies: Theory and empirical evidence, *European Economic Review*, 40(3-5), 847-859.

Groen, J. (2000), The monetary exchange rate model as a long-run phenomenon, *Journal of International Economics*, 52, 299-319.

Hadri, K. (2000), Testing for stationarity in heterogeneous panel data, *Econometric Journal*, 3, 148-161.

Hakkio, C. (1984), A re-examination of purchasing power parity : A multi-country and multi-period study, *Journal of International Economics*, 17(3-4), 265-277.

Hamilton, J. (1988) , A neoclassical model of unemployment and the business cycle, *Journal of Political Economy*, 96(3), 593-617.

Hamilton, J. (1989), A new approach to the economic analysis of nonstationary time series and the business cycle, *Econometrica*, 57(2), 357-84.

Hamilton, J. (1990), Analysis of time series subject to changes in regime, *Journal of Econometrics*, 45(1-2), 39-70.

Hamilton, J. (1993), Estimation, inference and forecasting of time series subject to changes in regime, in *Handbook of Econometrics*, edited by G. Maddala, C. Rao, and H.

Vinod, 4, Amsterdam: Elsevier.

Hamilton, J. (1994), *Time Series Analysis*, Princeton University Press.

Harberger, A. (1950), Currency depreciation, income and the balance of trade, *Journal of Political Economy*, **58**(1), 47-60.

Harberler, G. (1949), The Market for foreign exchange and the stability of the balance of payments: a theoretical analysis, *Kyklos*, **3**, 193-218.

Harrod, R. (1933), *International Economics*, London: James Nisbet and Cambridge University Press.

Hsieh, D (1982), The determination of the real exchange rate: the productivity approach, *Journal of International Economics*, **12**, 355-362.

Hume, D. (1752), Of the balance of trade, from E. Miller (ed.) (1985) of D. Hume (1777), *Essays: Moral, Political and Literary*, Indianapolis: Liberty Classics.

Inada, K.-I. (1963), On a two-sector model of economic growth: comments and a generalisation, *Review of Economic Studies*, **30**, 119-127.

International Monetary Fund (1998), *World Economic Outlook: a survey by the staff of the International Monetary Fund, World Economic and Financial Surveys*, International Monetary Fund, Washington, DC.

Im, K., Pesaran, M. and Y. Shin (2003), Testing for unit roots in heterogeneous panels, *Journal of Econometrics*, **115**, 53-74.

Imbs, J. , Mumtaz, H., Ravn, M. and H. Rey (2005), PPP Strikes Back: aggregation and the real exchange rate, *Quarterly Journal of Economics*, **120**(1), 1-43.

Isard, P. and S. Symansky (1997), Economic Growth and the Real exchange rate: an overview of the Balassa-Samuelson Hypothesis in Asia, mimeo, International Monetary Fund.

- Johansen, S. (1988), Statistical analysis of cointegrating vectors, *Journal of Economic Dynamics and Control*, **12**, 231-254.
- Johansen, S. (1991), Estimation and hypothesis testing of cointegrating vectors in Gaussian vector autoregressive models, *Econometrica*, **59**, 1551-1580.
- Johansen, S. (1995a), Identifying restrictions of linear equations with applications to simultaneous equations and cointegration, *Journal of Econometrics*, **69**.
- Johansen, S. (1995b), *Likelihood-based inference in cointegrated vector autoregressive models*, Oxford: Oxford University Press.
- Johansen, S. and K. Juselius (1990), Maximum likelihood estimation and inference of cointegration, with application to the demand for money, *Oxford Bulletin of Economics and Statistics*, **52**, 169-209.
- Johnson, H. (1958), Towards a general theory of the balance of payments, in H. Johnson, *International Trade and Economic Growth*, London: Allen and Unwin.
- Johnson, H. (1972), The monetary theory of balance-of-payments adjustment, *International Encyclopedia of the Social Sciences*, **8**, 91-96.
- Johnson, H. (1977a), The Monetary approach to the balance-of-payments theory, in Frenkel, J. and H. Johnson (eds.) (1977), *The monetary approach to the balance of payments*, Surrey: Allen & Unwin.
- Johnson, H. (1977b), The Monetary approach to the balance of payments: a nontechnical guide, *Journal of International Economics*, **7**, 251-268.
- Judd, J. and J. Scadding (1982), The search for a stable money demand function: a survey of the post-1973 literature, *Journal of Economic Literature*, **20**, 993-1023.
- Kahn, R. (1931), The relation of home investment to unemployment, *Economic Journal*,

41, pp.193, 195-196.

Kaminsky, G. and C. Reinhart (1999), The twin crises: the causes of banking and balance-of-payments problems, *American Economic Review*, **89**(3), 473-500.

Kenen, P. (1985), Macroeconomic theory and policy: how the closed economy model was opened, in R. Jones and P. Kenen (eds.), *Handbook of International Economics*, **2**, Amsterdam: North-Holland.

Kilian, L. (1999), Exchange rates and monetary fundamentals: what do we learn from long-horizon regressions?, *Journal of Applied Econometrics*, **14**, 491-510.

Kim, C.-J. and C. Nelson (2000), *State space models with regime switching*, Cambridge, Massachusetta: MIT Press.

Krolzig, H.-M. (1996), Statistical analysis of cointegrated VAR processes with Markovian regime shifts, Sonderforschungsbereich 373, 1996-25, Humboldt Universitaet, Berlin.

Krolzig, H.-M. (1997), *Markov-switching vector autoregressions*, Springer-Verlag, Germany.

Krolzig, H.-M. (1998). Econometric modelling of Markov-switching vector autoregressions using MSVAR for Ox. Discussion Paper, Department of Economics, University of Oxford ⁷⁵.

Krolzig, H.-M. (1999), Statistical analysis of cointegrated VAR processes with Markovian regime shifts, mimeo, Nuffield College and Department of Economics, University of Oxford.

Krolzig, H.-M., and J. Toro (1999), A new approach to the analysis of shocks and the cycle in a model of output and employment, European University Institute Working Paper, No. ECO 99/30, European University Institute, Florence, Italy.

⁷⁵<http://www.economics.ox.ac.uk/hendry/krolzig> and <http://www.kent.ac.uk/economics/staff/hmk/>

Krolzig, H.-M. (2001), Estimation, structural analysis and forecasting of regime-switching models with MSVAR for Ox, mimeo, Department of Economics and Nuffield College, University of Oxford.

Krugman, P. (1989), History Vs. Expectations, NBER Working Paper, No. 2971, National Bureau of Economic Research,

Laidler, D. (1977), *The demand for money: theories and evidence*, New York: Dun-Donnelley.

Laidler, D. (1984), The Buffer Stock Notion in Monetary Economics, *Economic Journal*, **94**, 17-33.

LeBaron, B. (1992), Forecast improvements using a volatility index, *Journal of Applied Econometrics*, **7**, 137-149.

Levin, A., Lin, C. and C. Chu (2002), Unit root tests in panel data: asymptotic and finite sample properties, *Journal of Econometrics*, **108**, 1-24.

Lothian, J. (1997), Multi-country evidence on the behaviour of Purchasing Power Parity, under the current float, *Journal of International Money and Finance*, **16**(1), 19-35.

Lucas, R. (1972), Expectations and the neutrality of money, *Journal of Economic Theory*, **4**, 103-124.

Lucas, R. (1975), An equilibrium model of business cycles, *Journal of Political Economy*, **83**, 1113-1344.

Lucas, R. (1976), Econometric policy evaluation: a critique, in K. Brunner and A. Meltzer (eds.), *The Phillips Curve and Labour Markets*, Vol. 1 of Carnegie-Rochester Conference Series on Public Policy, Amsterdam: North Holland.

Lucas, R. (1980), Methods and problems in business cycle theory, *Journal of Money*,

Credit, and Banking, **12(4)**, 696-715.

Lucas, R. (1987), *Models of business cycles*, Yrjo Jahnsson Lecture Series, London: Blackwell.

Lutkepohl, H. and H.-E. Reimers (1992), Impulse response analysis of cointegrated systems, *Journal of Economic Dynamics and Control*, **16**, 53-78.

MacDonald, R. (1995), Long-run exchange rate modelling: a survey of the recent evidence, *Staff Papers*, International Monetary Fund, **42(3)**, 437-489.

MacDonald, R. (1999), Exchange rate behavior: are fundamentals important?, *Economic Journal*, **109**, 673-691.

MacDonald, R. and I. Marsh (1997), On fundamentals and exchange rates: a Casselian perspective, *Review of Economics and Statistics*, 655-664.

MacDonald, R. and L. Ricci (2001), PPP and the Balassa Samuelson effect - the role of the distribution sector, IMF Working Papers, No. 01/38, International Monetary Fund.

Macdonald, R. and L. Ricci (2003), PPP and the Balassa Samuelson effect: the role of the distribution sector, DNB Staff Reports (discontinued), No. 81, Netherlands Central Bank.

MacDonald, R. and M. Taylor (1994), The monetary model of the exchange rate: long run relationships, short-run dynamics, and how to beat a random walk, *Journal of International Money and Finance*, **13**, 276-290.

MacDonald, R. and C. Wójcik (2004), *Catching Up: The Role of Demand, Supply and Regulated Price Effects on the Real Exchange Rates of Four Countries*, mimeo, Department of Economics, University of Strathclyde, Glasgow and Haas School of Business, University of California, Berkeley.

Maddala, G. and S. Wu (1999), A comparative study of unit root tests with panel data and a new simple test, *Oxford Bulletin of Economics and Statistics*, **61**, 631-52.

Mark, N. (1995), Exchange rates and fundamentals: evidence on long-horizon predictability, *American Economic Review*, **85**, 201-218.

Mark, N. and D. Sul (2001), Nominal exchange rates and monetary fundamentals: evidence from a small post-Bretton Woods panel, *Journal of International Economics*, **53**, 29-52.

Machlup, F. (1939), The theory of foreign exchanges, *Economica*, **6**, 365-397.

Marshall, A. (1923), *Money, credit, and commerce*, London: Macmillan.

Marston, R. (1987), Real exchange rates and productivity growth in the United States and Japan, in S. Arndt and J. Richardson (eds.), *Real financial linkages among open economies*, pp. 71-96, Cambridge, MA: MIT Press.

Matthews, K. (1979), An algorithm for solving the Liverpool model, appendix to Minford (1979).

McCallum, B. and E. Nelson (1999), An optimizing IS-LM specification for monetary policy and business cycle analysis, *Journal of Money, Credit and Banking*, **31**, 296-316.

McKinnon, R. and W. Oates (1966), The implications of international economic integration for monetary, fiscal, and exchange-rate policies, International Finance Section, Princeton University, Princeton, New Jersey.

McKinnon, R. (1969), Portfolio balance and international payments adjustment, in R. Mundell and A. Swoboda (eds.), *Monetary problems of the international economy*, Chicago: University of Chicago Press, 199-234.

Meade, J. (1951), *The Theory of International Economic Policy: The Balance of Pay-*

ments, London: Oxford University Press.

Meese, R. and K. Rogoff (1983), Empirical exchange rate models of the seventies: do they fit out-of-sample?, *Journal of International Economics*, **14**, 3-24.

Michael, P., Nobay, R. and D. Peel (1997), Transactions costs and nonlinear adjustment in real exchange rates: an empirical investigation, *Journal of Political Economy*, University of Chicago Press, **105**(4), 862-79.

Minford, A. (1979), A note on terminal conditions and the analytic solution of Rational Expectations models, University of Liverpool, Working Paper No. 7805.

Minford, A., Marwaha, S., Matthews, K. and S. Sprague (1984), The Liverpool macro-economic model of the United Kingdom, *Economic Modelling*, 24-62.

Mundell, R. (1960), The monetary dynamics of international adjustment under fixed and flexible exchange rates, *Quarterly Journal of Economics*, **74**, 227-257.

Mundell, R. (1961), The international equilibrium system, *Kyklos*, **14**(2), 153-172.

Mussa, M. (1976), The exchange rate, the balance of payments and monetary and fiscal policy under a regime of controlled floating, *Scandinavian Journal of Economics*, **78**, 229-248.

Neely, C. and L. Sarno (2002), How well do monetary fundamentals forecast exchange rates?, *Federal Reserve Bank of St. Louis Review*, Federal Reserve Bank of St. Louis.

Obstfeld, M. (1993), Model trending Real Exchange Rates, Center for International and Development Economics Research (CIDER), Working Papers C93-011, University of California at Berkeley.

Obstfeld, M. (1994), The logic of currency crises, *Cahiers Economiques et Monetaires*, **43**, 189-213, Paris: Banque de France.

Obstfeld, M. and A. Taylor (1997), Nonlinear aspects of goods-market arbitrage and ad-

justment: Heckscher's commodity points revisited, CEPR Discussion Papers 1672, C.E.P.R. Discussion Papers.

O'Connell, P. (1998), The overvaluation of purchasing power parity, *Journal of International Economics*, **44**, 1-19.

O'Connell, P. and S.-J.Wei (1997), The bigger they are, the harder they fall: how price differences across U.S. cities are arbitrated, NBER Working Paper, No. 6089, National Bureau of Economic Research.

Officer, L. (1976), The productivity bias in purchasing power parity: an econometric investigation, *IMF Staff Papers*, **10**, 545-79.

Papell, D. and R. Prodan (2003), Long run Purchasing Power Parity: Cassel or Balassa-Samuelson?, mimeo, Department of Economics, University of Houston.

Patinkin, D. (1965), *Money Interest and Prices*, 2nd Edition, New York: Harper & Row.

Pesaran, M. and S. Potter (1997), A floor and ceiling model of US output, *Journal of Economics Dynamics and Control*, **21**, 661-695.

Pigou, (1923), The exchange value of legal-tender money, in A. C. Pigou, *Essays in Applied Economics*, London: King and Son.

Pisanwanich, A. (2005), The impact of trade liberalization of WTO on the Thai agricultural and agro-industry products: the general equilibrium model approach, mimeo, University of the Thai Chamber of Commerce, Bangkok, Thailand.

Polak, J. (1957), Monetary analysis of income formation and payments problems, *International Monetary Fund Staff Papers*, **4**, 1-50.

Polak, J. (2001), The two monetary approaches to the balance of payments: Keynesian and Johnsonian, IMF Working Paper, No. WP/01/100, International Monetary Fund.

Prais, S. (1961), Some mathematical notes on the quantity theory of money in an open economy, *IMF Staff Papers*, **8(2)**, 212-226.

Psaradakis, Z. and N. Spagnolo (2003), On the determination of the number of regimes in Markov-switching autoregressive models, *Journal of Time Series Analysis*, **24(2)**, 237-252.

Rapach, D. and M. Wohar (2002), Testing the monetary model of exchange rate determination: new evidence from a century of data, *Journal of International Economics*, **58**, 359-385.

Rigobon, R. (2000), A simple test for stability of linear models under heteroskedasticity, omitted variables, and endogenous variable problems, mimeo, Sloan School of Management, MIT and National Bureau of Economic Research.

Robinson, J. (1947), The foreign exchanges, in J. Robinson, *Essays in the Theory of Employment*, Oxford: Basil Blackwell, 134-155.

Rodriguez, C. (1976), Money and wealth in an open economy income-expenditure model, in Frenkel and Johnson (eds.) (1976), *The monetary approach to the balance of payments*, London: Allen and Unwin.

Rogers, J. and Jenkins (1995), Haircuts or hysteresis? Sources of movements in real exchange rates, *Journal of International Economics*, **38(3-4)**, 339-360

Rogoff, K. (1992), Traded goods consumption smoothing and the random walk behaviour of the real exchange rate, *Bank of Japan Monetary and Economic Studies*, **10**, 1-29.

Rogoff, K. (1996), The Purchasing Power Parity puzzle, *Journal of Economic Literature*, **34(2)**, 647-668⁷⁶.

⁷⁶This recent survey provides an overview of developments with respect to research on PPP, including the emerging consensus that deviations from PPP do damp out but only very slowly, at roughly fifteen percent

Roll, R. (1979), Violations of purchasing power parity and their implications for efficient international commodity markets, in M. Sarnat and G. Szego (eds.), *International Finance and Trade*, Cambridge: Ballinger.

Saikkonen, P. (1992), Estimation and testing of cointegrated systems by an autoregressive approximation, *Econometric Theory*, **8**, 1-27.

Saikkonen, P. and R. Luukkonen (1997), Testing cointegration in infinite order vector autoregressive processes, *Journal of Econometrics*, **81**, 93-126.

Sarno, L., Valente, G., and M. Wohar, (2004), Monetary fundamentals and exchange rate dynamics under different nominal regimes, *Economic Inquiry*, Apr 2004, **42(2)**, 179-193.

Samuelson, P. (1964), Theoretical notes on trade problems, *Review of Economics and Statistics*, **46**, 145-154.

Schnatz, B., Visselaar, F. and C. Osbat. (2004), Productivity and the euro-dollar exchange rate, *Weltwirtschaftliches Archiv (Review of World Economics)*, **140(1)**, 1-30.

Sekioua, S. (2003), The nominal exchange rate and monetary fundamentals: evidence from nonlinear unit root tests, *Economics Bulletin*, **6(1)**, 1-13.

Shanno, D. (1970), Conditioning of Quasi-Newton Methods for Function Minimization, *Mathematics of Computation*, **24**, 647-656.

Sofat, P., Minford, A., Nowell, E., and D. Meenagh (2005), Overshooting RBC style real exchange rate, mimeo, Cardiff Business School, Cardiff University, January.

Spraos, J. (1955), Consumers' behaviour and the conditions for exchange stability, *Economica*, **22(86)**, 137-147.

Stock, J. and M. Watson, (1988), Testing for common trends, *Journal of the American Statistical Association*, **83**, 1055-1066.
per year. It remains difficult to explain why the estimated speed of convergence to PPP is so slow.

can Statistical Association, **83**, pp 1097-1107, reprinted in *Long-run economic relationships, readings in cointegration*, by R. Engle and C. Granger (eds.), Oxford: Oxford University Press.

Stockman, A. and L. Tesar (1995), Taste and technology in a two-country model of the business cycle: explaining international co-movements, *American Economic Review*, **85**, 168-185.

Taylor, M. (1995), The economics of exchange rates, *Journal of Economic Literature*, **33**, 13-47.

Tinbergen, J. (1952), *On the theory of economic policy*, Amsterdam: North-Holland.

Wei, J. and D. Parsley (1995), Purchasing Power Disparity during the floating rate period: exchange rate volatility, trade barriers and other culprits, NBER Working paper No. 5032.

Wolff, C. (1987), Time-varying parameters and the out-of-sample forecasting performance of structural exchange rate models, *Journal of Business and Economic Statistics*, 87-97.

7 Appendix 1: List of Symbols

7.1 Greek alphabets: Lower Case

α constant, coefficient, it represents net export demand in the Phillip's Curve in Equation 30.

β constant, coefficient (β represents the continuous-time price elasticity to the real exchange rate movement in Part I, and the discount factor in the RBC model in Part II).

γ constant, $\gamma \equiv 1/(1 + \lambda)$.

δ depreciation rate.

ϵ error term.

$\varepsilon_t = [\varepsilon_{1t}, \varepsilon_{2t}, \dots, \varepsilon_{Kt}]'$, a K -dimensional vector of Gaussian white noise processes with covariance matrix Σ .

$\varepsilon_t \sim NID(0, \Sigma)$.

θ the money multiplier.

λ the interest rate semi-elasticity of money demand.

μ the money multiplier, μ represents unemployment benefits in the RBC model.

π inflation rate.

π^e the expected inflation rate (the expected return on goods, since inflation is the increase in the price (value) of goods).

ρ in the RBC model, a fraction of the elasticity of substitution between countries' goods.

σ the elasticity of substitution between countries' goods, $\sigma = \frac{1}{1+\rho}$.

σ_ϵ^2 variance of the error term ϵ .

τ labour income tax.

ϕ in Part I (monetary model of the exchange rate), income elasticity of money demand and $\lambda > 0$.

ϕ in Part II (real business cycle model), consumption tax or value added tax (VAT).

ϕ^* in Part I, foreign country's income elasticity of money demand.

ψ the rate of nominal exchange rate growth, $\psi \equiv \lambda\gamma < 1$.

ω the weight of home goods in the consumption function.

ω^f the weight of foreign goods in the consumption function.

7.2 *Greek alphabets: Upper Case*

Δ denotes the change in a discrete variable.

Π denotes $K \times K$ matrices of parameters.

Σ covariance matrix of ε_t .

7.3 *English alphabets: Lower Case*

b domestic bonds.

b^f foreign bonds.

bub_t rational bubble.

c constant.

cc_t a variable denoting the cointegrating combination of nominal exchange rate and the RID monetary fundamentals.

d Frankel (1976) defines d as the expected rate of depreciation (in Part I: monetary model)

d denotes dividend per share in Part II (the real business cycle model).

$d_t = \ln(D_t)$ natural log level of the domestic credit.

d_i the forward discount, $d_i = (\log \text{ of the forward rate}) - (\log \text{ of the current spot rate})$.

f variable denotes economic fundamentals.

g sustainable growth rate, $g = (\text{plowback ratio}) * (\text{return on equity})$

h exchange rate sensitivity to the change in the labour supply in the RBC model.

i_t is the domestic nominal interest rate.

\bar{i}_t is the domestic country's long-run equilibrium value of the nominal interest rate.

iid independently and identically distributed (process).

j a small increment of discrete time unit.

k the inverse of the velocity of circulation, V .

l leisure hours consumed in the RBC model.

$\ln(.)$ natural logarithm of the variable in brackets.

m a constant representing the marginal propensity to import.

m_t the natural logarithm of the total domestic money stock, $m_t = \theta r_t + (1 - \theta) d_t$.

m_t^* the natural logarithm of the foreign money supply.

\bar{m}_t^* the natural logarithm of the long-run equilibrium value of the foreign money supply.

m_t^d the money demand.

p in Part I (monetary model), log of the nominal price level.

p in Part II (real business cycle model), the present value of shares, $p = \left(\frac{d}{(r-g)} \right) / (\text{no. of shares traded})$.

\bar{p} in Part I (monetary model), long-run equilibrium value of the log nominal price level of the domestic country.

\bar{p}^* in Part I (monetary model), long-run equilibrium value of the log nominal price level

of the foreign country.

\dot{p} represents a continuous movement of the price level

q_t the real exchange rate.

r the world real interest rate, represented here by the US Federal target rate.

re log of reserves.

r^*, r^f the foreign country's rate of interest.

r_m the expected return on money.

r_b the expected return on bonds.

r_e the expected return on stocks.

$re_t = \ln RE$ log of reserves level.

s log of nominal exchange rate (foreign currency in terms of domestic currency unit).

\bar{s} the long-run equilibrium value of the domestic country's log of nominal exchange rate.

\bar{s}^* the long-run equilibrium value of the foreign country's log of nominal exchange rate.

\dot{s} represents a continuous movement of the nominal exchange rate.

\dot{s}^e expected rate of depreciation (continuous time) $\equiv d$ according to Frankel (1976).

t denotes time period when subscripted, and time trend when appears in line.

v consumer real wage.

w producer real wage.

w^* equilibrium real wage.

y_t is the log of national output or national income, represented here by the GDP.

\bar{y} is the log of the long run equilibrium level of output.

7.4 *English alphabets: Upper Case*

Bub_t rational bubble at time t .

C_t consumption in period t , $C_t = \left[\omega (C_t^d)^{(1-\frac{1}{\sigma})} + (1 - \omega) (C_t^f)^{(1-\frac{1}{\sigma})} \right]^{\frac{\sigma}{\sigma-1}}$.

C^F foreign consumption.

D household debt.

DC_t is the level of domestic credit extended by the Central Bank.

E domestic expenditure,

$E_t(.)$ is the expectation operator of the variable in brackets at time t .

EX export.

IM import.

G government expenditure.

I investment.

I_t publically available information set.

IM import.

K net capital inflow of the nonbanking sector.

L is the actual liquidity to the balance of payments.

\hat{L} is a desired level of liquidity or money demand.

Lei_t is the amount of leisure time consumed in period t .

M_t money supply.

$M0_t$ is the log of monetary base, $M0 = R + D$.

N^d demand for labour.

NX net exports.

P_t price level at time t .

P_t^f foreign price level at time t .

$P_t^F = S_t P_t^f$ foreign price level in domestic prices, at time t .

PD primary deficit.

POP number of population in a country.

Q real exchange rate.

R is the reserves level of each country.

R_t is the stock of foreign exchange reserves held by the central bank.

S nominal exchange rate.

S^p demand for domestic shares.

\bar{S} supply of shares.

T lump sum tax.

V velocity of money.

X export.

Y total revenue from national output, $Y \equiv y * p$.

Y_p permanent income.

Z productivity.

8 Appendix 2: The Frankel Estimation

The author repeated the Frankel (1979) test for Thailand in the immediate aftermath of the Thai currency crisis, taking account of the endpoint data. First, an ordinary least squares of the log of spot Thai Baht per US Dollar is tested using monthly data from July 1997 to December 2003 on the relative money supplies, output, and interest differential (the difference between nominal interest rate and the expected long-run inflation), using Eviews 4.0. Frankel (1979) uses two kinds of proxies for the expected inflation differential: past inflation differentials (averaged over the preceding year) and long-term interest differentials (assuming that the long-term real interest rates are equal). The first set of instrumental variables for expected inflation differential has Consumer Price Index (CPI) inflation differential (average for past year), producer price index (PPI) inflation differential (average for past year), and long-term government bond yield differential. The second set of instruments has lagged values of the nominal exchange rate and the money supply, each by one period. The advantage of the long-term interest differential is that it is capable of reflecting instantly the impact of new information such as monetary growth target announcements. The long-term government bond rate differential is the proxy used in the reported regressions, though other proxies are used as instrumental variables.

Estimated equation 1: (OLS⁷⁷, pre-cointegration analysis): the log of nominal exchange rate on the relative money supply, relative income/output, relative interest differential and relative expected inflation differential. Newey-West heteroskedasticity and Autocorrelation consistent standard errors and covariance are employed.

⁷⁷Lag truncation = 3.

Estimated equation 2: Instrument list: constant relative money supply, inflation differential, past inflation differential, and relative expected inflation.

Estimated equation 3: (FAIR) Instrument list: the lagged values of the nominal exchange rate by one period, the lagged values of the relative money supply by one period, the relative industrial production index, the relative interest rate differential, and the relative expected inflation.

Estimation	Constant	$m - m^*$	$y - y^*$	$r - r^*$	$\pi - \pi^*$	R^2	DW	RID	Obs.
RID1: OLS	4.36**	0.77**	-0.01**	1.12**	-2.00	0.39	0.72	-0.88**	78
Standard Err.	(0.11)	(0.14)	(0.00)	(0.31)	(1.17)				
RID2: INST	5.08**	1.64	-0.02	1.14	-1.50	-0.58	1.44	-0.36	77
Standard Err.	(1.65)	(1.93)	(0.02)	(2.13)	(5.88)				
RID3: FAIR	4.56**	1.04**	-0.01**	1.16**	-0.94	0.26	1.01	0.22*	77
Standard Err.	(0.15)	(0.19)	(0.00)	(0.31)	(1.19)				

Table 47: Coefficients and Standard Errors from RID Estimation Results

** Significant at 5%

* Significant at 10%

Figure 19 plots the actual and fitted values of the OLS estimates, together with the OLS residuals.

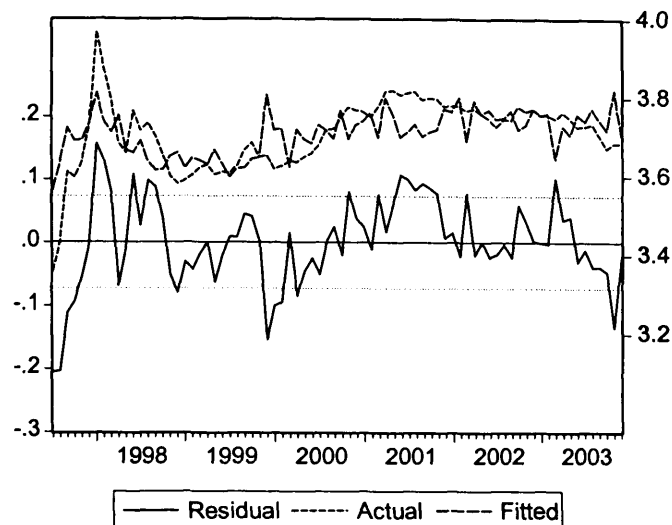


Figure 39: OLS regression on Thai floating data

Estimating RID Equation 1: The OLS Results As the reader can see from the table, all of the theories are not supported by the data (notably in the relative real inflation differential–RID–term) for the real interest differential part, the elasticity for relative money and relative output have the right signs and for the relative money the right magnitude, close to or even equal unity where the instruments suggested by Ray Fair (Fair, 1970) were used as there is evidence for LM-test for serial correlation for the OLS residuals. Fair suggests the use of lagged endogenous variables where there is evidence of the residuals having first order-autocorrelation as indicated in Table 4 below.

Test Statistic	Probability
<i>F-stat</i> 19.896	0.000
<i>Obs*R²</i> 28.015	0.000

Table 48: The Breusch-Godfrey Serial Correlation LM Test

The coefficients of the real interest rate differential term (the combination of the nominal interest rate differential and the expected inflation differential) comes out with the wrong

sign. FPM also does not hold because of the negative coefficients on the expected inflation differential. The output elasticity from all the tests have the right negative sign and are almost insignificant with near-zero values. The coefficients for the expected inflation differential are significantly negative values. According to Frankel (1979), the sum of the coefficient on the nominal interest differential and the coefficient on the expected inflation differential is an estimate of the semi-elasticity of money demand with respect to the interest rate. This number is **-0.88**, -0.36 and **0.22** for OLS, INST, and FAIR results, which is $(-0.88) \times 12 = -10.56$, $-0.36 \times 12 = -4.32$, and $0.22 \times 12 = 2.64$. With an average interest rate of 5.4%, this implies an interest elasticity of around $-10.56 \times 0.054 = -0.57$ for the OLS result, $-4.32 \times 0.054 = -0.23$ for the first set of instruments, and $2.64 \times 0.054 = 0.14$ for the second. The point estimate of α_r is **1.16** in our best (FAIR) case. This implies that, had the signs been correct (negative in the case of nominal interest rate and positive in the case of expected inflation) when a disturbance creates a deviation from purchasing power parity, $(1 - \frac{1}{1.16}) = 16\%$ per cent of the deviation is expected to remain after one month, and $(0.16)^{12} = 2.81 \times 10^{-10} \approx 0\%$ is expected to remain after one year.

Estimation with Instrumental Variables (INST) The explanatory variables maybe endogenous since the exchange rate maybe determined by our proxy of the expected inflation differential, the long term bond yield differential and thus the resulting OLS estimates maybe biased and inefficient. As a result instrument variables are used to avoid the correlation in the residuals as a result of the endogeneity of the explanatory variables within the system. The Cochrane-Orcutt procedure were applied, using the lags of order 1 of all the dependent and explanatory variables (the one period lagged log nominal exchange rate or LNBAHT(-

1), the one-period lagged nominal relative money supply or $MM(-1)$, and the one-period lag of the relative nominal income, $YY(-1)$, and the one-period lagged nominal interest rate differential ($RR30(-1)$) as well as the lag of order one of the expected inflation differential ($PIPI(-1)$). The results in the second ‘Cochrane’ row of Table 3 show a marked improvement in capturing the correlation of the residuals, all of the coefficient are significant and remain the same wrong signs as before. The second set of instruments (IV-1) has LNBAHT, MM, Consumer Price Index Differential (CPID), Producer Price Index Differential (PPID), and the expected inflation differential (PIPI) in it and yields similar results, giving the hypothesized unity for the relative money supply. The third set of instrument, LNBAHT(-1), MM, Industrial Production (IP) differential as a proxy for the nominal income differential, short term interest differential which captures the liquidity effects (RR30) as a proxy for the nominal interest differential, and the expected inflation differential, PIPI. Again our third set of instruments yield very similar results to the second set and produce the same wrong signs as the two instrument variable sets that were tested before it.

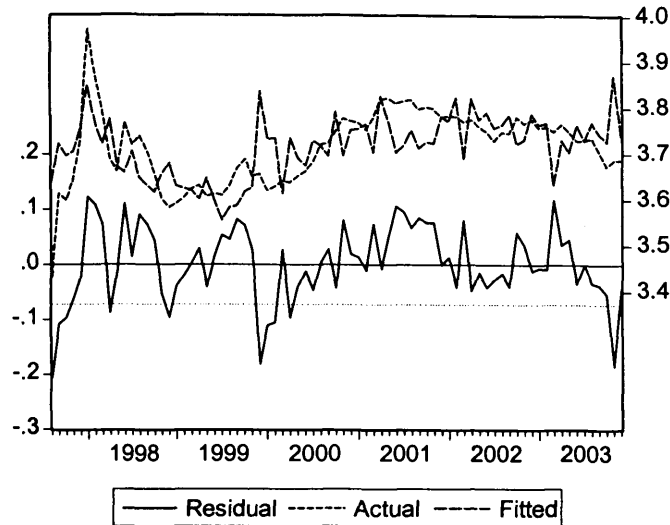


Figure 40: The Fair Set of instrumental variables provides the best first estimates for the RID theory on the Thai data

Estimation with Fair's Set of Instrumental Variables (FAIR):

In the Frankel exercise, when we do not yet take into account the possible cointegrated relationship between the exchange rate and the monetary fundamentals, the FAIR set of instrumental variables estimated in two stage least squares in EViews 4.0 gives the best fit to the data. With nonstationarity in the data, the OLS estimates are not accurate and in the thesis, the coefficients from the Johansen cointegrating equation were instead used .

9 Appendix 3: Rolling Forecasts

Traditionally, the government budget process has been a one-off event, albeit a long and arduous one, and the forecasts, though more frequent, remain as a series of one-off quarterly events. However, significant gains can be made from eradicating this single period/annual mindset and moving to a rolling forecast approach. Government operations do not switch off at the end of August each year and start afresh on September 1. Agents do not think of Government in this way, so there is less incentive as such to monitor and manage the economy in discrete timeframes.

9.1 The concept of a 12-month rolling forecast

As each additional month's actual information is finalized, the forecast is updated to provide an additional months forecast, thus always providing a 12-month projection into the future. The move to rolling forecasts provides a number of benefits. First, it reduces or eliminates the traditional approach of the previous period. This approach forces the individuals undertaking the forecasts to update their projections each month and embed the activity in monthly procedures. Second of all, it helps to eliminate the annual mind-set and focus on the current year, acknowledging that the Government functions as an ongoing operation and needs to be managed accordingly. Thirdly, the rolling forecast provides a continual 12-month Government's economic outlook at all times, enabling management to take remedial action as forecast economic and business conditions change. Fourthly, it eliminates the unrealistic August-to-September gap that appears when next year's budget is calendarized for the first time. By undertaking rolling forecasts, the August-to-September forecast is no

different than any other two-month period. Finally, the rolling forecasts reduce or potentially eliminate the annual budgeting process. At the normal budget time, the Government will already have a very good idea of what the following fiscal year will look like from their latest rolling forecast. For example, an organization operating a 15-month rolling forecast will already have, at the end of the third quarter, a complete projection of the next fiscal year.

An alternative to a true rolling forecast is a fixed period rolling forecast, with which a number of organizations operate. Although this approach has the benefit of ensuring that forecasts are updated monthly, the benefits just described are not fully realized because the forecast remains focused on the current period. The key problem with this approach is that the government still has a fixed horizon with associated implications.

Increasingly, companies have moved or are moving toward rolling forecasts. Usually there is significant cultural attachment to the forecasting and budgeting process, so the transition to rolling forecasts should not be underestimated. A budgeting process, for example, that starts in March and ends in August can become a *raison d'être* for the finance organization during this time, with much political power and control associated with the process.

Unfortunately since the data on Thai capital fluctuates wildly in our Thai data, the model cannot solve when the residuals are removed and thus the rolling forecast for the Thai data was not reported in this thesis. The model is known to solve in the case of the UK economy (Sofat et al., 2005), and ongoing research at the Julian Hodge Institute of Applied Economics now includes data for the whole Indian economy. It will be interesting to see how the models compare and contrast once the work on the Indian economy is undertaken.

