

# Towards a model of speculation in the foreign exchange market

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A thesis submitted in partial fulfilment of the requirements  
for the degree of Doctor of Philosophy

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# Declaration of Authorship

I, Rob HAYWARD, declare that this thesis titled, 'Towards a model of speculation in the foreign exchange market' and the work presented in it are my own. I confirm that:

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*“There is no sphere of human thought in which it is easier to show superficial cleverness and the appearance of superior wisdom than in discussing questions of currency and exchange.”*

Winston Churchill  
House of Commons  
September 29, 1949

UNIVERSITY OF BRIGHTON

## *Abstract*

Business

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### **Towards a model of speculation in the foreign exchange market**

by Rob HAYWARD

The recent slowdown in global economic activity has shown that macroeconomic models without a well-structured representation of the financial sector will fail to provide understanding of the way that disruptions in credit markets, capital markets and banking can affect the rest of the economy. An investigation of foreign exchange speculation is used to get a better knowledge of the interaction between the financial sector and the economy as a step towards improving macroeconomic models and policy.

The first part of this research looks at speculation at the macroeconomic level by using a structured vector auto regression (SVAR) to assess the relationship between capital flows and the US real exchange rate. The second assesses whether speculation can be used to identify price reversals in foreign exchange markets. The final section seeks to understand more about speculative risk with a detailed analysis of uncovered interest parity and the speculative attempt to take advantage of times when it does not hold.

Speculative activity is a significant contributor to changes in the real exchange rate. No informational content is found in the extremes of speculative activity but it is shown that speculators are compensated for taking *crash risk* and that their activity may increase the amount of crash risk in the markets where they are operating.

The main contributions of this work are applying a microstructure approach at the macro level; adding speculation to a model of international capital flows; the use of a unique series of options data to identify speculative sentiment; using a *carry trade model* to understand more about uncovered interest parity and the returns to speculation; using the event study method to investigate speculative extremes; and using all this to suggest ways to improve macroeconomic models and policy.

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# Contents

<b>Declaration of Authorship</b>	<b>ii</b>
<b>Abstract</b>	<b>iv</b>
<b>Acknowledgements</b>	<b>v</b>
<b>List of Figures</b>	<b>xi</b>
<b>List of Tables</b>	<b>xiii</b>
<b>Abbreviations</b>	<b>xv</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Speculation . . . . .	1
1.2 Political economy and speculative activity . . . . .	2
1.2.1 Findings . . . . .	4
1.2.2 Minsky: The financial instability hypothesis . . . . .	6
1.2.3 Expected utility theory . . . . .	7
1.2.4 Speculation and uncertainty . . . . .	10
1.2.5 Speculation and investment . . . . .	13
1.3 Speculation at the micro level . . . . .	16
1.3.1 The informational content of speculation . . . . .	17
1.3.1.1 Rational expectations . . . . .	19
1.3.1.2 Bubbles . . . . .	20
1.3.2 The returns to speculation . . . . .	21
1.4 Outline . . . . .	24
1.4.1 International capital flows, speculation and the real exchange rate	24
1.4.2 Informational content of speculation . . . . .	25
1.4.3 The nature of speculative returns . . . . .	25
1.4.4 Modelling and policy . . . . .	26
<b>2 International Capital Flows and Speculation</b>	<b>27</b>
2.1 Introduction . . . . .	27
2.2 Literature review . . . . .	29
2.2.1 Purchasing power parity . . . . .	29

2.2.2	Uncovered interest parity . . . . .	30
2.2.3	Monetary approaches . . . . .	32
2.2.4	Harrod-Balassa-Samuelson . . . . .	34
2.2.5	The PPP adjustment process . . . . .	36
2.2.6	International capital markets . . . . .	37
2.2.7	Portfolio flows . . . . .	40
2.2.8	Measuring capital flow . . . . .	42
2.2.9	Microstructure . . . . .	44
2.3	Methodology . . . . .	46
2.3.1	The exchange rate . . . . .	46
2.3.2	Capital flows . . . . .	47
2.3.3	Trade flow . . . . .	49
2.3.4	Data preparation . . . . .	52
2.3.5	Dummy variables . . . . .	57
2.3.6	Endogeneity . . . . .	58
2.3.7	Vector autoregression . . . . .	65
2.3.8	Identification . . . . .	67
2.3.9	VAR restrictions . . . . .	69
2.4	Results . . . . .	70
2.4.1	Model selection . . . . .	73
2.4.2	Model specification and diagnostics . . . . .	75
2.4.3	Parameter stability . . . . .	80
2.4.4	Impulse response functions . . . . .	82
2.4.5	Confidence intervals . . . . .	84
2.4.6	Alternative models . . . . .	86
2.4.6.1	System three: structural VAR . . . . .	87
2.4.7	Comparison of identification methods . . . . .	91
2.5	Speculation has real and significant effects . . . . .	93
<b>3</b>	<b>The Informational Content of Speculation: An Event Study</b>	<b>95</b>
3.1	Introduction . . . . .	95
3.1.1	Fundamental value . . . . .	96
3.2	Literature review . . . . .	97
3.2.1	Failures of market efficiency . . . . .	99
3.2.1.1	Empirical evidence . . . . .	100
3.2.1.2	Normal distribution . . . . .	102
3.2.1.3	Institutional features . . . . .	103
3.2.1.4	Decision-making . . . . .	103
3.2.1.5	Behavioural finance . . . . .	104
3.3	Methodology . . . . .	107
3.3.1	The implications of the noise-trader model . . . . .	112
3.3.2	The results of simulation . . . . .	113
3.3.3	Measuring the intensity of speculative sentiment . . . . .	113
3.3.4	Measuring the proportion of speculators . . . . .	119
3.3.5	Event studies . . . . .	123
3.3.6	Analysis of events and abnormal returns . . . . .	125
3.4	Analysis of the results . . . . .	125



3.5	Speculation and foreign exchange returns . . . . .	134
<b>4</b>	<b>The Carry Trade, Uncovered Interest Parity and Crash Risk</b>	<b>137</b>
4.1	Introduction . . . . .	137
4.2	Literature review . . . . .	139
4.2.1	Risk premium . . . . .	139
4.2.2	Expectations . . . . .	141
4.2.3	Crash risk . . . . .	142
4.2.4	European financial markets . . . . .	144
4.3	Methods . . . . .	145
4.3.1	The carry sample . . . . .	145
4.3.2	A carry-trade model . . . . .	146
4.3.3	Exchange rate regime . . . . .	147
4.3.4	Risk and uncertainty . . . . .	147
4.3.5	Measuring international risk aversion . . . . .	149
4.4	Results . . . . .	151
4.4.1	UIP test . . . . .	151
4.4.2	Carry trade tests . . . . .	152
4.4.3	Risk-adjusted return . . . . .	152
4.4.4	A carry-trade model . . . . .	156
4.4.5	Moderation and Crisis . . . . .	158
4.5	The carry trade and speculation . . . . .	166
<b>5</b>	<b>Conclusion</b>	<b>169</b>
5.1	Speculation and exchange rates . . . . .	169
5.1.1	Enterprise and speculation . . . . .	170
5.1.2	Uncertainty and noise . . . . .	171
5.1.3	Confidence . . . . .	173
5.2	Macroeconomic models . . . . .	174
5.2.1	Modelling speculation . . . . .	174
5.2.2	Modelling bank lending . . . . .	176
5.3	Policy . . . . .	177
<b>A</b>	<b>R Code for Chapter 2</b>	<b>181</b>
A.1	Introduction . . . . .	181
A.2	Data preparation . . . . .	181
A.3	Dummy variables . . . . .	182
A.4	Time Series Plot of Variables . . . . .	183
A.5	VAR lag selection . . . . .	183
A.6	VAR model . . . . .	184
A.7	Diagnostic Tests . . . . .	184
A.8	SVAR . . . . .	185
A.9	Plotting IRF . . . . .	187
A.10	System Two . . . . .	187
<b>B</b>	<b>R Code Chapter 3</b>	<b>191</b>

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B.1	My stats function . . . . .	191
B.2	Code for Monte Carlo Simulation of the Noise Trader Model . . . . .	192
B.3	Data preparation . . . . .	194
B.4	Descriptive Statistics . . . . .	195
B.5	Code for Tables 3.6 and 3.7 Figures 3.1 and 3.2 . . . . .	195
B.6	Event windows . . . . .	199
<b>C</b>	<b>R and Eviews Code Chapter 4</b>	<b>201</b>
C.1	Data Preparation . . . . .	201
C.2	VIX . . . . .	201
C.3	Carry trade model . . . . .	202
C.4	Eviews analysis of carry returns in crisis and moderation . . . . .	203
C.5	Crisis and Moderation Plots . . . . .	205
	<b>Bibliography</b>	<b>207</b>

# List of Figures

2.1	Cumulative capital flows and USD . . . . .	55
2.2	Cumulative net bond to GDP . . . . .	56
2.3	Cumulative net FDI to GDP . . . . .	57
2.4	Impulse Response Functions for RTWI for System Three . . . . .	72
2.5	Autocorrelation of residuals . . . . .	77
2.6	Time Series of Model Residuals . . . . .	79
2.7	Histogram of model residuals . . . . .	80
2.8	Cumulative sum of residuals stability test . . . . .	82
2.9	Impulse Response Functions for RTWI for System One . . . . .	90
2.10	Impulse Response Functions for RTWI for System Two . . . . .	92
3.1	Event Study: Extreme (High 99th percentile) Risk Reversal Skew and 16 day event window . . . . .	128
3.2	Event Study: Extreme (Low - 10th percentile) Risk Reversal Skew and 16 day event window . . . . .	129
3.3	Event Study: Extreme (95th percentile), Non-commercial net per OI (S2), 6 week event window . . . . .	132
3.4	Event Study: Extreme (90th percentile), Non-commercial net long (S1), 6 week window . . . . .	133
4.1	The VIX index and critical thresholds used in the study . . . . .	150
4.2	The Distribution of USD Carry Trade Returns in Moderation and Crisis .	163
4.3	The Distribution of EUR Carry Trade Returns in Moderation and Crisis .	165



# List of Tables

2.1	Major Currency TWI weights . . . . .	47
2.2	Important capital flows and exchange rate data . . . . .	54
2.3	SVAR Restrictions . . . . .	68
2.4	Model Selection . . . . .	74
3.1	Results of the Monte Carlo Simulation of the Noise-Trader Model . . . . .	113
3.2	Descriptive Statistics for Daily Exchange Rate Returns: 2 January 1996 to 6 September 2002 . . . . .	116
3.3	Descriptive Statistics for Risk Reversals: 2 January 1996 to 6 September 2002 . . . . .	118
3.4	Descriptive Statistics for Weekly Exchange Rate Returns: 30 September 1998 to 31 December 2008 . . . . .	121
3.5	Descriptive Statistics for S1 (Speculative Sentiment) and S2 (Speculative Weight): 30 September 1998 to 31 December 2008 . . . . .	122
3.6	Event Study: Cumulative Abnormal Returns and Extreme Risk Reversal	127
3.7	Event Study: Cumulative Abnormal Returns and Extreme Speculative Positions . . . . .	131
4.1	IMF Exchange Rate Arrangements and Monetary Policy Frameworks 1994 - 2010 . . . . .	148
4.2	Descriptive Statistics of Sample One Month Carry Trade against the US dollar . . . . .	153
4.3	Descriptive Statistics of Sample One Month Carry Trade against the Euro	155
4.4	Influences on the carry trade funded by US dollars . . . . .	157
4.5	Influences on the carry trade funded by the Euro . . . . .	158
4.6	Carry trade vs US dollar: A comparison of Crisis (C) and Moderation (M) modes . . . . .	161
4.7	Carry trade vs the Euro: A comparison of Crisis (C) and Moderation (M) modes . . . . .	162



# Abbreviations

<b>AMCM</b>	<b>A</b> daptive <b>M</b> insky <b>C</b> redit <b>M</b> odel
<b>ARA</b>	<b>A</b> bsolute <b>R</b> isk <b>A</b> version
<b>CAPM</b>	<b>C</b> apital <b>A</b> sset <b>P</b> ricing <b>M</b> odel
<b>CARA</b>	<b>C</b> umulative <b>A</b> bnormal <b>R</b> eturns <b>A</b> fter event
<b>CARW</b>	<b>C</b> umulative <b>A</b> bnormal <b>R</b> eturns <b>W</b> hole window
<b>CDO</b>	<b>C</b> ollateralised <b>D</b> ebt <b>O</b> bligation
<b>CDS</b>	<b>C</b> redit <b>D</b> efault <b>S</b> wap
<b>CEE</b>	<b>C</b> entral and <b>E</b> astern <b>E</b> urope
<b>CFTC</b>	<b>C</b> ommodity <b>F</b> utures <b>T</b> rading <b>C</b> ommission
<b>CIS</b>	<b>C</b> ommonwealth of <b>I</b> ndependent <b>S</b> tates
<b>CNB</b>	<b>C</b> umulative <b>N</b> et <b>B</b> onds
<b>CNE</b>	<b>C</b> umulative <b>N</b> et <b>E</b> quity
<b>CNFDI</b>	<b>C</b> umulative <b>N</b> et <b>F</b> DI
<b>CRSP</b>	<b>C</b> entre for <b>R</b> esearch into <b>S</b> ecurities <b>P</b> rices
<b>CoT</b>	<b>C</b> ommitment of <b>T</b> raders
<b>DSGE</b>	<b>D</b> ynamic <b>S</b> tochastic <b>G</b> eneral <b>E</b> quilibrium model
<b>EMH</b>	<b>E</b> fficient <b>M</b> arket <b>H</b> ypothesis
<b>ETF</b>	<b>E</b> xchange <b>T</b> raded <b>F</b> unds
<b>FDI</b>	<b>F</b> oreign <b>D</b> irect <b>I</b> nternational
<b>FIH</b>	<b>F</b> inancial <b>I</b> nstability <b>H</b> ypothesis
<b>IRF</b>	<b>I</b> mpulse <b>R</b> esponse <b>F</b> unction
<b>IMF</b>	<b>I</b> nternational <b>M</b> onetary <b>F</b> und
<b>MPM</b>	<b>M</b> is- <b>P</b> erception <b>M</b> odel
<b>OTC</b>	<b>O</b> ver <b>T</b> he <b>C</b> ounter
<b>RBC</b>	<b>R</b> eal <b>B</b> usiness <b>C</b> ycle

<b>RRA</b>	<b>R</b> elative <b>R</b> isk <b>A</b> version
<b>RTWI</b>	<b>R</b> eal <b>T</b> rade <b>W</b> eighted <b>I</b> ndex
<b>RWM</b>	<b>R</b> andom <b>W</b> eight <b>M</b> odel
<b>UIP</b>	<b>U</b> ncovered <b>I</b> nterest <b>P</b> arity
<b>VaR</b>	<b>V</b> alue at <b>R</b> isk
<b>VAR</b>	<b>V</b> ector <b>A</b> uto <b>R</b> egression
<b>VNM</b>	<b>V</b> on <b>N</b> eumann <b>M</b> orgenstern



*For Suzie, Isobel and George.*



# Chapter 1

## Introduction

### 1.1 Speculation

Speculation can denote engagement in a risky business transaction or it can be synonymous with gambling; it can be associated with entrepreneurship or it can be a term of abuse; in economic thinking there is similar ambiguity about the concept. Though speculation plays an important part in economic activity, its understanding has been a peripheral, specialist and limited pursuit that has been restricted to explaining entrepreneurship, booms and busts and market bubbles. Standard macroeconomic *Dynamic Stochastic General Equilibrium* (DSGE) models that dominate academic and official economics of central banks and finance ministries do not have a role for speculation as they are populated by agents with representative endowments, preferences and information. If information changes, economic actors refine their behaviour so that there is an adjustment to a new equilibrium that is consistent with the news. Financial markets, where heterogeneous agents exchange financial assets and money, have a limited role in these models outside of the fairly functional intermediation of savings and the transfer resources across generations. There is no place for speculation.

In standard microeconomic analysis information is freely available, equally distributed and markets shift from one equilibrium to another. Comparative-static analysis does not usually give much attention to the process that facilitates this change. However, the adjustment may not be smooth and, as Keynes noted, excessive focus on the long run and aggregate behaviour runs the risk of ignoring the very interesting “tempestuous seasons” that can blow up between periods of calm (Keynes, 1923, p. 80 ). In microeconomics, these informational assumptions can be relaxed to good effect to show, for example, how information is the key to smooth functioning of markets (Akerlof, 1970) or how economic agents can make signals that convey their inside knowledge (Spence, 1973). Speculative

activity is currently most widely studied in the context of financial markets, where it is a more prominent phenomenon and where a heterogeneity of agents and beliefs is required to justify exchange. However, even here there is no consensus. Within the literature on financial markets, speculation may take many different forms: it may be regarded as the action of traders who make use of noise rather than information; it may denote those who follow trends in the execution of momentum strategies; it may be regarded as the action of fully informed investors taking advantage of fundamental or specialist knowledge about market inefficiencies. Understanding more about the nature of speculation is the aim of this study. There are three specific questions: does speculation have effects outside the short-run, do extreme speculative positions convey information, what is the nature of the economic returns that speculators achieve?

## 1.2 Political economy and speculative activity

The financial crisis that was felt most intensely in the period between 2007 and 2009 has reminded economists that Keynes' "tempestuous seasons" cannot be ignored even during a period of extended moderation and that a fuller understanding of the heterogeneity of agents, the effect of speculative booms and busts and the way that the financial system can affect the broader economy is nearly always important. Indeed, one of the key themes of this doctorate is that calm conditions in the economy, particularly in the financial sector, will allow attention to be distracted from the build up of speculative pressures that make the economic system vulnerable to financial shocks. Currently, the speculative excesses have subsided as economic agents, including financial institutions and economists, have become fully aware of the imbalances that can be caused by speculative pressure. Therefore, vigilance is high when it is probably least important.<sup>1</sup>

This thesis uses the foreign exchange market to examine short-term market activity as it seeks to understand more about the role of speculation in raising risk and vulnerability in the economy. The foreign exchange market is the focus because it is considered to be close to a perfectly competitive market and widely believed to suffer from an abundance of speculative activity. For example, the BIS triennial survey of activity in

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<sup>1</sup>Amongst the examples of the increased attention that is being paid by macroeconomics to the working of the financial system are the following: *The Financial Cycle and Macroeconomics: What have we learnt?* from the BIS, which calls for finance to be brought back into macroeconomic analysis (Corio, 2012); an analysis of the role of collateral in the *leverage cycle* (Geanakoplos, 2010); the University of Columbia hosted a conference in February 2011 on heterogeneous agents and economic stability - <http://econ.columbia.edu/conference-heterogeneous-expectations-and-economic-stability>; the LSE ran a conference titled *Reconstructing Macroeconomics* where one of the key themes was the need to articulate the financial system in the ISLM and DSGE models. In addition, the economists that were always more interested in the economic storms, tribulations and upsets have been given more prominence. For example, Professors Fontana and Brancaccio bring together a number of criticisms of pre-crisis thinking (Brancaccio and Fontana, 2011).

the foreign exchange market shows that in April and June of 2010 the average **daily** volume in the international foreign exchange market was \$4.0trn, of which \$1.5trn were spot transactions. While the dealer-orientated system of price discovery means that \$518mn (or 35%) of this spot activity is probably part of the market-making process, this still leaves \$755mn (or 51%) of average daily trading activity between banks and other financial institutions and \$217mn (15%) average daily activity between banks and non-financial customers (BIS, 2010). It could also be argued that the market-making system, where dealers *pass-the-parcel of orders* amongst each other, like a hot potato, to furnish price discovery, adds to the speculative nature of the market where information is at a premium. Lyons and Evans provide explanation and analysis of the microstructure of foreign exchange (Lyons, 2006) and (Evans and Lyons, 2002).

Milton Friedman used the foreign exchange market as an example of ideal markets.

“Because money imparts general purchasing power and is used for such a wide variety of purchases abroad as well as at home, the demand for and supply of any one country’s currency is widely spread and comes from many sources. In consequence, broad, active and near perfect markets have developed in foreign exchange, wherever they have been permitted - and usually even when they have not been”<sup>2</sup>

(Friedman, 1953, p. 162).

The abundance of liquidity that is achieved in the foreign exchange market is an important contributor to the level of speculative activity as it allows financial institutions like hedge funds to take large positions with large orders with minimum of *price slippage*<sup>3</sup> while the low transaction costs associated with high levels of liquidity are important for individual speculators willing to make lots of small bets that would be overwhelmed by large trading costs.<sup>4</sup>

The nature of the foreign exchange market provided the initial focus of the *Tobin Tax* to curb speculative activity. At the time of the breakdown of the Bretton Woods system

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<sup>2</sup>On this latter point note the *non-deliverable forward* (NDF) market that has developed outside China for the forward settlement of renminbi in non-domestic currency and the unofficial exchanges in Iran and Pakistan (Fung et al., 2004).

<sup>3</sup>*Price slippage* is the tendency for prices to adjust when larger orders are being made as market-makers respond to larger than usual orders by widening the dealing spread or where limit orders more distant from the bid-ask are required for the transaction to be completed. Each of these cases will increase the cost of trading, raising the threshold that must be overcome to find profitable, speculative investment opportunities. This makes other, less liquid markets less attractive for speculation.

<sup>4</sup>An analysis of the bid-ask spreads for USD-JPY, GBP-USD and EUR-USD for the period January 2001 to 2005 and finds that the average spread for each is 0.342%, 0.305% and 0.326% respectively. This would be the cost for a round-trip (buying and selling immediately)(Chelley-Steeley and Tsorakidis, 2013).

of fixed exchange rates, amidst concern about the effect of speculation on price stability, Tobin proposed a tax on foreign exchange transactions.<sup>5</sup> Tobin built on Keynes' observation that the reason that speculation appeared to be less prominent in London than in New York could be due to the transfer tax that was payable in the UK (Keynes, 1936, pp. 159 - 160). Others have subsequently proposed to extend this sort of tax on financial activity to other markets, such as that of government bonds in the euro area, where speculation is believed to have become excessive.

The arguments for and against this sort of tax depend on the answers to many of the questions that will be addressed in this work. If speculation is an activity that can be treated as *an externality* that has consequences that are not taken into account, such as increasing the volatility of markets, a tax can apply a cost to the activity so that these consequences are considered by economic agents; if speculation is believed to be a non-productive activity, there will be little concern if the tax leads to a reduction in its supply. Shiller has presented evidence that stock prices are much more volatile than the underlying information that they are supposed to reflect, arguing that this suggests that speculation increases volatility (Shiller, 1981). Roll argues that just one third of the change in stock prices is a function of news (Roll, 1984) while there are similar findings by Cutler, Porterba and Summers using the residuals from a Vector Autoregression (VAR) to account for news (Cutler et al., 1986). However, Gray reports on a natural experiment where onion futures trading was banned in the US from 1958 and shows greater volatility in price before and after there was a flourishing futures market than in the period when speculation was allowed (Gray, 1963). Therefore, if speculation is seen as part of the process of *price discovery* that facilitates the absorption of information into price and has a role in creating liquidity in markets by providing willing buyers and sellers, then a reduction of speculation through taxation may not be costless and could even result in the unintended consequence of increasing volatility. There is debate about the relative merit of a financial transaction tax relative to regulation (Masciandaro and Passarelli, 2013) and a rather mixed picture of empirical evidence (Pomeranets, 2012).

### 1.2.1 Findings

The main findings of this study are that that speculation has real effects, even in the medium-term. The addition of measures of speculative activity to a model of capital flows and the real exchange rate adds explanatory power and impulse response functions show that speculative activity can have a more significant influence on the level of the real exchange rate than flows of equity, bond or foreign direct investment. However, speculation is not just noise. Event studies reveal that there is little informational

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<sup>5</sup>This was first raised at the 1972 Janeway Lectures at Princeton.

content to the build up of speculative positions, whether measured by intensity of opinion or weight of speculative activity. As such, the timing of any reversal of speculative activity is very difficult to predict, complicating the work of economic modelling and policy makers.

The risk that speculation assumes and creates is unconventional. Analysis of one particular form of foreign exchange speculation, carry trade, reveals that though the return to speculation may sometimes be considered as resulting from monopolistic use of information, as an *excess return* or the *alpha* of the Capital Asset Pricing Model (CAPM), these returns are more likely to be compensation for taking *crash risk*. Crash risk is the asymmetric, fat-tailed and unpredictable risk that is generated by speculation which makes those parts of the economy that are subject to increased speculative pressure, most notably banking and financial markets, more vulnerable to shocks and reversals. In the extreme, it seems that excessive speculation can create economy-wide crash risk that increases the likelihood of macroeconomic shocks. These shocks are usually of financial nature and often severe.<sup>6</sup> It appears that speculators not only receives compensation for assuming crash risk from other economic agents, but that speculation tends to increase the amount of crash risk in the economy.

For economic modelling, the findings suggest that specification of the financial sector should be based on the principles of fat-tailed and asymmetric, stochastic financial shocks that become more powerful and disruptive the longer the period of calm that has proceeded the reversal. The extremes occur much more often than would be expected from a normal probability distribution and the negative shocks are more extreme, because of a more intense feedback mechanism, than the positive shocks, which build more gradually. However, the timing of these shocks is very difficult to identify. Research here indicates that it is not just a function of speculative activity (though that does appear to increase the size of any subsequent reversal - as would be expected). For the economy as a whole, these findings suggest that measures to limit speculation have economic advantages that would be associated with increased macroeconomic stability and greater ability of the economy to absorb shocks. However, these benefits are most likely to be apparent when economic conditions have been stable for a while, and when confidence and speculation are high and memories of shocks are distant. It is important to be vigilant when it seems to be least necessary.

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<sup>6</sup>Reinhart and Rogoff make a systematic assessment of financial crises across sixty-six countries and eight centuries. They find that the most severe shocks are those that are fueled by speculative credit expansion which fundamentally undermine the banking system and other parts of the financial sector (Reinhart and Rogoff, 2009).

### 1.2.2 Minsky: The financial instability hypothesis

The standard macroeconomic model is part of the general equilibrium synthesis of neo-classical and Keynesian macroeconomic models that aim to bridge the span between macroeconomic aggregation and the optimisation and incentives of microeconomics. Broadly, the prime examples are the DSGE and Real Business Cycle (RBC) models that put the focus on long-term trends and the way that shocks affect fluctuations around those trends. The fluctuations in the DSGE model are caused by the stickiness of price adjustment. These models cannot easily explain financial shocks. For a review of the development and use of DSGE models (Tovar, 2008) and for an explanation of the use of DSGE models by the European Central Bank (Smets and Wouters, 2002), and for more on the RBC approach (Kydland and Prescott, 1982).<sup>7</sup> These models predict a business cycle fluctuating around an overall growth trend, constrained by imperfectly elastic labour and credit supply. By contrast, the macroeconomic model implied by Hyman Minsky is one where excess can develop spontaneously and where crisis is an endogenous feature (Minsky, 1975, 1986, 1992). Minsky argued that the economic system was much less stable than these standard models would imply and asserted that credit-fueled expansions could facilitate explosive growth that would become destabilising. Indeed, Minsky argued that while the economy may frequently experience modest cycles around an overall expansion, it was the stable nature of these economic conditions that sowed the seeds of future imbalances, crises and economic depression: liabilities tended to increase relative to the income available to service those liabilities; the proportion of assets with stable prices to total assets fell. Minsky called this “the evolution of an initially robust financial structure into a fragile structure” (Minsky, 1995, p. 85). The increase in debt relative to income initially fueled and extended the expansion in economic activity but ultimately meant that any shock to the economy ran a greater risk of being transmitted into an amplified and cumulative debt-deflation.

In the FIH Minsky brought an analysis of incentives and innovations in the financial services industry back into the heart of the macroeconomic model. For Minsky, finance is not just on the sidelines smoothly facilitating financial transactions without friction or incident. This focus on the financial system and the way that financial incentives and innovation can affect the broader economy is clearly important in the aftermath of a financial shock that has been at least partly the result of new instruments like

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<sup>7</sup>Recent developments in DSGE models suggest that some adjustments can be made to allow the financial sector to have more of an influence of cyclical behaviour. For example, a Bernanke-Geltner-Gilchrist type financial accelerator can be added (Christiano et al., 2013) and Bayesian techniques can be used to allow for time-varying parameters or regime switching which could be developed to model periods of calm and times of financial stress (Primiceri, 2005). The RBC models are less likely to be successfully modified to understand the short-ruin influence of the financial sector. The only way that they can current post-crisis rise in unemployment is by asserting that it must be a function of increased household preference for leisure. In many ways, it could be argued, this is a tool for a different task.



Collateralised Debt Obligations (CDOs), Credit Default Swaps (CDS) and evolution of *Shadow Banking* in a fashion which changed the way that credit has been intermediated, allowing some economic, institutional and regulatory constraints on credit expansion to be overcome.<sup>8</sup>

At the heart of the FIH is the categorisation of income-debt relationships into hedge, speculative and Ponzi finance. Hedge finance means that liabilities can easily be met by income. The larger the share of equity in financing, the more hedge financing is taking place and the more stable are economic arrangements. Speculative financing means that, though liabilities can be met with available current income, there is no repayment of principal. Liabilities have to be *rolled-over*, increasing vulnerability. In Ponzi finance, income is no longer sufficient to make either the repayments of principal or the interest. Asset sales or new debt must be used to meet obligations. There is a dependency on rising asset values. The Ponzi era tends to be short and explosive. It is hard to predict when it will end.<sup>9</sup>

Once the economy has embarked on an explosive, speculative Ponzi path, it is a matter of time before the bubble bursts and things swiftly reverse. It is unsustainable. Fisher had already coined the phrase *debt deflation* to characterise the downward spiral of asset sales, falling prices, bankruptcy and depression that followed the crash from a speculative build-up of debt. This was his analysis of the 1930s post-Wall Street Crash that had driven the US economy into prolonged economic weakness. Fisher identified nine factors in the deflationary spiral: over-indebtedness; collapse in the volume of currency (as the money supply shrank with the repayment of debt); a falling price level; a decline in net worth; declining profits; falling production, trade and employment; the replacement of optimism with pessimism; the hoarding of cash and the slowing of velocity of circulation; and the constraint on monetary accommodation imposed by the inability of the nominal rate of interest to fall below zero (Fisher, 1932, 1933).

### 1.2.3 Expected utility theory

A large part of the analysis of speculation will involve some discussion of expectations. It therefore seems important to consider *expected utility theory* or the standard method of

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<sup>8</sup>For an early, technical overview of these credit instruments (Lopez, 2001) and (Brandon and Fernandez, 2005). There are many more post-crisis papers that analyse the market, including (Menge, 2007), (Instefjord, 2005) and (Heyde and Neyer, 2010). See (Chick, 1997) for an analysis of the institutional changes in the financial system that have contributed to the increase in fragility.

<sup>9</sup>Paul McCulley of Pimco Asset Management has coined the phrase *Minsky Moment* as the point at which the financial bubble bursts (McCulley, 2009). This has some popularity though it appears that the term was never used by Minsky himself. Indeed, like many bubbles (see Section 1.3.1.2 for further discussion of rational bubbles) it is often very difficult to identify the catalyst for a bursting bubble. When financial frailty has reached a point where things are ready to collapse, it may be something extremely innocuous that can tip the balance towards a reverse cascade.

dealing with *rational decision-making* in economics. This is a benchmark against which much of the following analysis will be located. This is a rather mechanical method of understanding how economic agents make choices about events for which there is some uncertainty. The outline stems from the work of Von Neumann and Morgenstern (Von Neumann and Morgenstern, 1944). They propose a utility function that relates the utility that is derived from particular events to the probability that these events occur.<sup>10</sup> They assert that, given four axioms of *rationality*, an economic agent can be said to have a utility function that is composed of the expected utility so that different prospects can be compared.

$$E[U] = p(A)u(A) + p(B)u(B) \quad (1.1)$$

where E is the expectations operator and U is the utility derived and  $p(A)$  and  $p(B)$  are the probabilities of event A and B respectively.

The proposed axioms are: *completeness*, such that there should be preference for one prospect or indifference between prospects; *transitivity*, such that if A is preferred to B and B preferred to C, A must be preferred to C; *continuity* so that if A is preferred to B and B to C as above, there is a combination of A and C that will be equal to B; *Independence* of options so that if A is preferred to B it remains preferred even when a third element C is added.

This utility function need not be linear so that risk aversion can be accommodated such that a certain prospect may be preferred to an uncertain prospect that has equal or greater expected value. The term *certainty equivalence* identifies the (lower) certain value that would provide utility that is equal to the expected utility of the uncertain prospect for a non-risk-loving person. For example, a person may prefer 100 pounds with certainty to a lottery that has a 50% chance of 90 pounds or 50% chance of 130 pounds, giving an expected return of  $0.5 \times 90 + 0.5 \times 130 = 110$  pounds. In this case, the economic agent would be willing to give up 10 pounds, as the difference between the expected value of the lottery and the certain outcome, in order to avoid the risk of losing 10 pounds by ending up with 90 pounds after the lottery. In utility-wealth space, the *Von Neumann-Morgenstern utility function* (VNM) will be concave to the origin.

It is common to identify two measures of risk aversion. *Arrow-Pratt Absolute Risk Aversion* (ARA) can be identified as

$$ARA(w) = -\frac{u''(w)}{u'(w)} \quad (1.2)$$

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<sup>10</sup>The terms *prospects* or *lotteries* are usually used for these uncertain events.

and *Relative Risk Aversion* (RRA) is

$$RRA(w) = -\frac{wu''(w)}{u'(w)} \quad (1.3)$$

(Arrow, 1965) and (Pratt, 1964).

There are also refinements that developed due to the advance of computing power and the use of *Bayesian decision-making* that seek to understand decision-making according to *Bayes' Theory*. A *prior* probability estimate is updated to a *posterior* by weighing evidence as it arrives. This is a *subjectivist* view of probability that seeks to improve and refine estimates of probability as opposed to the standard view, outlined above, that is based on objective probabilities that are out in the world waiting to be discovered. Using standard probability,

$$p(A, B) = p(A|B)p(B) \quad (1.4)$$

in words, the *joint probability* of A and B is equal to the *conditional probability* of A given B multiplied by the unconditional probability of B. Also,

$$p(A, B) = p(B|A)p(A) \quad (1.5)$$

and equating Equation 1.4 with Equation 1.5 and rearranging gives *Bayes' Rule*.

$$p(A|B) = \frac{p(B|A)p(A)}{p(B)} \quad (1.6)$$

If A is the event that to assess and B is the new evidence that has arrived,  $p(B)$  can be ignored because it does not affect A and Equation 1.6 becomes

$$p(A|B) \propto p(B|A)p(A) \quad (1.7)$$

$p(A)$  is the prior probability estimate,  $p(B|A)$  is the likelihood function or the probability that this evidence would be seen given the prior belief about A and  $p(A|B)$  is the posterior probability that is *proportional to* the likelihood  $p(B|A)$  and updated in light of the evidence received (Koop, 2003, pp. 1-3).

This method of understanding decision-making, though widely used, partly due to its simplicity and mathematical tractability, is widely criticised as being too mechanical and rigid and being clearly at odds with the way that people really make decisions.

#### 1.2.4 Speculation and uncertainty

A key element of the assessment that Keynes made of the macroeconomic effects of speculation involved an exploration of the difference between risk and uncertainty (Keynes, 1936). This distinction had already been identified by Frank Knight. Indeed, the term *Knightian uncertainty* is used to resolve doubts about the future into 'risks' that can be quantified in some way and 'uncertainty' that cannot (Knight, 1921). In contrast to the precision that flows from expected utility theory, Keynes asserted that investment decision would contain many elements that would be uncertain. Rather than having precise estimates of probabilities and outcomes, there would be large areas where knowledge would be "vague and scanty" (Keynes, 1936, p. 148). Business leaders would look for other ways of making decisions and would seek short-cuts to help to make predictions about the future. As a result, Keynes argues, when making investment decisions, expectations about the future are likely to be formed by placing a disproportionate weight on current conditions, where there is less uncertainty, and these present conditions will tend to be projected into the future unless there is some good reason to anticipate that things will change.

As a consequence of this alternative analysis of decision-making, Keynes asserted that there would be a tendency for investors to be myopic speculators rather than people concerned with long-run, fundamental value. The shortening of investment horizons would be a consequence of the difficulty that investors have with determining fundamental value when information is scarce and the future uncertain in the Knightian sense of being beyond any reasonable means of quantification. Keynes also noted the social and institutional constraints that would reduce the incentive to invest on the basis of views about the long-term. Amongst these constraints are the high and increasing proportion of speculators in the public investment markets, the irrationality of some market activity (such as the seasonal pattern of stock prices), and, most particularly, the presence of herd behaviour that is influenced by sentiment, hearsay or fashion.

With investment behaviour dominated by speculation about short-term price movements and changes in sentiment, Keynes thought that investment would tend to become dominated by the focus on what other investors were thinking and how they were going to act rather than the effort to estimate long-term value.

“They are concerned, not with what an investment is really worth to a man who buys it for keeps, but with what the market will value it at, under the influence of mass psychology, three months or a year hence. Moreover, this behaviour is not the outcome of a wrong-headed propensity. It is an inevitable result of an investment market organised along the lines described. For it is not sensible to pay 25 for an investment of which you believe the prospective yield to justify a value of 30, if you also believe that the market will value it at 20 three months hence.”

(Keynes, 1936, pp. 154-155)

In *The Treaties on Probability* Keynes tried to quantify uncertainty by looking at the “weight of evidence” or the confidence with which it is possible to make estimates about the future (Keynes, 1921, p. 77). From a standard probability estimate, Keynes suggests multiplying the probability by  $1/(1+q)$ , where  $q$  is a measure of risk aversion and multiplying by  $2w/(1+w)$ , where  $w$  measures uncertainty, to deal with risk aversion and uncertainty in the probability estimate respectively. In *The General Theory* Keynes seems to be a little more cautious about the ability of economic agents to estimate probabilities to make decisions. This is a controversial area. However, the differences between the two may have been overstated. In *Treaties* Keynes argues that some probabilities will not be quantifiable and precise decision-making may be impossible, either because the inability to quantify is intrinsic or due to a lack of available information (Keynes, 1921, p. 341). Therefore, when addressing the receding nineteenth century hope that ‘moral sciences’ could be solved with “mathematic reasoning”, Keynes argues “Mathematical reasoning now appears as an aid in its symbolic rather than its numerical character” (Keynes, 1921, p. 349). Suggesting that even in this later work mathematical understanding of uncertainty could be useful even if it was not precise. Brady argues that there is no major difference between Keynes’s view in *Treaties* and *The General Theory* (Brady, 1993) while Heering asserts that Keynes’s version of *subjectivistic view of probability* is of a standard two-dimensional form that combines a probability estimate with some sort of confidence with which the estimate is made (Heering, 1996). The two modifications to expected outcomes based on probabilities are presented in *The General Theory* in Chapter fifteen when speaking about the *risk premium* and Chapter seventeen when talking about the *liquidity premium*. As in *Treaties*, the risk premium relates to the issue of risk aversion while the liquidity premium relates to the uncertainty that can change perception.

“The owners of wealth will then weigh the lack of ‘liquidity’ of different capital equipments . . . as a medium in which to hold wealth against the

best available actuarial estimate of their prospective yields after allowing for risk. The liquidity-premium, it will be observed, is partly similar to the risk-premium, but partly different; - the difference corresponding to the difference between the best estimate we can make of probabilities and the confidence with which we make them.”

(Keynes, 1936, p. 240)

There is a distinction between uncertainty that is caused by the general state of knowledge and that which is a consequence of the amount of knowledge that is held by the decision-maker. In the former it is impossible to be very precise about probabilities. In the latter case there is a chance that information could be acquired that would affect the decision. Keynes is clearly speaking about the second case. In this instance, it may be possible that the decision-maker can have a notion of the probabilities of different outcomes and some idea of the probability of being wrong. It may be imagined as being something that is equivalent to an imprecise probability density function. In the first case there is not much likelihood that any precision can be achieved.

Another major contributor to the debate about information and uncertainty was Shackle. Shackle was particularly interested in time and uncertainty and the process through which the economy could move from one instant picture or *comparative static* outturn to another. Shackle was sceptical about the ability of individuals to know very much about the future. Shackle argued that economic agents could *imagine* different versions of the future and could make some assessment of how likely these outcomes would be. However, precision would be lacking and this activity of imagining a range of possibilities could not, for Shackle, be in any way compared to something as precise as the mental construction of a probability density function. At best there could be some understanding of the boundaries of what was feasible, with some imagining of the best and worst possible outcomes. This is a more fluid and ephemeral view of the future where a large body of experience is required before expectations can become more accurate and where the experience of extreme and unlikely events will not be sufficient to allow rigorous quantification. As such, vague and *ad hoc* methods using intuition and sub-conscious processes would be used to form expectations. Many events, argued Shackle, would be *non-divisible* or *non-seriable* and could therefore not be subject to the equivalent of the frequentist approach to probability estimation (Shackle, 1952, p. 95).<sup>11</sup>

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<sup>11</sup>This is rather similar, but in a much more skeptical way, to the idea that uncertainty must be 'consolidated' to be comprehended that is put forward by Knight (Knight, 1921) and consistent with the notion of the 'weight of evidence' in Keynes (Keynes, 1921). These ideas are covered more fully in Section 1.3.2.

Shackle coined the term *kaleido-statics* to account for the complexity of economic phenomena and as a means of emphasising the limits of *comparative static* analysis. The term suggests constant flux and interactions with components moving at different speeds that may produce temporary patterns that can vanish when one small, relatively inconsequential component has adjusted. Therefore, it could be impressionistic *notions* that could have the greatest effect on the action of people in business rather than *objective* reality (Shackle, 1965, p. 43). Shackle argued that the use of the *ex-ante* and *ex-post* analysis of Gunnar Myrdal would have provided greater insight into the adjustment process in *The General Theory* (Myrdal, 1939) and would have been more useful than the re-use of the Marshallian equilibrium concept (Shackle, 1965, p. 49).

Shackle suggested three ways that people could deal with uncertainty: they could ignore it, work under the assumption that current thinking is an accurate assessment of the future or they could try to find out what other people believe under the assumption that others may have more information or are better able to process the information that is available (Shackle, 1965, p. 44). This implies that opinion will be held with little conviction and that there is a constant risk of violent swings from periods of calm acceptance of continuation to extremes of group-reinforcing panic or euphoria. Shackle describes the effect of expectations and the lurch from one equilibrium to another by Keynes in *The General Theory* as “A twist of the hand, a piece of ‘news’, can shatter one picture and replace it with another one” (Shackle, 1965, p. 48).

### 1.2.5 Speculation and investment

Keynes had argued that the uncertainty, which could be exacerbated by speculation, would make short-term, liquid savings vehicles relatively more attractive than long-term investments. This uncertainty would encourage the holding of non-productive liquid assets and could mean that the amount of business investment in the economy was insufficient to maintain a level of activity to ensure that all available economic resources were fully employed. This was particularly likely to be evident in a period of economic caution and uncertainty, which prevailed in the 1930s when Keynes was writing *The General Theory* and, more recently, following the crisis in the financial systems of developed nations in 2007 and 2008. An increase in precautionary savings may not be matched by an increase in business investment. Speculation, adding to uncertainty, could exacerbate the problem. Even without the risk that volatility caused by speculative activity could increase uncertainty and reduce business investment, leading to *underinvestment*, Keynes argued that “When the capital development of a country becomes the by-product of the activities of a casino, the job is likely to be ill-done” (Keynes, 1936, p. 139).

It is possible to suggest a synthesis of Minsky, Fisher, Keynes, Kalecki and Levy to create a model of business investment where a natural accelerator effect is fueled by Keynes and Shackle's views of the formation of expectations while Kalecki-Levy provide the mechanical, circular link between profits and investment, while Minsky and Fisher emphasise the asymmetry of the process that builds gradually but recoils violently. There is a connection between speculation and macroeconomic activity that can be self-reinforcing and liable to over-shooting. Amidst the debate over the relative roles of Keynes and Kalecki, Patinkin argues that for a simultaneous convergence of Keynes and Kalecki to a similar notion of effective demand (Patinkin, 1982), with a focus on the aggregate where investment determines output: Keynes from a personal experience of financial volatility; Kalecki from a family experience of the business cycle. Kalecki had a richer narrative of the investment process, distinguishing between orders, output and delivery with orders dependent on the ratio of profits and the capital stock as well as the long-term interest rate. The profit-stock ratio will increase as capital is used more intensely and, with the long-term interest rate making a more gradual adjustment to economic cycle than short rates, there is an accelerator effect. Investment output is a delayed function of investment orders and, eventually, as new capital equipment is added more rapidly than depreciation, an increase in the capital stock with a consequent reduction in the ratio of profits to capital stock. For Keynes, investment is a function of the marginal efficiency of capital and the interest rate, with the former being based on expectations about the future. These expectations can change dramatically (Keynes, 1936) and can expand and contract in a non-linear fashion in response to consequences of the multiplier (Shackle, 1965, pp. 127 - 128).

Kalecki's profits model assumes that, with minimal household savings, capitalists' consumption and government activity, there is a direct association between profits and investment: an increase in investment will raise profits. Though Levy presented a more complex and complete picture of the mechanism, the models are fundamentally the same and have equivalent implications. Investment and economic growth depend on profits (Kalecki, 1965) (Levy and Levy, 1983). In conjunction with this mechanical link between investment and profits, Minsky and Keynes add expectations that can be self-reinforcing: expectations of future profits can spur successful investment and profitability, leading to unsustainable credit-fueled booms in the case of Minsky; or in Keynes' doubts about the future can reduce investment and the economic growth that is necessary for full employment.

The concern for Kalecki and Keynes, at a time of very low levels of investment and moribund levels of economic activity, was that a revival in the economy would not take place just because there were clear opportunities for profit as expectations and general business sentiment were too depressed to allow rational calculation of financial



ventures, in the sense of the expected utility model discussed in Section 1.2.3. For Kalecki, the tendency towards monopoly would reduce the incentive for investment and profits, resulting in chronic unemployment. These concerns are apparent again today with a lack of private investment and cash hoarding on the side of private enterprise. This lack of business investment is again a key contributor to subdued levels of economic activity in developed economic nations as it is combined with additional savings from households and government as they try to repair their balance sheets. Others identify more of a Marxist dearth of profitable investment opportunities behind the weakness of investment and economic growth in developed economies (Gordon, 2012) and (Cowen, 2010). This is an updated version of the 1930s concern about capitalist investment prospects. Keynes argued that long-term investment or enterprise would depend on "animal spirits" or business sentiment, rather than direct calculation of expected utility theory. This, he argued, meant that there was a limit to what changes in interest rates could do to spur investment and economic activity. It would depend on sentiment or speculative activity which could become depressed in self-reinforcing fashion, requiring government intervention to break the circle.

There is another, more positive macroeconomic view of speculative activity which puts the emphasis on the creative element of speculation. There are hints of this in Levy where the motivation of profit can encourage investment that will fuel growth and job creation. Schumpeter appropriated Marx's term "creative destruction" to discuss the process where business and ideas are replaced. While Marx placed the emphasis on the destruction and the turbulence of capitalist development (Marx, 1867), Schumpeter was much more interested in the way that new ideas and ways of doing things would drive out the old and facilitate economic growth and improvement (Schumpeter, 1934). Indeed, there is a broad microeconomic literature that assesses the interaction between speculation and over-confidence that can encourage investment at times when risk and uncertainty are high. This branch of behavioural economics blurs the line between speculation and enterprise to argue that many investments that contribute to economic growth and general well being would not be undertaken if there were a dispassionate assessment of the probability of success and that society is well served by these activities. This is almost the opposite of the view proposed by Keynes, as now individual self-confidence will cause investment projects to be carried out when they would not be undertaken if there were a reliance on the cold, hard calculation of the sort suggested by expected utility theory.

For example, Benabou and Tirole present a model of optimism and the benefits that it can bring to investors. They identify three main elements: personal, reputational and motivational benefits of being optimistic. This is particularly important for entrepreneurs and investors where perseverance and decisive activity are likely to be

important. The Benabou-Tirole model involves a cost-benefit time inconsistency as entrepreneurs can refrain from investing in projects that appear to provide too little future benefit relative to the current cost. However, resolve, modelled as a low level at which future benefits are discounted, can ensure that a larger proportion of projects are undertaken. Of course, the entrepreneurs' judgment of their ability to successfully complete the task will have a major effect on whether the task will be undertaken and therefore more confident individuals are more likely to take the chance (Benabou and Tirole, 2002) and (Benabou and Tirole, 2004).

Empirically, Malmendier and Tate have investigated the link between the confidence of corporate managers and their level of investment, finding that those with the greatest confidence, measured by their refusal to reduce their exposure to company specific risk, invest the most and undertake more acquisitions (Malmendier and Tate, 2005). To the extent that investment success is random, it can then be argued, the more investment activity that is undertaken, the more successful investments and the greater the social welfare. Keynes acknowledges the positive role for some speculative-like activity in the economy. His *animal spirits* (Keynes, 1936, p. 161) are an intuition that can be the key to overcoming doubts caused by uncertainties about the future. See section 1.3.2 for fuller coverage of the way that speculative entrepreneurship helps to generate investment projects that are beneficial for society even when they may be disappointing individually and even on average.

### 1.3 Speculation at the micro level

While the negative effects of speculation, particularly its potential effect on credit, investment and economic volatility, tend to dominate the macroeconomic discourse, in the micro sphere there is more ambiguity. The discussion centres on the nature of speculation. There are two particular areas of interest: whether speculation is informed or uninformed; the return that speculators will receive as compensation for their activity. These questions have implications for the macroeconomic level: if speculation is informed and receives a return for providing a service, measures to curtail speculation may have negative and unintended consequences, in terms of reducing liquidity and undermining the process of price discovery. However, macroeconomic consequences are also important. If speculation distorts prices in the medium-term, there is more justification for taking regulatory action that may cause some harm to individual markets for the benefit of the greater good. Questions about the relationship between speculation and information and about the medium-term effect of speculation on prices are assessed in this work.

### 1.3.1 The informational content of speculation

Black coined the term 'noise-trader', to make the distinction between market participants who are informed and those who are uninformed and are trading on noise (Black, 1986). Keynes feared that speculative noise-traders would focus too much on guessing what others thought about short-term valuation and that this would draw other investors away from focusing on long-term valuation. In this view speculation encourages consensual thinking and leads to fickle, volatile and myopic activity.<sup>12</sup>

Milton Friedman presents a more positive view of speculators and argues that speculative noise-traders will be brushed aside by informed speculators. Friedman argues that speculation will only be destabilising if speculators are uninformed, trading on noise with a tendency to buy when prices are high and sell when prices are low. Friedman argues that, by contrast, informed speculators will take advantage of the opportunities offered by noise-traders activity to sell when prices are too high and buy when they are too low, making profits at the expense of the noise-traders so that an evolutionary *survival of the fittest* will increase the proportion of informed speculators in the market by driving the noise-traders out of business. For Friedman, speculators are informed and help to stabilise markets (Friedman, 1953).

There are a number of models which assess the interaction between noise and fundamental speculative traders. Cootner develops a system which augments the random walk of the securities price with a barrier or corridor beyond which professional speculators, who have lower costs of acquiring information than regular investors, will find sufficient profit opportunity to encourage them to step into the market to use their knowledge and to drive prices back towards equilibrium (Cootner, 1962). This is rather similar to the more modern threshold models that have been developed to explain non-linear relationships where costs may limit the scope for arbitrage within a specific region.

Keynes argued, apparently from personal experience, that while securities markets would be more efficient if there is a large proportion of investors basing their decisions on estimates of long-term value, there are a number of, largely institutional, factors that tend to suppress the number of investors that focus on long-term fundamental value, encouraging them to focus on the short-term: the difficulty and risk of fundamental analysis relative to trend following; the pressure from human nature for swift results; the excitement of gambling rather than the *boring* work of analysis; the inability to borrow to finance long-term investment due to the fear that loans will be recalled if short-term

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<sup>12</sup>There are exceptions to Keynes's hostile attitude towards speculation. In *A Tract on Monetary Reform* he cites the abnormal difference between spot and forward sterling-lira rates in February 1921 (along with a number of other cases) and the subsequent movement of the currency, as evidence that speculators make correct forecasts of future direction of exchange rates (Keynes, 1923, p. 130).

losses increase; the likelihood that, despite providing a public service by promoting market efficiency, long-term investors would have to go against public opinion and risk being considered maverick when successful and worse when unsuccessful.<sup>13</sup>

De Long, Summers, Shleifer and Waldmann present a model (to be discussed more fully in Chapter 3) where *noise-trader risk* and finite horizons can provide an impediment to fundamental arbitrage to refute Friedman's assertion and to analyse the interaction between noise and fundamental traders (De Long et al., 1990). Under certain conditions, noise-traders can make greater profits and they can drive out the fundamental traders. Grossman and Stiglitz model the interaction on the basis of a cost-benefit analysis of the speculative traders acquiring information, arguing that there will be an equilibrium balance of noise and informed traders at that point where the cost of acquiring information is equal to the benefit to be derived from the use of that information in a permanently inefficient financial market (Grossman and Stiglitz, 1980).

This divergence of opinion over the nature of speculation highlights an important area of contention over the operation of markets where Keynes and Minsky diverge from Friedman and the Austrian economist Hayek. Keynes viewed a world of uncertainty and institutional frictions where sentiment and social phenomena were important to expectations formation. The speculator tries to guess what everyone else will think and therefore speculation can exacerbate deviation from fundamental value (Keynes, 1936). Hayek emphasised the strength of the market in processing fragmented information and dealing with the problem of *local knowledge*, the unorganised, unscientific and particular rather than general uncertainty that is often found. Statistical aggregates, argues Hayek, cannot account for the total of knowledge as the differences in many cases are as important as the similarities. As such, he asserts that the complexity of many economic processes mean that they can never fully be understood.

Speculators are atomised and act on their own limited but precise knowledge. Hayek focused on the *spontaneous order* that markets could provide by aggregating disparate items of individual information. Speculation here would be partially informed but the market outcome or the product of the speculations would be fully informed (Hayek, 1945). Where Keynes argued that increased speculation amplifies divergence from intrinsic value, for Hayek increased speculation increases the informational efficiency of the market. The different view are partly the consequence of whether speculators are viewed as independent and acting on their own information or whether they start to influence each other. These extremes of speculation can be assessed more easily after some discussion of *rational expectations* and *rational bubbles*. The theory of rational

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<sup>13</sup>Skidelsky notes that in 1928 Keynes was forced by margin calls as a result of his exposure to rubber, corn, cotton and tin to sell shares and that a short time later the value of his portfolio fell from £44,000 to £7815 (Skidelsky, 1983, pp. 417-18).

expectations is a world of Friedmanite fundamental speculators with full information about the workings of the economy, ready to jump on any deviation from fundamental value; rational bubbles is a place of volatility as well as boom and bust where investors are chasing short-term profits and look to sell over-valued assets to a *greater fool*.

### 1.3.1.1 Rational expectations

Since the late 1970s, much of the economic discussion of expectations has been dominated by the *rational expectations* revolution. Muth argued that expectations should be regarded as being a consequence or outcome of the system or model that is being considered. In other words, “expectations, since they are informed predictions of future events, are essentially the same as the predictions of the relevant economic theory” (Muth, 1961, p. 316). The subjective probability distribution of expectations is the same as the objective distribution of the model. Muth shows, with a simple model of production based on expected future price, that any expectations that are inconsistent with the model mean that there is an opportunity for speculators to profit from their use of the model by inventory speculation or the sale of forecasting services (Muth, 1961, p. 316).

These are Friedman-style informed speculations. Muth shows that this model is consistent with the evolution of prices in some commodity markets. The development of the theory implies that trial-and-error and learning from mistakes ensure that economic agents will not make systematic errors. See (Fischer, 1980) (Sargent, 1986) and (Lucas, 1987) amongst others for fuller details on the role of rational expectations in economic modelling.<sup>14</sup> Once again, an understanding of the way that economic agents get to understand and know the model is interesting.

However, given what is known about actual decision-making and the interactions of participants in many markets, rational expectations must be seen as more of a modelling technique than something that can be used to understand the mechanics of adjustment. It is useful if the model wants to set aside the process of expectations formation and adjustment by providing an extreme benchmark for what happens in the world of informed speculation, but it assumes away the detail. It does not explain how or why or when speculation is likely to cause the adjustment.

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<sup>14</sup>Incidentally, Muth shows that inventory speculation is profitable and it reduces the variability of price in response to a shock. When prices are some distance from where the model suggests that they will be in future, there may be speculation. Speculation is a function of the utility derived from the moments of the probability distribution of future price.

### 1.3.1.2 Bubbles

Financial bubbles appear to be clear cases where expectations are not formed rationally. However, it is possible to have *rational bubbles* where speculators have investment horizons that are short. Under rational expectations, the price of financial assets should be

$$p_t = E_t \left[ \frac{p_{t+1} + d_{t+1}}{1 + r} \right] \quad (1.8)$$

Where the current price ( $p_t$ ) is the sum of the discounted value of the future price and the dividend ( $d_{t+1}$ ). Solve this equation forward and use the *law of iterated expectations*,

$$p_t = E_t \left[ \sum_{\tau=1}^{T-t} \frac{1}{(1+r)^\tau} d_{t+\tau} \right] + E_t \left[ \frac{1}{(1+r)^{T-t}} p_T \right] \quad (1.9)$$

This means that the price is equal to the discounted value of the expected future dividends for the period between  $t$  and  $T$  plus the expected value of the security at time  $T$ . If the security has a maturity date of  $T$ , the value at  $T + 1$  is equal to zero and the value is just the discounted future dividend stream, if the security has an infinite horizon, the price is equal to the fundamental value of the expected future dividend stream only under the *transversality condition* that  $\frac{p_t}{(1+r)^t}$  tends to zero as  $t$  approaches infinity. (Blanchard and Watson, 1982) breaks the security price into fundamental value ( $v$ ) and bubble ( $b$ ) so that  $p_t = v_t + b_t$ . Now

$$b_t = E_t \left[ \frac{1}{(1+r)} b_{t+1} \right] \quad (1.10)$$

Therefore, the bubble component  $b_t$  has to grow in expectations at a rate of  $r$ . If the bubble persists in each period with probability ( $\pi$ ) and bursts with probability ( $1 - \pi$ ), the bubble has to grow at a rate of  $(1+r)/\pi$  to survive. In theory, through the process of *backward induction* this should remove the possibility of bubbles in commodities where there are possible substitutes or securities that are not in elastic supply and should ensure that *rational bubbles* are confined to cases where the required return is less than the growth rate of the economy.

An important element of the bubble literature is that of *common knowledge*. Everyone may know that the security is over-valued but they do not know that everyone else knows: it is not common knowledge. It is possible for rational finite bubbles to exist even in a general equilibrium framework if there is no common knowledge about the initial pareto allocation (people must believe that there are gains from trade), there is

asymmetry of information that remains in place even after trade has taken place and there are some constraints on short-selling (Allen et al., 1993).

### 1.3.2 The returns to speculation

The second question about the nature of speculation concerns the return or compensation that speculators can expect to get for their activity. The standard view is that speculators receive a recompense for taking risk from those economic entities that desire to reduce the amount of risk that they hold. There is a payment made in return for risk-taking. For example, oil companies may want to reduce the risk of a decrease in oil prices and, in the absence of an airline company with whom they can agree a price for future delivery, the same agreement can be made with a speculator willing to invest or *bet* that the price will rise. Keynes and Hicks make the case that it is natural to find futures prices at a discount to the price expected at maturity and for them to generally rise towards this expected level as maturity approaches. This phenomenon, termed *normal backwardation*, they argue, is a return that speculators receive for taking risk from those that want to hedge (Keynes, 1930) and (Hicks, 1946). It is quite possible for expectations about future prices to be disappointed or surprised and for speculators to lose money in these transactions. However, in the aggregate, speculators must *expect* to make a return or they will not enter the market and provide the service of assuming risk.

While analysing the foreign exchange market Keynes says

“ the speculator with resources can provide a useful, indeed almost an essential service. Since volume of actual trade is spread unevenly through the year, the seasonal fluctuation . . . is bound to occur with undue force unless some financial, non-commercial factor steps in to balance matters. A free forward market, from which speculative transactions are not excluded, will give by far the best facilities for the trader, who does not wish to speculate, to avoid doing so.”

(Keynes, 1923, p. 135).

However, in *Risk, Uncertainty and Profit*, Knight investigates the nature of *profit* as the return that goes to enterprise or speculation, and outlines the evolution of economic understanding of profit from the belief that it is akin to a regular payment like income or rent towards the position of Keynes and Hicks where it is compensation for risk-taking. Knight is unhappy with either of these definitions as he argues that payments

for supplying labour or taking risk are things that can be pre-determined. For Knight, quantifiable risk can be insured and therefore a standard payment can be made for the service. For Knight, enterprise or speculation is a consequence of uncertainty. This is Knightian uncertainty that is immune to quantification in style of VNM expected utility theory.

Knight says that uncertainty can be addressed in one of two related ways: it can be reduced by being consolidated; or it can be transferred by being passed to a *specialist*. In each case, there is an attempt to reduce the uncertainty through aggregation. This is the same as the second type of uncertainty that was identified by Keynes in *The General Theory*: the information is available but it needs to be drawn together to be understood. The specialists are called entrepreneurs by Knight but they seem to play the role of speculators. For Knight, it is the uncertainty that is key to enterprise and the basis of the return, as profit, made to the entrepreneur. As such, Knight argues that profits come from *upset anticipations*. Specialisation of uncertainty has generated *speculation*. This is the outsourcing of holding of uncertainty. “The most important instrument in modern economic society for the specialization of uncertainty, after the institution of free enterprise itself, is speculation” (Knight, 1921, p. 255).

“ The practical difference between the two categories, risk and uncertainty, is that in the former the distribution of the outcome in a group of instances is known (either through calculation *a priori* or from statistics of past experience), while in the case of uncertainty this is not true, the reason being in general that it is impossible to form a group of instances, because the situation dealt with is in a high degree unique.”

(Knight, 1921, p. 233)

This means that there are three different levels: risk, uncertainty and something like *true uncertainty*. This is a point that has been developed by Shackle and Hayek. They argue that many decisions will be based on situations that are sufficiently unique to prevent any aggregation. In this instance, it is not likely that anything approaching a probability estimate can be made. It is close to pure uncertainty. At this point it is impossible to make any estimates and it is left to pure belief, pure confidence, maybe self-confidence, maybe over-confidence.

Knight implies that speculators will in general be unsuccessful in their pursuit of profit. There is a picture here of a group of overconfident, speculative entrepreneurs taking risks in the hope of vast wealth. Although a few are successful, most are not. We hear from the successful; those that fail are less prominent. This can make it seem as if there



is a particular skill or insight amongst those that are successful, rather than just luck. However, there is a strong chance that what is evident is *survivorship bias*.

In fact, the distinction between uncertainty and pure uncertainty is fuzzy. When are there sufficient samples to ensure that there is really a pattern? It is well known that there is a tendency to see patterns when none exists. Kahneman has called this *the law of small numbers* and details a number of experiments where even psychological experiments have been conducted with sample sizes that are too small for valid inference (Kahneman, 2012, p. 112). It is widely believed that basketball players (indeed all sports players) have runs for excellent form and periods when they slump. (Gilovich et al., 1985) looked at basketball players and found that they could not identify any statistically significant patterns to scoring patterns. In some cases there may be market inefficiencies and opportunities, in others there is just noise.

Indeed, Knight suggests that entrepreneurs as a group will tend to suffer losses as a result of their over-confidence as they bid up the price of assets and opportunities in competition with each other (Knight, 1921). This is very similar to Thaler's description of the *Winner's Curse* where a successful auction will be awarded to the highest bidder, but, assuming that the average forecast of value is most likely to be accurate, this will be most likely to be too high (Thaler, 1988). This suggests a combination of Friedmanite and noise-traders with inefficiencies, real and imagined, swiftly eliminated and the crowd action causing new divergences.

“The receipt of profit in a particular case may be argued to be the result of superior judgment. But it is judgment of judgment, especially one's own judgment, and in an individual case there is no way of telling good judgment from good luck, and a succession of cases sufficient to evaluate the judgment or determine its probable value transforms the profit into a wage.”

(Knight, 1921, p. 311)

Keynes seems to echo Knight in arguing that the outcome of uncertain investments are likely to be disappointing on average due to the fundamental inability of people to consistently forecast uncertain future events. Most speculators content themselves with trying to ascertain what will happen in the short run, but some will embark on the difficult task of enterprise to understand long-term value. Though the latter is difficult, it is essential for the efficient allocation of capital. One of the main concerns of Keynes in *the General Theory* is that expected investment returns will not be sufficient to encourage owners of firms to think about the long-term future. There may not be sufficient confidence or desire for speculative activity.

In this sense, Knight appears to be arguing that speculation is just a return to having confidence. However, the greater the number of speculators the more the pie must be shared and the greater the risk of over-bidding. Over-confidence in the realm of entrepreneurship can be socially beneficial as it may lead to more investment and an increased chance that good ideas will be put into practice. The costs are born largely by the individual in failures and are not widely apparent. However, with speculation in financial markets, the social benefits of speculative activity, such as improvements in price discovery and the provision of liquidity, may be offset by social costs of financial shocks when speculators make large, co-ordinated mistakes. The benefits of successful speculation accrue largely to the individual.

## 1.4 Outline

This work seeks to do three things. Firstly, to investigate the effect of speculation on the price of assets relative to their fundamental value. If speculation is more than short-term noise, it has potential to cause disruption and imbalance and should be addressed by policy-makers. Secondly, to assess whether speculation is based more on noise or information. If speculation is noise, it is destabilising and there will be benefits from curtailing its activity; if speculation is informed it will help to drive prices back towards their fundamental value and it is part of the process of price discovery. Finally, there is an analysis of the returns that are achieved by one form of speculative activity. If speculators receive a return for taking risk from other economic units and for providing liquidity, reducing their ability to operate can have negative consequences; if speculation increases the amount of crash risk in the economy it would be beneficial to reduce its influence.

### 1.4.1 International capital flows, speculation and the real exchange rate

Chapter 2 looks at speculation at the macroeconomic level by using a structured vector auto regression (SVAR) system to assess the relationship between capital flows and the real US exchange rate. Measures of speculative activity are added to conventional series of bond, equity and foreign direct investment to assess the factors that drive the real exchange rate away from equilibrium. The SVAR method is used to overcome the problem of endogeneity of capital flows and the real exchange rate in the absence of realistic instruments. The system is identified using naive and plausible restrictions. A number of studies of capital flow show that equities are an important contributor to

medium-term changes in the exchange rate, however, this work finds that speculation is more important and tends to dominate the effect of other capital flows, even in the medium-term. Impulse response functions show flows that are based on sentiment and momentum as well as those that respond to interest rate differentials have a significant effect on the real exchange rate out to three quarters and, therefore, speculation affects real variables outside the short run.

### **1.4.2 Informational content of speculation**

Chapter 3 tries to assess the informational content of speculation. While Keynes argued that speculation was fixated with the short run, and that it was destabilising (Keynes, 1936), Friedman has suggested that evolutionary market forces would ensure that informed speculators profit at the expense of the uninformed and that the proportion of informed to uninformed traders will increase as a consequence (Friedman, 1953). If speculative traders are uninformed, their activity will be random and will not affect prices on average. Speculation may then perform a positive role by providing liquidity. However, if traders influence each other, as Keynes avowed, their activity will not be independent and their buying and selling will tend to push prices back and forth according to changes in market mood. In the latter case, extremes of speculative activity will raise the greatest risk of price reversal as they will have caused the greatest deviation in price and this deviation will not be the result of information.

Extreme speculation is measured in two ways in this study: firstly, using a unique set of option prices for similar puts and calls as a measure of the intensity of speculative sentiment; and secondly, using a regulatory measure of speculative positions for the weight of speculation in the market. An event study method is used to assess the effect of extreme speculation on exchange rate returns. Extreme speculative sentiment and extreme weight of speculative activity do not provide information about future returns. This suggests that speculation is at least partially informed and part of the price discovery process whereby information is transferred to market price. It is likely to be the case that the initial movement of speculators is driven by information but their activity will feed on itself to create fragility. The findings here suggest that it is very difficult to identify when bubbles will burst.

### **1.4.3 The nature of speculative returns**

Chapter 4 seeks to understand more about speculative risk with a detailed analysis of uncovered interest parity (UIP) and the speculative attempt to take advantage of times when it does not hold. While a large number of studies have found that the forward

rate is a biased predictor of the future exchange rate, this study takes a sample of carry trades that borrow low-interest-rate currencies and deposit in high-interest-rate currencies to assess the nature of the returns to this speculative strategy. Though this activity provides a positive return on average, the skewness and serial correlation in the returns suggest that these returns are not an excess over the return for taking risk but a compensation for taking a particular type of risk that is associated with market crashes and extreme events. This not only solves the puzzle of the biased forward rate but also adds to the understanding of speculative risk. The serial correlation that is often evident in the sample of carry trade returns indicates that an increase in speculation will add to the trades expected return in the short run, but it will also increase the probability of crash risk by adding to the number of positions that will be unwound if there is a broad expectation that exchange rates are starting to reverse.

The carry trade appears to be a micro version of Minsky's FIH. The build up is gradual and self-fulfilling as the establishment of carry positions means that the funding currency will tend to depreciate and the investment currency will tend to appreciate. However, this process means that fragility rises as speculators push the investment currency away from its equilibrium. As is the case with the FIH, it appears that the more extended the period over which positions are built, the greater the shock when reversal does happen.

#### **1.4.4 Modelling and policy**

Therefore, speculation has real effects, speculation is partly informed and speculation gets a return for taking crash risk but also contributes to the build-up of crash risk. These are important findings and will be used in two ways: to help to improve macroeconomic modelling and to provide some suggestions for policy changes that can contribute to improved economic outcomes. Models need to make a link between speculation, credit and real values in the economy; they should incorporate positive feedback in credit expansion and real activity; and, there should be a stochastic break that varies in intensity in proportion to the time that has been covered since the last shock. Policy makers need to be most vigilant when economic conditions are calm and should maintain a particular attention to the rate of credit expansion as the nature of financial fragility is likely to evolve with time and in response to regulations that are designed specifically to contain it.

## Chapter 2

# International Capital Flows and Speculation

### 2.1 Introduction

Standard DSGE models can be opened up to the world to assess trade and exchange rates. However, the nature of the model means that the main focus is the disturbance from equilibrium and the path back to stability. These disturbances are stochastic and not the main part of the analysis.<sup>1</sup> One way to gain an understanding of the dynamics behind the disturbances to equilibrium is to leave the current account and to analyse the effect of capital flows on the real exchange rate. The *FIH* suggests that there will be significant and real macroeconomic effects from speculation. The aim of this chapter is to understand more about the role of speculation on the real exchange rate and to see how far the addition of measures of speculative activity can add to the explanatory power of capital flow models of the exchange rate. It is found that the addition of measures of speculative activity have real effects on the exchange rate and that these effects dominate those of net equity, bond and foreign direct investment, suggesting that speculation in the foreign exchange market is even more powerful and important than previously thought.

Standard monetary and portfolio balance models of foreign exchange have been augmented with non-linear relationships and incorporate recent developments in the modelling of expectations as well as a deeper analysis of the nature of the distribution of asset price returns (see Chapters 3 and 4 for some examples of these techniques). However, while the medium-to long-term direction of exchange rates can sometimes be projected

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<sup>1</sup>For an overview of the open economy models (Obstfeld and Rogoff, 1995) for a full treatment of the conventional DSGE models (Woodford, 2003) and (Obstfeld and Rogoff, 1996).

with some confidence, short-term foreign exchange forecasting has been much less successful. In the first decade of the twenty first century, the US dollar has defied a widening current account deficit which would, on a range of conventional theories, be expected to cause a large depreciation. Large capital inflows, drawn by a buoyant economy and then by the apparent safety and liquidity of US assets, are usually cited as reasons for the resilience of the US unit. However, the empirical support for this assertion remains fragile.

This chapter seeks to get a fuller understanding of exchange rate dynamics by building a system to examine the interplay of exchange rates and capital flows. A range of sources are used to construct series to measure the flow of international capital. Vector Autoregression (VAR) is employed to deal with the issue of endogeneity with plausible and naive restrictions identifying the effect that shocks to a variety of different forms of capital flow have on the real exchange rate. Understanding more about the relationship between capital flows and real exchange rate is important in a world where these financial account activities are becoming increasingly significant and where persistent current account imbalances have been seen to have major global consequences<sup>2</sup> as well as more usual effects of real exchange rate misalignment can have on domestic economies<sup>3</sup>. This paper takes the US as its focus for three reasons: there is a large amount of public data available about the international sale and purchase of US financial assets which can help to overcome the paucity of information that has been something of a constraint on testing of comprehensive capital flow models; the US represents a most significant example of the divergence between conventional theory and the evolution of exchange rates; the US is at the heart of the global imbalance story.

The main findings of the research are that capital flows associated with relative interest rates and speculative sentiment have significant effects on the level of the real exchange rate. Net equity flows also appear to be positively related to the real exchange rate but the picture with net foreign direct investment and net bond flows is more ambiguous. When bond flows are divided into those conducted by official organisations (like central banks) and others, the former have the expected positive effect, because they reflect

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<sup>2</sup>There is a strand of thought that sees the global imbalance as one of the main causes of the recent financial crisis. This view argues that the US current account deficit required a balancing inflow of capital to the US and that this capital flow either reduced long-term interest rates or removed a portion of safe assets from the market, as central banks bought safe and liquid treasuries. The first of these reduced US long-term interest rates, combining with the Fed's easy policy to make house purchase more attractive. The second encouraged the creation of synthetic 'safe' assets like the most credit-worthy tranches of CDOs and other financial innovations which increase the amount of credit in the US economy (Eichengreen and Park, 2006), (Obstfeld and Rogoff, 2009), (Portes, 2009) and others.

<sup>3</sup>From Keynes' *Economic Consequences of Mr. Churchill* (Keynes, 1925) through to current debate about competitiveness in the euro area, the level of the real exchange rate has been widely regarded as an important determinant of domestic economic conditions. For a discussion of the issues that would determine the appropriate level for CEE and CIS countries to join the Euro (Hölscher and Jarmuek, 2005).

central bank foreign exchange intervention, while the latter do not seem to be influential. The rest of this chapter proceeds as follows: section two reviews the literature; section three discusses methodological issues; section four presents the results; section five concludes.

## 2.2 Literature review

There are two broad strands to the way that exchange rates are to be understood: a focus on real goods and services and the current account, and a focus on capital flows and the financial account.<sup>4</sup> The former is based on the law of one price with the theory of purchasing power parity implying that exchange rates will adjust to ensure that price levels in different currencies will be broadly similar. The latter seeks to understand the international flows of capital, usually by looking at international investors response to relative rates of return of different assets in different currencies.

### 2.2.1 Purchasing power parity

Gustav Cassel is credited with the first use of the term *purchasing power parity* as the “quotient between the purchasing power of money in one country and the other” (Cassel, 1916, p.298).

The average price of a basket of home goods and services is represented by  $P$ , those of another country by  $P^*$ , with the \* superscript used throughout to represent overseas variables, and the exchange rate expressed as domestic currency per unit of overseas as  $S$ , if arbitrage is possible, the law of one price implies that price level of the domestic basket should be the same as the overseas basket.

$$P^*S = P \tag{2.1}$$

or, using lower case to denote logarithms and re-arranging,

$$s = \ln(S) = \ln P - \ln P^* = p - p^* \tag{2.2}$$

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<sup>4</sup>Throughout this work, the term ‘financial account’ will refer to the mirror of the current account of the balance of payments recording the main portfolio or real investment flows that take place between the home countries and the rest of the world. This is consistent with the terminology used by the International Monetary Fund (IMF, 2001, ch.2 p. 9). The term ‘capital account’, which is used for these activities in some places, is here reserved for valuation adjustments to holding of international assets and will not play a significant part in the story.

Therefore, under PPP, the exchange rate should adjust to ensure that if prices in one country change, there is a potential arbitrage that will tend to bring them back into line. The adjustment may come through the price via the effect of changes in demand at home and abroad or it may come through the exchange rate, if that is allowed to fluctuate, due to demand for currency used to satisfy purchase of relatively cheap products and services. This may be called *absolute PPP* while a less strict version of *relative PPP* would imply that changes in relative price level or two countries will tend to equalise.

$$\Delta S = \frac{\Delta P}{\Delta P^*} \quad (2.3)$$

The real exchange rate ( $Z$ ) is then the relative price of a representative basket of goods and services when domestic prices have been converted into a common unit.

$$Z = \frac{SP^*}{P} \quad (2.4a)$$

so, in logs

$$z = s + P^* - p \quad (2.4b)$$

where  $z$  is the real exchange rate. Given two countries, an appreciation of the real exchange rate for the home country (a decrease in  $Z$ ) means that its relative money prices have risen compared to the overseas country. The theory of PPP says that the real exchange rate should be stable or that it should return to a long-run level. Therefore the test of the theory of PPP is that the real exchange rate is stable, mean-reverting or stationary.<sup>5</sup>

### 2.2.2 Uncovered interest parity

The forward rate is the rate that is set now for an exchange of currencies in the future. Covered Interest Parity (CIP) asserts that, given the free flow of international capital and competitive markets, the difference between the spot rate and the forward rate

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<sup>5</sup>A stationary series is one that has, amongst other things, an arithmetic mean that is stable over time. Therefore, statistical tests of stationarity, such as unit root tests, have been used to test the PPP proposition. These tests have been less conclusive than would be anticipated. For more details about the issues associated with the statistical power of the tests of stationarity and the methods that have been used to try to overcome them (Taylor, 2003). One of these is the apparent positive relationship between the real exchange rate and the level of economic development or GDP per capita. The Harod-Belassa-Samuelson theory is discussed more fully in Section 2.2.4



must be equal to the interest rate differential for the two currencies for the same period. Otherwise, there is an arbitrage opportunity that will encourage parity to be restored.

$$\frac{F_{t,j}}{S_t} \times (1 + i_{t,j}^*) = (1 + i_{t,j}) \quad (2.5)$$

where  $F_{t,j}$  is the forward exchange rate at time  $t$  for domestic currency in terms of overseas for  $j$  periods ahead;  $S_t$  is spot exchange rate under the same terms at time  $t$ ;  $i_{t,j}$  is the interest rate for the home currency in period  $t$  for  $j$  periods ahead;  $i_{t,j}^*$  is the interest rate for the overseas currency at time  $t$  for  $j$  periods ahead.

Therefore,

$$\frac{F_{t,j}}{S_t} = \frac{(1 + i_{t,j})}{(1 + i_{t,j}^*)} \quad (2.6)$$

Re-arranging

$$\frac{F_{t,j} - S_t}{S_t} = \frac{(i_{t,j} - i_{t,j}^*)}{(1 + i_{t,j}^*)} \quad (2.7)$$

If it is assumed that expectations are formed rationally (see Section 1.3.1 on speculation, information and expectations for a fuller discussion of rational expectations and Section 1.2.3 below for an assessment of what happens when this assumption is relaxed), the forward rate should be the best, unbiased estimate of the future spot rate and therefore, Equation 2.7 becomes.

$$\frac{E[S_{t+j}] - S_t}{S_t} = \frac{(i_{t,j} - i_{t,j}^*)}{(1 + i_{t,j}^*)} \quad (2.8)$$

if  $i^*$  is relatively small, this can be approximated by

$$E[s_{t+j}] - s_t = i_{t,j} - i_{t,j}^* \quad (2.9)$$

where  $s_t$  is the log of the exchange rate at time  $t$ ,  $s_{t+j}$  is the log of the exchange rate at  $t$  plus  $j$ ,  $i_{t,j}$  is the  $j$ -period interest rate at time  $t$  and  $i_{t,j}^*$  is the the foreign currency  $j$ -period interest rate at time  $t$ .

Assuming that CIP holds so that the forward rate can account for the interest rate differential, a test of UIP can take the form of

$$\Delta s_{t+j} = \beta_0 + \beta_1 f_{t+j} + \varepsilon \quad (2.10)$$

where  $\Delta s_{t+j}$  is the change in the log of the exchange rate between period  $t$  and  $j$ ,  $f_{t+j}$  is the forward premium expressed as the difference between the logs of the spot rate and the forward rate for period  $j$ ;  $\varepsilon$  is an error term that is assumed to be an independent and identically distributed random variable with a mean of zero, while  $\beta_0$  and  $\beta_1$  are the coefficients to be estimated. If UIP holds,  $\beta_0$  should be equal to zero and  $\beta_1$  should be equal to unity as the forward rate should be an unbiased estimate of the future exchange rate. There may be frequent errors in the estimate (represented by  $\varepsilon$ ), but these should on average be zero.

However, this standard test of UIP consistently finds that estimates of  $\beta_1$  are less than one. A meta-study by Froot and Thaler found that the average of 75 published estimates had an average value of -0.88 for  $\beta_1$  (Froot, 1990). This is sometimes called the *forward premium puzzle*. Hodrick gives a thorough overview of the evidence on unbiasedness (Hodrick, 1988).

### 2.2.3 Monetary approaches

To get a fuller understanding of the relationship between the exchange rate and other parts of the economy, economists have sought to augment the theory of PPP by adding theories for money and expectations. Given the *quantity theory of money*, which states that, assuming stable money demand and exogenous money supply, the price level is function of the quantity of money, thus PPP is determined by the growth of relative money supplies. Expectations can start to play a role as relatively high money growth can create an instant anticipation that the exchange rate will adjust with a depreciation as relatively high money growth leads to an anticipated increase in relative prices, even if prices are sticky and adjustment takes some time. Therefore, there are two broad monetary models: the flexible price and sticky price models. The first of these will assume that PPP always holds. See, for example (Frenkel, 1976), (Mussa, 1976) and (Bilson, 1978). Here, the nominal exchange rate ( $s$ ) is a function of relative prices, as in Equation 2.2, while the price level is determined by conditions in the money market at home

$$m - p = \alpha y + \beta i \quad (2.11)$$

and abroad, assuming that domestic and overseas money demand functions equivalent.

$$m^* - p^* = \alpha y^* + \beta i^* \quad (2.12)$$

Everything is in logs;  $m$  is the stock of money,  $p$  is the price level,  $y$  is national income and  $i$  is the nominal interest rate or, more appropriately,  $m$ ,  $p$  and  $y$  are deviations from their long-run growth path,  $\alpha$  and  $\beta$  are parameters to be estimated for the income elasticity of money demand and the price elasticity of money demand measured by the interest rate opportunity cost. Plugging these Equations (2.11) and (2.12) into the exchange rate Equation (2.2) gives

$$s = (m - m^*) - \alpha(y - y^*) - \beta(i - i^*) \quad (2.13)$$

To the extent that relatively high money growth is not a function of an increase in relative money demand (as a consequence of a change in income or the opportunity cost of money), there is an effect on the exchange rate via price levels and the law of one price.

However, prices do not instantly adjust to changes in the stock of money. With flexible exchange rates it is clear that there is a gap between the swift adjustment of exchange rates in the asset market and the more gradual adjustment of goods prices. Therefore, the sticky price model of exchange rates is more widely known and more defensible against the empirical evidence of sluggish adjustment of prices to economic shocks (including monetary shocks). This model also allows some integration of the two strands of exchange rate analysis as what is happening in the goods markets is combined with what is happening in the asset market. One of the pioneering examples of the sticky price approach is the Dornbusch Overshooting model (Dornbusch, 1976).

The key to this model is the gap between the gradual adjustment of prices in the goods market and the more rapid change for asset market prices. PPP does not always hold as there are short-run deviations as relative prices adjust to the relative growth of money stocks. The model is augmented with uncovered interest parity (UIP) condition to make a connection to the asset markets.

$$E[\Delta s_{t+1} | \Omega_t] = \beta(i - i^*) \quad (2.14)$$

Where  $E$  is the expectations operator,  $\Delta s_{t+1}$  is the change in the exchange rate between  $t$  and  $t + 1$  and  $\Omega_t$  is the information set available at time  $t$ . Then, given the level of prices and the interest rate differential, there is a long-run level for the exchange rate and a current spot rate that matches the interest rate differential.

$$s = (m - m^*) - \alpha(y - y^*) - E[\Delta s_{t+1} | \Omega_t] \quad (2.15)$$

A permanent increase in nominal quantity of money will lead to an instant adjustment of the exchange rate which is a reflection of the long-run change in the relative price level and the short-run change in relative interest rates. There is over-shooting here because for any given price level, the exchange rate adjusts instantly to clear the asset market. In the case of a monetary expansion that will eventually lead to higher prices and a fall in the nominal exchange rate, there is overshooting of the exchange rate to maintain equilibrium in the asset market as money growth will also reduce the domestic interest rate relative to other countries and this requires an appreciation of the nominal exchange rate to compensate for the income loss, as demanded by the model's assumption of UIP. While the overshooting model helped to explain the volatility of floating exchange rates and is consistent with the evidence of a positive relationship between interest rates and the exchange rate, the implication that overshooting would be followed by a gradual adjustment back to the appropriate PPP level does not appear to be supported (see Chapter 4 Section 4.2 for a fuller discussion of this, including speculative attempts to take advantage of this failure).

#### 2.2.4 Harrod-Balassa-Samuelson

PPP occupies a central position in international economics and has acquired a number of extensions in the face of some discomfiting empirical evidence (Taylor, 2003). Real exchange rates are stationary in many cases but there are also times when there appear to be deterministic trends (Froot and Rogoff, 1995). Tests on the stationarity of the real rate is very sensitive to the period studied and the existence of financial crises (Zhou and Kutan, 2011). For an overview of empirical evidence (Taylor and Taylor, 2004). The law of one price may hold for commodities which are traded and exchanged around the world. However, while the price of some traded goods may be very similar in different countries, transaction costs, taxation or other frictions or barriers for many products and services very often start to drive a wedge between prices in different countries. Though Krugman finds that PPP generally holds in the long-run despite significant short-run deviations, there is a tendency for the real exchange rate to appreciate with economic development (Krugman, 1978).

Harrod outlined the main ideas of what has come to be known as *Harrod-Balassa-Samuelson Effect* in some of the early editions of his *International Economics* textbook (Harrod, 1933). Balassa identified the evidence of a positive relationship between the per capita income levels and the real exchange rate with the explanation that productivity

gains were mostly concentrated in the traded goods sector and that wage competition between traded and non-traded sectors would push up the relative price of non-tradables with development. He supported this assertion with information about the productivity levels in different sectors of the economy of major nations and the relationship between the ratio of the GNP deflator to manufacturing wholesale prices to manufacturing per capita output (Balassa, 1964).

This is the international outcome of *Baumol's Effect* (Baumol and Bowen, 1966) whereby the wages of those sectors of the economy that do not achieve productivity increases rise in some proportion to those sectors that do so as to maintain some equilibrium in the two sectors. Baumol used the example of musicians playing a string quartet as an industry where productivity has not increased but where wages have risen in line with others in the economy. De Gregorio conducted an analysis of sectoral price data for OECD countries in the period 1970 to 1985 and found that inflation in non-tradables exceeded that of tradables. The investigation also found that a combination of a demand shift towards non-tradables and a faster pace of productivity growth in the traded goods sector were the main cause of this phenomenon (De Gregorio et al., 1994).

Samuelson argues that the frequent and prolonged deviations from purchasing power parity that are seen are a result of the wide spectrum of goods where unit labour requirements can differ in different countries (Samuelson, 1964). Using the \* for overseas variables,  $a_i$  for the unit labour requirement for good  $i$  (as Samuelson did), ( $w$ ) for money wages and ( $s$ ) for the exchange rate measured as the foreign price of domestic currency, it is possible to project two extremes between which the economy would move from a position of competitive advantage for all goods to a competitive disadvantage for all goods.

$$\text{Min} \frac{a_i}{a_i^*} \leq \frac{w}{sw^*} \leq \text{Max} \frac{a_i}{a_i^*} \quad (2.16)$$

Productivity differentials ( $a_i/a_i^*$ ) define the boundaries for wage costs once they are translated into a common currency. For example, if the most extreme productivity differentials are 1/5 this means that the exchange rate adjusted wage differential cannot go above 1/5 before all goods are uncompetitive; if 8/1 is the maximum productivity extreme, the barrier is 8/1 before all goods are competitive for the home country. Within this range, for a given exchange rate, there is a borderline product where cost of production at home or abroad will be very similar, such that

$$s = \frac{w}{w^*} \frac{a_i}{a_i^*} \quad (2.17)$$

The exchange rate can fluctuate between the two extremes and there will be a trade surplus or trade deficit depending on what part of the productivity spectrum the exchange rate occupies at one particular time.

$$\frac{w}{w^*} \text{Min} \left[ \frac{a_i}{a_i^*} \right] \leq s \leq \frac{w}{w^*} \text{Max} \left[ \frac{a_i}{a_i^*} \right] \quad (2.18)$$

The price of most goods and services will not be in equilibrium and the borderline good will change over time in response to changes in productivity, preferences and demand - as well as the exchange rate. Therefore, the relative price of most goods in two countries will be different and the real exchange rate can fluctuate substantially over time. This is before capital flows are allowed to have some effect. Samuelson states that “once we leave barter equilibrium aside and admit capital movements and gold flows into the picture, the sky becomes the limit” for the real exchange rate (Samuelson, 1964, p. 146).

### 2.2.5 The PPP adjustment process

It should be no surprise, therefore, that the real exchange rate can fluctuate substantially. Even when there is a return to a mean PPP value, it appears that this can take a considerable amount of time. It has been common to assess the adjustment by measuring the so-called half-life of the deviation process. This is the time that the exchange rate takes to return half way to PPP level after a shock (see (Frankel, 1986) and (Frankel and Froot, 1987)). In the most well known investigation of the speed at which the real exchange rate returns to parity after a shock, Rogoff found that it would take an average three to five years for the real exchange rate to move half-way back to its original position after a shock (Rogoff, 1996). This leaves a wide window where factors other than relative price can have a major influence on exchange rates.

There are many historic examples where a significant deviation from PPP has been sustained for a considerable period. In the Samuelson formulation, if there is one commodity for which there is comparative advantage, there can be others which become uncompetitive. This deviation can be the result of having an endowment of one or more important commodities, goods or even services. The *Dutch Disease*,<sup>6</sup> where the real

<sup>6</sup>The Dutch Disease is the term coined by *The Economist* for the experience of the Netherlands in the 1960s where discovery of large natural gas fields led to an increase in the trade surplus and some inflow of capital with a consequent appreciation of the real exchange rate to the point where the rest of the Dutch manufacturing sector became uncompetitive. It is partly this experience which led the Norwegian government to create the Strategic Petroleum fund to hold receipts from Norwegian international crude oil sales in foreign currency to prevent real appreciation of the Norwegian Crown. For a more formal overview of the Dutch Disease see (Corden and Neary, 1982). Bruno and Sachs present a model of “perfect foresight, intertemporal equilibrium” that is used to analyse the effect that the discovery of north sea oil has on the UK economy (Bruno and Sachs, 1982, p. 846).

exchange rate and wage rates are elevated to a point where much of the output of an economy is internationally uncompetitive, is an extreme example of this. Though the appreciation of the real exchange rate in the Netherlands in the 1970s is the most usual example of this, the idea can also be more widely applied to cases like the UK where the presence of an international financial centre cause real exchange rate appreciation or the US where the production of safe and liquid international assets may also have the same effect. In each case, there is evidence of this demand for assets having a substantial effect on capital flows that can lead a to sustained and significant effect on the real exchange rate.

### 2.2.6 International capital markets

As a consequence of the rising prominence of international capital flows and as one response to the evidence of large and persistent deviations from PPP, there has been increased attention paid to the role of capital flows in determining changes in the exchange rates. To assess capital flows it is necessary to go back to the balance of payments and look at the relationship between trade and finance. The standard model of international accounting defines the current account of the balance of payments as

$$CA_t = B_{t+1} - B_t = Y_t + r_t B_t - C_t - G_t - I_t \quad (2.19)$$

(Obstfeld and Rogoff, 1996, p. 15) where  $B_{t+1}$  is the value of net foreign assets at the end of the current period,  $Y_t$  is current income,  $G_t$  is government spending in the current period,  $I_t$  is domestic gross fixed capital formation and  $CA_t = B_{t+1} - B_t$  is the balance of payments, stating that the current account must be financed or, in other words, offset by an equal change in the financial account. The return earned on the net foreign assets held in the previous period is  $r_t B_t$ , with  $r_t$  as the weighted average return on international assets. If national savings is defined as national income less spending of households and the government, and denoted as  $S_t$ <sup>7</sup>

$$S_t \equiv Y_t + r_t B_{t+1} - C_t - G_t \quad (2.20)$$

Equation (2.19) becomes

$$CA_t = S_t - I_t \quad (2.21)$$

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<sup>7</sup>This is a little confusing given that  $S_t$  has already been used to denote the nominal exchange rate. However, given the convention in this area and in the absence of any clear, logical alternative, it will be followed for the next few paragraphs.

or the current account balance is equal to the difference between domestic savings and investment. Therefore, in the absence of a government, the accumulation of net foreign assets will be equal to domestic savings less investment,

$$B_{t+1} - B_t = S_t - I_t \quad (2.22)$$

and the determination of the current and financial account becomes an issue of intertemporal allocation of spending.

To use this simple model of the balance of payments to assess more than one country and the exchange rate, the variables for an overseas country can be denoted with a superscript asterisk (\*) as usual. Therefore,  $Y^*$  would be other-country income,  $S^*$  would be other-country savings and  $C^*$  denotes other country consumption. Using the identity for income and output and allowing the two countries to trade goods and assets, would mean that

$$Y_t + Y_t^* = (C_t + C_t^*) + (G_t + G_t^*) + (I_t + I_t^*) \quad (2.23)$$

The standard forward-looking representative agent used in these models would seek to smooth consumption over time and would therefore adjust savings and consumption to maximise utility in each period given expectations about future income and evolving preferences.<sup>8</sup> Given the assumptions of this model, an increase in productivity and expected future income should lead to a current account deficit as the representative household takes advantage of a rise in the present value of future income. The rundown in net foreign assets is compensated by the increased net present value of future income. Obstfeld and Rogoff present a model of permanent balance of payment components based on an annuity value at the current interest rate to give a *fundamental equation for the current account* (Obstfeld and Rogoff, 1996, p. 74). Sachs provides one of the first of these long-run, dynamic, intertemporal models of current account (and therefore financial account) adjustment (Sachs, 1982).

$$CA_t = B_{t+1} - B_t = (Y_t - \bar{Y}) + (I_t - \bar{I}) - (G_t - \bar{G}) \quad (2.24)$$

where  $\bar{Y}$ ,  $\bar{I}$  and  $\bar{G}$  are the *permanent* levels of income, investment and government spending respectively based on discounting expected future values back to the present.

<sup>8</sup>This smoothing can take place in a closed economy only if agents have heterogeneous endowments, preferences or expectations. The idea is the same here, but the heterogeneity is across countries.



For a constant interest rate, the permanent level of each component at time  $t$  is given by

$$E[\bar{Y}] = \frac{r}{1+r} \sum_{t=s}^{t=\infty} \left( \frac{1}{1+r} \right)^{s-t} Y_s \quad (2.25)$$

This is an annuity of the component at the set interest rate. This can be solved as infinite-period version of the standard two-period utility optimisation subject to budget constraints.<sup>9</sup> This implies that current account imbalances are the result of changes in expected long-run levels of income, investment or government spending and the rate of interest or preferences. The model suggests that if the capital accumulation required for economic development cannot be satisfied by domestic savings, the imbalance of savings and investment require a current account deficit or a financial account surplus and a run-down of net foreign assets, balanced by an increase in expected future income.

When the other parts of the conventional new-Keynesian macroeconomic model are added, this is the basis for the open economy dynamic stochastic general equilibrium model. Again, see (Obstfeld and Rogoff, 1995) for a comprehensive overview of the main features of the model and (Lane, 2001) for a survey of the different varieties of open-economy DSGE model.

However, as is the case with the more general criticism of DSGE models, when the model is opened up to the rest of the world (and called an open-economy dynamic general equilibrium model), equilibrium is assumed and the main focus therefore is to assess the way back to the equilibrium once a shock has created a disturbance. The, perhaps more interesting, cause of the shocks or the immediate consequences of the shocks are largely ignored. For the exchange rate, the anchor is the path of relative money growth and relative consumption demand at home and abroad. As a result of a money, preference or productivity shock, the exchange rate jumps immediately to the new trajectory that is consistent with equilibrium, prices may adjust in a sticky fashion, but there is no scope for deviations from the short-run path back to equilibrium. As indicated in the footnotes, Obstfeld and Rogoff “are assuming away speculative exchange rate bubbles” (Obstfeld and Rogoff, 1995, p 640). In addition, the models usually assume that representative households are risk averse and fully diversified, leaving no unsystematic risk. To get to an analysis of the short-term capital flows that can affect the

<sup>9</sup>As such, this is a version of Friedman’s *permanent income theory* (Friedman, 1957). In the simple case where the representative agent’s time preference (denoted  $\beta$ ) is  $1/(1+r)$ , there is no government (G) or business activity (I) and output is exogenous and set a constant level  $\bar{Y}$ , the optimal consumption will be  $C = \bar{C} = rB + Y$ . As simplifying assumptions are relaxed, the calculation becomes more complex, but the basic idea remains the same: any change in expectations about future output, spending or interest rates results in an adjustment of inter-temporal consumption through the current account and, therefore, the financial account (Obstfeld and Rogoff, 1996, pp. 59-89).

exchange rate outside of the equilibrium, it is necessary to make the models increasingly complex<sup>10</sup> or to break away from general equilibrium to focus on individual parts of the economy. To understand how international demand for assets can drive exchange rates general equilibrium, representative agents and long-run expectations about income and productivity must be abandoned. To examine the relationship between short-term capital flows and the exchange rate it is necessary to put capital flows back to the centre of the analysis.

### 2.2.7 Portfolio flows

To focus exchange rate models on capital flows is not entirely new. Portfolio balance models have been around since at least the 1970s. Amongst those that have contributed to this research are (Kouri and Porter, 1974) (Kouri, 1977), and (Branson and Henderson, 1985).

Portfolio balance models can look at either stocks of international assets or the flow of funds into international assets. The major problem that the early versions of these models encountered was the lack of data against which they could be evaluated. Information about the flow of capital has traditionally been very difficult to collect. As a result the early models tended to simplify capital flows. The first of the models would only include international bonds  $B$  as being representative of broader asset markets and the supply of bonds was frequently measured as the accumulation of government debt. This is a two country model.

$$B_f = \beta W_d \quad (2.26)$$

Where  $B_d$  are domestic bonds and  $B_f$  are foreign bonds as denoted by the sub-script.  $\beta$  is the share of domestic wealth (denoted  $W_d$ ) that is allocated to overseas bonds. For these models, it is assumed that the share of  $B_f$  would be determined by rates of return, relative interest rates and expected changes in the exchange rate (Kouri and Porter, 1974). Indeed, this can be seen as a portfolio optimisation problem where the share of international assets in a portfolio is determined by adjusting the expected return for the expected amount of risk. The demand equations for domestic and foreign bonds become.

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<sup>10</sup>See (Devereux and Sutherland, 2011) for an example of an attempt to apply portfolio optimisation to the international financial economics. The big difficulty is that optimisation weights have to be constructed but, in turn, portfolio weights will determine the return on international assets. Devereux and Sutherland find a complex solution to this as one way of understanding international asset allocation. However, it is not clear that this method would be able to deal with short-run disturbances and exchange rate shocks.

$$B_d = [a_d + b(i - i^* - \Delta s^e)]W_d \quad (2.27)$$

$$B_f = [a_f + b(i - i^* - \Delta s^e)]W_f \quad (2.28)$$

Where  $a_d$  is the autonomous demand for domestic bonds and  $a_f$  is the autonomous demand for foreign bonds,  $i$  is the domestic interest rate,  $i^*$  is the overseas interest rate,  $\Delta s^e$  is the expected change in the exchange rate, defined as overseas units of domestic currency,  $b$  is the interest elasticity of capital flows. The equations can be amalgamated to get an equation for world wealth.

$$B = a_d W_d + a_f W_f + b(i - i^* - \Delta s^e)W \quad (2.29)$$

Re-arrange for the risk premium

$$i + i^* - \Delta s^e = \frac{1}{b} \left( \frac{B}{W} \right) - \frac{a_d}{b} \left( \frac{W_d}{W} \right) - \frac{a_f}{b} \left( \frac{W_f}{W} \right) \quad (2.30)$$

An increase in the share of domestic assets relative to the world assets  $\left( \frac{W_d}{W} \right)$  will require an increase in autonomous demand for assets from domestic sources ( $a_d$ ) or an increase in relative interest rates ( $i + i^*$ ) or an expected appreciation of the domestic currency ( $\Delta s^e$ ). This can be used as an exchange rate model if interest rates are anchored with uncovered interest parity (UIP) and the purchasing-power-parity link to money growth is added to tie down long-run exchange rate expectations. The exchange rate adjusts to bring the supply and demand for international assets into balance. There are two strands to this adjustment: expected changes in the value of the exchange rate affect expected asset returns; the exchange rate affects the balance of payments via the trade balance and this causes an offsetting adjustment in the financial account.

The most basic form of this model, which is restricted to the bond market and relies only on the return to bonds, is based on three demand equations: for money ( $M$ ), domestic bonds ( $B$ ) and foreign bonds ( $B^*$ ) respectively. Demand is determined by the domestic interest rate ( $i$ ) and the expected change in the exchange rate ( $E[\Delta s_{t+1} | \Omega_t]$ ). The subscript shows the sign of the relationship.

$$M = \left( i, \quad E[\Delta s_{t+1} | \Omega_t] \right) \quad (2.31)$$

$$B = (i_+, E[\Delta s_{t+1} | \Omega_t]) \quad (2.32)$$

$$B^* = (i_-, E[\Delta s_{t+1} | \Omega_t]) \quad (2.33)$$

Therefore, demand for money is a negative function of the domestic interest rate and a positive function of exchange rate expectations; demand for domestic bonds is positively associated with domestic interest rates and with exchange rate expectations; foreign bond demand is negatively affected by domestic interest rates and expectations about the domestic exchange rate. There are two additional constraints to complete the model. All wealth ( $W$ ) must be allocated to these assets,

$$W = M + B + B^* \quad (2.34)$$

and the balance of payments must balance so the financial account must equal the current account. Therefore the holdings of foreign bonds must be equal to the trade balance ( $TB$ ) and the interest received on holdings of foreign bonds ( $i^*B^*$ ). An increased return (often called a risk premium) is required to encourage domestic and overseas investors to hold more assets.

$$\Delta B^* = TB + i^*B^* \quad (2.35)$$

This ties the investment side to the real economy and trade because a trade deficit may be financed by surplus on the financial account, but the increase in the net overseas debt will tend to increase the risk to foreign investors of holding domestic debt and they will require an increased risk premium to compensate for that. (Kouri and Porter, 1974) focus on cumulative bonds for four international markets (Australia, Italy, the Netherlands and Germany) and show that their restricted portfolio balance model can explain much of the international bond market flow in the period between the first quarter of 1960 and the final quarter of 1970.

### 2.2.8 Measuring capital flow

A turn in attention back to portfolio balance models has been encouraged by the increased availability of data. This has allowed new models to be tested against the

empirical evidence. Key international organisations have sought to improve the information that is being provided about international capital flows. This includes the IMF, the World Bank and the BIS (*Coordinated Portfolio Investment Survey*, 2012), (*World Bank Quarterly External Debt Statistics*, 2012) and (*BIS Statistics*, 2012). A number of economists have sought to use existing information to create data series that can be used to analyse the key components of international capital. Amongst these are (Lane and Milesi-Ferretti, 2007) as well as (Chris Kubelec, 2010).

Therefore, after a period when these capital flow models disappeared from view, attention has turned again to the flows associated with the re-balancing of international asset portfolios. For example, Hau and Rey develop a model where the relationship between exchange rates, stock prices and capital flows are assessed and tested against a data set that records the transaction of US global mutual funds. They find that higher returns in the home equity market relative to the foreign equity market are associated with domestic currency depreciation, like an equity market version of UIP, while net equity flows into a foreign equity market are associated with a foreign currency appreciation (Hau and Rey, 2006). As mentioned before, other attempts have sought to mix open economy models with optimisation of country portfolios (Devereux and Sutherland, 2011). This is a very complex system that seeks to balance the problems of simultaneously defining the optimal allocation of assets with the expected returns that are a consequence of that optimisation. However, the model cannot break away from the DSGE system and remains a model of deviations from the steady state.

Siourounis constructs a model of international capital flows. A vector autoregression (VAR) model is used with monthly capital flows, equity return and interest rate data. The net position between the US and the UK, Germany and Switzerland is recorded for the period between January 1988 and December 2000. Incorporating net equity flows to a standard exchange rate model is shown to improve the out of sample forecasting ability while the use of net bond flows does not make any substantial improvement; improvement in relative equity returns encourages capital inflow and exchange rate appreciation while an increase in relative interest rates is more likely to be offset by currency depreciation (Siourounis, 2004). The minimal influence that net bond flows have on the exchange rate is explained by the propensity to hedge bond positions. A survey of 200 bond funds finds that more than 90% of international bond buying is hedged compared to just less than 12% for equities (Siourounis, 2004, p. 3).

While there have been positive developments in the modelling of exchange rates with capital flows, there remains only a limited understanding of the short-run adjustment process. This is where a fuller focus on speculation and its effect may be useful. None

of the models presented so far makes any attempt to consider the role of speculative activity.

### 2.2.9 Microstructure

There is also a literature on exchange rates from the field of microstructure which puts the emphasis on the way that the market institutions and market processes can affect the evolution of asset prices. For example, (Evans and Lyons, 2002) and (Lyons, 1995) give an overview of the microstructure approach to exchange rates. The approach combines microstructure techniques that have been developed in the area of equity markets (O'Hara, 1998) with the unique features of the dealer-orientated foreign exchange market to use order flow to enhance exchange rate models. Lyons and Evans use a unique dataset that records deals undertaken by foreign exchange market-makers (or dealers). The data show active or *signed* deals as well as passive deals. Signed deals are the ones that initiate the transaction. It is the party that makes the call that ends in a transaction. Information about signed foreign exchange orders are added to regular macroeconomic variables to create the following model

$$\Delta s_t = f(i, m, z, ) + g(X, I, Z) + \epsilon_t \quad (2.36)$$

where  $\Delta s_t$  is the change in the nominal exchange rate,  $f(i, m, z, )$  are the macro components of the model and  $g(X, I, Z)$  are the order-flow components. For example,  $i$  is the vector of interest rates,  $m$  is the vector of money and  $z$  contains any other variables that are going to be used, such as trade balance;  $X$  is order flow and  $I$  is dealer inventory with  $Z$  for other factors that may affect dealer activity. Inventory is important. It can be assumed that foreign exchange dealers choose an inventory of foreign currency with which they are comfortable, similar to a portfolio allocation. It is assumed that the dealers will maintain this inventory unless there is some specific information that encourages them to make a change. Transactions that these dealers undertake to fulfil customer orders are passive in nature, in the sense that they are acting as a market-maker and responding to customer initiative. However, these orders will change the composition of the dealer inventory. It is assumed that the dealers will then take action to bring their inventory back to the previous position. This is most likely to be achieved by the dealer initiating an active order of their own. Therefore, the active dealer order is a response to a customer order or a deliberate decision to change their own inventory that is presumably the result of new information.

Evans and Lyons use 3 months of orders from the Reuters dealing system to identify *signed orders*. Though each transaction has a buy order and a sell order, signed orders are those orders that can be identified as orders that initiate a transaction. These are active rather than passive orders. In other words, if one dealer contacts another dealer and sells currency, that is a *signed* sell order. There is a positive decision to sell. The other side of the transaction is the passive, enabling buy order. These orders are included in a model with relative interest rate differentials to explain between 50% and 60% of the change in the Dollar-Mark and Dollar-Yen in the period between May 1st to August 31st 1996 (Evans and Lyons, 2002).

At first glance, this seems to show no more than increased demand raises price, a trivial finding. However, while in most macroeconomic theories there is no role for orders, in practice orders are important as they provide a summation of a wide range of diverse information. Lyons and Evans suggest that order flows have substantial information content about valuation and risk premia. Dealer orders are also a summation of orders from financial and non-financial customers of the foreign exchange dealers. As such, the orders reflect information about the expectations and forecasts of final investors or *real money*. Therefore the order flow will contain information about expectations concerning a wide range of economic features that may affect the exchange rate including the future trade balance and future portfolio flows as well as the risk appetite and other preferences of these institutions. From the microstructure perspective, order flow is capturing something that is complex and time-varying that would be extremely difficult to model in a more formal fashion.

There are a number of links between the microstructure approach and the analysis of capital flows. Order flow is not the same as demand. Lyons finds that orders from financial institutions are more important and have a greater price impact than that of orders from other institutions. This, it is suggested, is because the orders from financial institutions are more likely to contain information; they are deliberate and considered actions. The orders that come from other institutions may be more likely to be passive, liquidity-driven and passively responding to changes that are taking place elsewhere (Lyons, 1995, p.188). One of the aims of the current study is to establish whether different varieties of capital flow have varying effects on the real exchange rate.

## 2.3 Methodology

There are two main methodological issues that affect the development of exchange rate models. Firstly, as the exchange rate is at the heart of the economy, it is difficult to narrow down the number of variables that should be used in the model to something that is manageable. This chapter will address this by focusing on supply and demand and by following an approach that is similar to the microstructure method of using orders to amalgamate information that may explain price changes. The variables in the model will be orders associated with the balance of payments - most notably, the current account and key capital flows. Secondly, the estimation of exchange rate models is plagued by endogeneity: there is two-way causality. Most of the variables that affect the exchange rate are likely to be affected by changes in the exchange rate themselves. This means that standard methods of estimating relationships between variables are unreliable and some other methods must be used to deal with this. A vector auto regression (VAR) will be used to address this problem.

### 2.3.1 The exchange rate

The aim is to understand fluctuations in the real exchange rate. Therefore data on the real trade-weighted exchange rate are taken from the Federal Reserve. There are a number of indices offered by the US central bank. The broad trade-weighted index that includes only major countries, adjusted for relative prices, is used in this study. According to PPP, this series should be stable or should at least return to an average level. The aim is to get a fuller understanding of the fluctuations in the real exchange rates; what causes divergence from PPP. The quarterly average of the daily values of the real and nominal indices are utilised. See (Lorentan, 2005) for an overview of the composition and calculation of the US Federal Reserves Exchange Rate Indices. The nominal exchange rate is also studied for an understanding of the relationship between the two series and the differences in the way that they may be affected by capital flows.

Details of the weights of currencies in the Fed's broad trade-weighted index are given in Table 2.1. The main thing to note is that there has been some reduction in the trade share of most of the major countries. However, this is not surprising given the rise of the emerging nations. For example, China's share in world trade has increased from 7.88% in the year 2000 to 19.76% in 2012 and Brazil has gained from 1.68% to 2.07%. Nonetheless, given that this paper is focused mostly on capital flows it seems to be better to look at the effect of the US dollar against more significant financial centres, which are more likely to be the source of large investment flows. One problem that may arise is that while China will be a significant contributor to the increase in Official Treasury



TABLE 2.1: Major Currency TWI weights

Economy	2003	1997	Change
Euro area	34.28	30.00	4.28
Canada	29.96	28.99	0.97
Japan	19.29	24.45	-5.16
UK	9.43	9.82	-0.39
Switzerland	2.63	2.45	0.18
Australia	2.28	2.24	0.04
Sweden	2.12	2.09	0.03
Major weight	54.84	58.37	-4.43
Total	100	100	-

The percentage is the weight of each currency in the Major currency index. Major weight is the weight of the major currencies in the Broad Currency Index. The change is the percentage point change between the periods. (Lorentan, 2005).

holdings due to its intervention in the foreign exchange market to purchase US dollars to maintain the exchange rate peg (COT inflows in this model), this will not have a direct effect on the exchange rate as it is just offsetting flow that is happening elsewhere in the system. In the case of China, the increase in the net official purchase of US government and agency bonds is a mirror of the flow associated with the Chinese trade surplus. There is a similar phenomenon for many other emerging economies, particularly those that are major commodity producers.

### 2.3.2 Capital flows

Focusing on orders means that a layer of complexity has been removed. To move away from the general equilibrium approach means using a model that gives greater understanding of the factors that determine the real exchange rate. Rather than trying to understand the interplay of factors that affect financial flows, the starting point is the net demand for international assets. The factors behind this demand are left to be understood elsewhere.<sup>11</sup> This means that the number of variables to be considered can be considerably reduced. The starting point will be the Balance of Payments and its components.

<sup>11</sup>This means that another investigation can address the causes of the net international demand for different asset classes and this can feedback into the overall analysis. Therefore, if net international equity flows are seen to have a particular effect on the real exchange rate and another factor influences net equity flow, there can be a two-stage process to understand the underlying factors behind the real exchange rate. However, if this is done in gradual steps, some of the simplifications and generalising assumptions that are often made with general equilibrium models can be avoided.

The Balance of Payments balance: for each purchase of goods, services or international assets, there must be a sale. Equally, in the foreign exchange market, for each sale of US dollars, there must be a purchase. Using an extension of the microstructure approach at the macroeconomic level, this study will try to identify the part of the exchange that is active and doing the forcing and use this as the factor that conveys information. Of course, there must be an offsetting side to the transaction that will ensure that it can be completed. It is assumed that this side of the transaction is more passive, or benign or indifferent or accommodating. The application of the microstructure approach here will make the assumption that the most important, forcing transactions are those that buy and sell international assets: bonds, equity and real assets (foreign direct investment) as well as deliberate, speculative money market flows. The residual or offsetting transaction is assumed to appear in the money market or banking components of the balance of payments where foreign exchange dealer inventory will be adjusting for the initial order. This passive element will facilitate the change in the value of the exchange rate, but it is the forcing or active component that is behind the change.

Imagine an international equity fund that decides to increase its holding of US equities. The demand for US dollars that are used to purchase the equities will be the result of a deliberate action to change portfolio allocation that will ultimately be based on some fundamental views about the US economy; US profitability, US political developments or, at the very least, the US environment relative to the rest of the world. These are all components that have been left out of the model; they are all factors that are difficult to simplify into a manageable system.<sup>12</sup> The dollars sold by the bank to the fund, if they do not come from other funds' deliberate selling of US equities, bonds or making money market adjustments, will come from the bank's inventory in a passive fashion. The bank will then decide what to do with this unexpected reduction in its US dollar inventory in the same way as is described at the micro level by Lyons and Evans (Evans and Lyons, 2002), (Lyons, 1995) and (Lyons, 2006). Everything else equal, the bank will have to restore equilibrium by bidding for US dollars, increasing the price if we assume that the supply is not perfectly elastic. Therefore, the net capital flow should lead to an increase in the value of the US dollar. The initial decision taken by the fund leads to a change in the real exchange rate.

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<sup>12</sup>Even if the demand for US equities comes from a passive index fund, this can be considered a random action which can be represented by a random variable with a zero mean and constant variance. The aggregate of all these passive flows will cancel out and leave the net flow effect to be dominated by those deliberate flows that have an opinion of value and risk.

### 2.3.3 Trade flow

In addition to capital flows, there are also deliberate decisions taken to buy and sell currency for trade purposes. Importers and exporters will be major buyers and sellers. It is uncertain whether the current account should be added to the key capital flows to get a more comprehensive view of the deliberate demand for currency. If the trade flows are included in the series that are used to identify exchange rate movements, a direct connection can be made between the real and financial sectors of the economy. However, the supply and demand of currency for trade purposes is much more likely to be driven by long-term factors: contracts are set in advance and are much less likely to be swiftly adjusted than portfolio flows. It can also be argued that the trade flows may already be incorporated in the real exchange rate if it is deemed that trade flows are a function of relative price. As such the basic model will be based on the assertion that capital flows explain the deviations in the real exchange rate and that PPP holds in the long-run. However, this is a major assumption and it will be assessed by taking a look at models with the current account position and the nominal exchange rate.

The current account data are taken from the US balance of payments that are released by the Bureau of Labor Statistics. The data are not seasonally adjusted. This is to make sure that they are compatible with the flow data which are also not adjusted for seasonal influences. The data on capital flows are derived from a number of sources. The first source is the US balance of payments data. These data give a broad overview of the position of the US relative to other economies. The series that explain the flow of foreign direct investment (FDI) come from the balance of payments data. The net of private, direct investment in foreign-owned assets in the US and US assets abroad are combined. However, on financial flows the data that are available as part of the balance of payments statistics are lacking in detail. There is some relatively broad information on the net holdings of overseas securities by US residents and some even more general data recording the US securities that are held by people and institutions that are resident in other countries. However, there is no detail on the type of security. This lack of granularity has tended to limit the empirical testing of models in the past.

Fortunately, there are some other sources of information that can fill some of the gaps for capital flows. Since January 1977, the US Treasury has released a monthly report providing significant detail about the changes in the holding of long-term securities amongst US and overseas investors. This report is part of a series of reports under the Treasury International Capital Department (commonly known as the TIC data). See (Siourounis, 2004, p. 29) and the US Treasury (US Treasury, 2012) for more details on the data. The data include information about the buying and selling of long-term securities by US and overseas investors. The primary report is released once a month (with a delay of

several months) and provides detail on the purchase and sale of government, corporate and agency bonds as well as domestic and overseas equities. The overseas securities are those issued in another country no matter what currency. From the gross figures for purchase and sale of specific securities by US-based and overseas investors, a net flow figure for each direction can be constructed for each security type by amalgamating gross purchase of overseas securities by US investors with the gross sale of US securities by overseas.

$$NB = NUSB + NFB \quad (2.37)$$

Where NB is net bonds; NUSB is net US bonds; NFB is net foreign bonds.

$$NUSB = NT + NA + NC \quad (2.38)$$

NT is net treasuries; NA is net agency securities; and, NC is net corporate bonds. The net position is calculated by subtracting the gross sale of securities by overseas investors to US residents from the gross purchase of securities from overseas investors from US residents.

$$NE = NUSE + NFE \quad (2.39)$$

Where NE is net equity; NUSE is net US equities; NFE is net foreign equities. As before, the net position is the difference between gross purchase and gross sales by US residents.

The other data that are available from the US Treasury are details on the transactions carried out by international monetary authorities. These *official* institutions are mostly central banks but can also include the IMF and other quasi-official organisations. By far the largest component of these are the purchase and sale of US Treasury bonds. The breakdown of these data show that the flows of capital associated with these transactions are dominated by the official intervention in the foreign exchange market by those countries that have pegged their exchange rate to the US dollar. As such, an increase in capital inflow to the US associated with official flows would be expected to come from pressure for appreciation of domestic currency vs the US dollar. The most obvious example of this is “Mainland China” where the Chinese monetary authorities have acquired a huge holding of US Treasury bonds as they have bought US dollars against their own currency to maintain competitiveness (US Treasury, 2012).

The monthly official bond flow are subtracted from the total bond flows to leave a figure for the private sector and one for the public sector as well as a monthly series for net

equity flows. Once the three series are added together to get quarterly figures they are placed with the current account and foreign direct investment flows (which came from the balance of payments) and all of these are cumulated from the starting point to get something approaching a stock of international assets and are then deflated by nominal GDP to facilitate the comparison across time.

It is clear that not all money market flows are passive, accommodating changes in position. There are deliberate, forcing speculative flows that would appear in the balance of payment components of the money market or banking that are influenced by short-term factors such as sentiment, momentum, technical analysis or algorithmic models. These sort of activities will be discussed more fully in Chapter 3, where the relationship between speculation and prices and the informational content of speculation will be analysed. There are also speculative flows that seek to take advantage of relative interest rates. This *carry trade* will be assessed more fully in Chapter 4, where the nature of the returns that are achieved by this activity will be assessed in detail. These are each deliberate flows based on views about the stability, direction or risk associated with exchange rates. They are not passive, and therefore, if the method of identifying active components of capital flows is to be employed, they should be included in the model.

The Bank for International Settlements releases information about international banking assets and liabilities. However, it is not possible to disentangle the active from passive activities or the ones that may have exchange rate effects from those that will not. They show the change in net overseas assets and liabilities for the banks for each reporting country. For example, if Hungarian liabilities to the German banking system increase, this Euro-based Hungarian credit may be the first leg of a carry trade that will sell these Euros to purchase Hungarian forint to deposit money at relatively attractive interest rates, or it may be used by Hungarian investors to purchase real or portfolio Euro-area assets (*BIS Location Banking Statistics*, 2012). Therefore, rather than try to disentangle this knot of data, two new series are created to represent speculative capital flows. The first uses data from the US regulator *The Commodities, Futures, Trading Commission* (CFTC) and the second uses the short-term interest rate differential as a proxy for carry trade activity.<sup>13</sup>

The first speculative money market series are compiled to account for speculative sentiment, momentum or technical trading flows. The series for the speculative flows are the positions held by speculative funds in the main currency futures markets in the US. These are positions that must be reported to the US derivative regulator, the US Commodity Futures Trading Commission (CFTC). The positions are held in foreign currency

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<sup>13</sup>Analysis carried out in Chapter 4 shows that the interest rate differential is a significant contributor to the carry-trade profit.

vs the US dollar. The key contracts are Canadian Dollar (contract of 100,000 Canadian dollars), UK Sterling (contract of 62,500 sterling), Japanese yen (12,500,000 yen), Swiss franc (125,000 CHF) and Euro (125,000 EUR) or Deutschmark before the introduction of ECU trading. The data and explanation about the differentiation between commercial (hedgers) and non-commercial (speculators) is available from the CFTC web site (CFTC, 2012). The outstanding long or short speculative positions are amalgamated across currencies and normalised to the total number of speculative positions (S1) or the total open interest positions (S2) to get an overall measure of sentiment. Once the two series are constructed, they are multiplied by -10 to make something easier to work with and to ensure that a speculative inflow to the US is a positive number (see Appendix A Section A.2 for the R code and full details of the data preparation).

The interest rate data are taken from the IMF International Financial Statistics. The interest rates are short-term interest rates and usually 'money market rates' where available. The three month rate is used. An index of international money rates is compiled and compared to the equivalent US interest rate. The index is composed with weights equal to those used in the Major Currency trade-weighted index that is compiled by the US Federal Reserve (Lorentan, 2005). For the Euro, an equal weight of French and German rates is taken until the arrival of the ECU. Mexico causes some problems as it has a relatively large trade weight with the US and, in the 1980s, had very volatile interest rates. This means that the interest rate spread is quite volatile in the early years of the series. Therefore, there are two spread series created. The first (SPREAD1) includes Mexico and the second (SPREAD2) excludes Mexico. In the VAR analysis, a dummy variable is also used to account for the interest rate volatility in the early 1980s (see Section 2.3.5 for more details).

### 2.3.4 Data preparation

Therefore, there are seven main variables that are to be used in the analysis and a number of variations that can be applied to the model. Full details of the preparation, including R code and data files, is available in Appendix A Section A.2. The main variables are: the cumulative current account balance per GDP (CCA); the cumulative net bond per GDP (CNB); the cumulative net equity per GDP (CNE); cumulative net foreign direct investment per GDP (CNFDI); cumulative net official treasuries per GDP (COT); the real trade-weighted index (RTWI); and the nominal trade-weighted index (NTWI); the spread between US short rates and the rates of the main trading partners (SPREAD1 includes Mexico and SPREAD2 does not); and, a measure of speculative sentiment measured in two ways (S1 and S2). The full data set run from the first quarter of 1973 through to the first quarter of 2010. However, the series taken from the

Transactions in Long Term Securities data (TIC) only begin in the second quarter of 1977, the data on official holdings of US Treasury bonds begin in the second quarter of 1978 and the sentiment data begin in the first quarter of 1986.

A sample of the data are presented in Table 2.2. The capital flow and current account are percentage of GDP, the trade-weighted exchange rate are indices, interest-rate spreads are percentage point differences and the speculative sentiment are a percentage of total derivative positions. The main thing to note is that the current account to GDP ratio is substantially larger than any of the other series.

Table 2.2 and Figure 2.1 provide an overview of the data that will be used in the capital flow model. There are two immediate observations: the current account series is not stationary and shows a pattern that is very different from any of the other series; the variation of many series does not appear to be stable, with larger flows around the turn of the century and the financial crisis and some dampening in the size of changes that have been seen in relative interest rates.

The current account poses a problem for the analysis. There is some debate about whether variables in a VAR should be stationary. While some argue in favour of using series in levels, suggesting that important information about long-term relationships is lost in differencing (Sims, 1980) and (Sims et al., 1990), others emphasise the bias that can be caused by the lack of stationarity. However, rather than taking a stand on these particular methodological issues, it is proposed that three separate models be evaluated: model one with the net stock of current account assets in levels ; model two with the change in the net stock of current account assets; and, model three will remove the current account from the investigation and concentrate only on the capital flows.

TABLE 2.2: Important capital flows and exchange rate data

	CCA	DCCA	CNB	CNE	CNFDI	COT	RTWI	SPREAD	S1	S2
Q1 2007	-179.02	-5.22	12.92	-0.55	-2.99	0.71	89.89	2.63	-0.08	-0.12
Q2 2007	-181.66	-5.44	13.80	2.37	-3.27	0.28	87.68	2.38	0.02	0.02
Q3 2007	-184.95	-5.21	7.67	0.27	-3.21	-0.31	85.45	2.00	0.14	0.23
Q4 2007	-187.92	-4.62	5.45	0.49	-5.32	-0.19	81.58	1.46	0.21	0.33
Q1 2008	-191.90	-4.25	9.53	2.55	-6.07	2.13	80.40	0.42	0.15	0.25
Q2 2008	-194.88	-4.87	11.26	-0.17	-6.19	2.23	79.34	-0.57	0.04	0.07
Q3 2008	-200.48	-5.32	8.52	0.22	-6.51	1.10	82.82	-0.73	-0.08	-0.14
Q4 2008	-209.21	-4.26	0.52	2.02	-6.03	-0.11	90.14	-0.99	-0.08	-0.15
Q1 2009	-214.35	-2.31	-0.36	1.92	-7.46	0.04	91.40	-0.63	-0.08	-0.14
Q2 2009	-217.36	-2.40	3.24	0.74	-8.45	1.24	88.12	-0.50	-0.03	-0.06
Q3 2009	-219.53	-3.21	4.07	1.13	-9.21	1.89	84.08	-0.52	0.16	0.25
Q4 2009	-219.87	-2.94	6.70	1.93	-9.83	3.36	81.46	-0.57	0.12	0.19
Q1 2010	-219.52	-2.58	9.95	1.58	-11.48	2.82	83.65	-0.56	-0.10	-0.16

These are the data that are used in the analysis. CCA is the cumulative current account normalised by GDP; DCCA is the change in the cumulative current account; CNB is the cumulative net bond position per GDP; CNE is the cumulative net equity position per GDP; CNFDI is the cumulative net flow of foreign direct investment per GDP; COT is cumulative official treasuries purchase per GDP; RTWI is the real trade-weighted index of major currencies; SPREAD is the spread between US 3 month LIBOR and a basket of equivalent overseas rates (the same currencies as the trade-weighted index); S1 and S2 are indexes of speculative sentiment based on the average speculative positions disclosed to the CFTC by buyers of currency futures relative to the US dollar (Japanese yen, Swiss Franc, Euro or Deutschemark and Pound Sterling). S1 is the net position of speculators relative to speculative positions; S2 is the net position of speculators relative to the open interest (total of all outstanding open positions). A positive number is a US asset, an appreciation of the exchange rate, a US interest rate advantage or speculation in favour of the US dollar.



FIGURE 2.1: Cumulative capital flows and USD

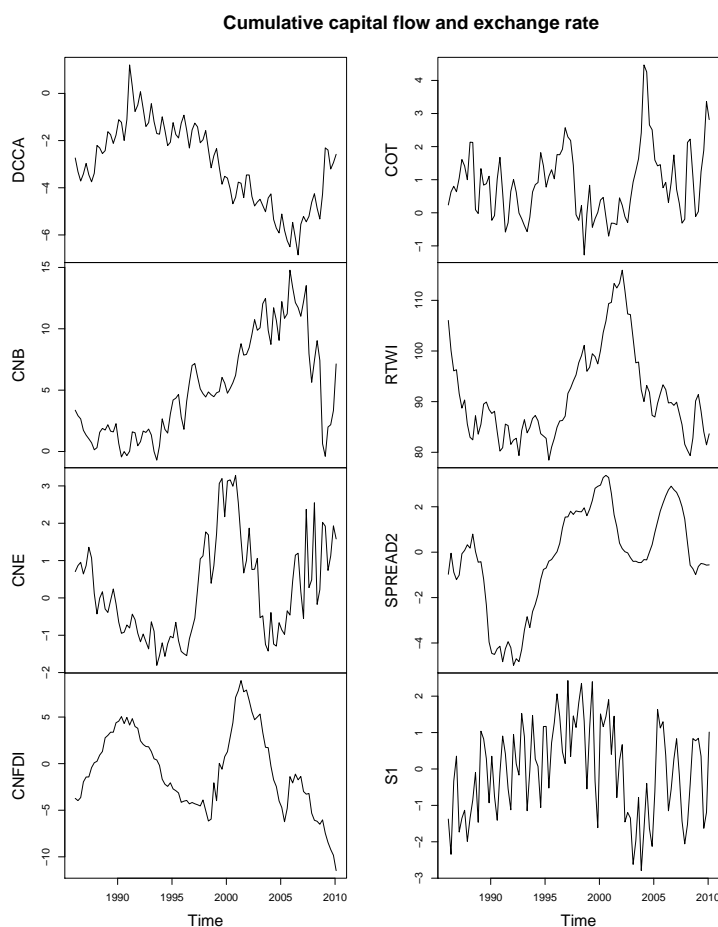
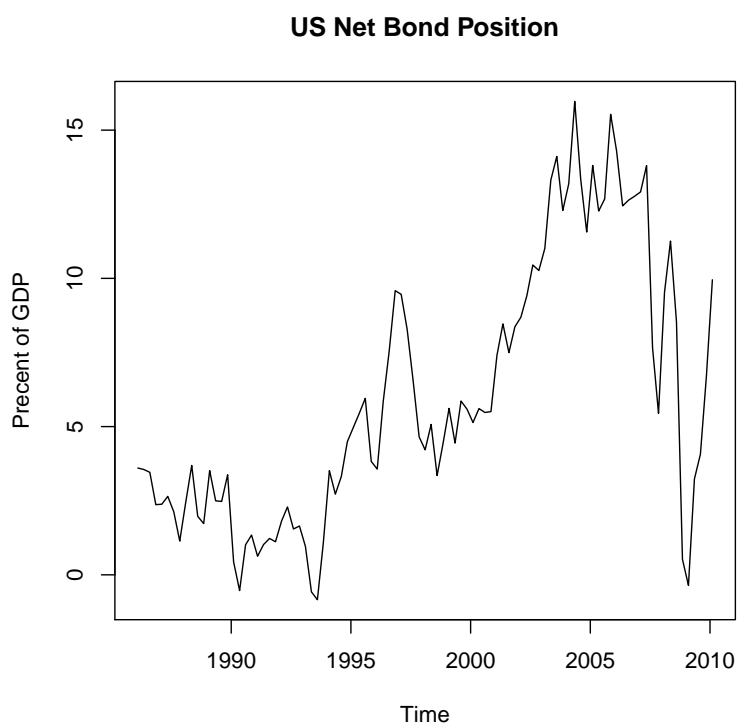


Figure 2.1 also shows the significant changes that have taken place amongst capital flows. A number of these warrant more attention. For example, in Figure 2.2 the scale of the fluctuation in net bond flows becomes apparent. Cumulative net bond flows increase steadily through the period from 1995 from a fairly flat position to reach a peak of close to 15 percent of GDP at the eve of the financial crisis. With a nominal GDP of \$3.5trillion in the first quarter of 2010, this is a net increase of around \$500 bn in the space of 10 years. It can be seen from the Cumulative Official Treasury (COT) in the combined diagram Figure 2.1 that central banks were also making large purchases. This is clearly the activity of Asian exporters and commodity producers, particularly Japan, China and oil nations, fighting the appreciation of their exchange rates. Remarkably, there was a return to close to a zero bond balance by the end of 2009 as overseas investors dumped US debt assets. It is evident from detailed inspection of the Treasury International Capital flow data, that a large proportion of this was a result of the sale

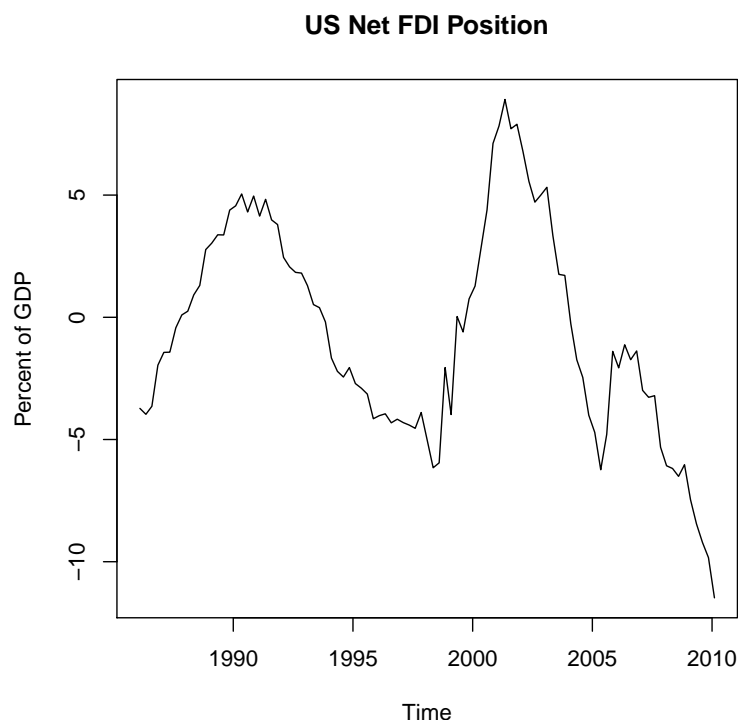
of US agency securities. The US-Government-sponsored enterprises Federal National Mortgage Association (Fannie Mae) and the Federal Home Loan Mortgage Corporation (Freddie Mac) were taken under direct control of the government in September 2008. From September 2008 through to the end of 2009, there was a net sale of \$120bn of agency securities by overseas investors. The detail of the data show that the Chinese monetary authorities were major sellers of agency bonds in this period (US Treasury, 2012). Remarkably, there is a rebound in the stock of overseas net holdings of US debt securities from zero to close to 10% of GDP in the period following the immediate aftermath of the crisis and the beginning of 2010. This is roughly equivalent to a \$400bn net inflow and, at face value, would suggest a flight to the safety and liquidity of US assets.

FIGURE 2.2: Cumulative net bond to GDP



The evolution of foreign direct investment is also of some interest. The cumulative net equity and net FDI series reveal the large real and portfolio flows to the US the last few years of the 1990s. This seems to be associated with the boom in technology stocks. The bubble burst and the NASDAQ index peaked in March 2000. This leads to a reversal of equity and FDI flows. The FDI data show a consistent outflow since that point which may be consistent with the offshoring that is said to have taken place in US business over the last 10 years. Rough calculations indicate that the swing from a positive net FDI balance of 5% of GDP in 2000 to a deficit or liability of 10% in 2010 amounts to about \$500bn in net investment. See Figure 2.3.

FIGURE 2.3: Cumulative net FDI to GDP



There have also been some substantial changes in speculative flows. The SPREAD series show that the US has moved from a position of having interest rates much lower than the rest of the world at the beginning of the 1980s to being equal to slightly higher than the average of its trading partners in the more recent period. The speculative sentiment index reveals a gradual move away from the US through the 1980s and a reversal through the 1990s but this is much more volatile and subject to short-term trends as would be anticipated.

### 2.3.5 Dummy variables

The time series plots are also useful for identifying special situations or extreme circumstances that may not be easily understood by the model and where it may be useful to add some *dummy variables*. These are a form of *transfer function* that seek to account for particular exogenous events. It is proposed that three dummy variables be created and their ability to improve the performance of the model assessed. The first dummy (D1) is going to cover the period from the third quarter of 1986 to the first quarter of 1988. This is an extreme move in the variable SPREAD1 caused by a sharp movement in Mexican interest rates. This, of course, is not needed if the SPREAD2 variable that excludes Mexican interest rates is used. The second dummy (D2) covers the period

from the second quarter of 1994 to the second quarter of 1995 to cover the shock of the increase in US interest rates and the dramatic international outflows from the US bond market. The third dummy (D3) runs from the third quarter of 2007 to the end of 2008 and represents the disturbance caused by the financial crisis. Dummies for the dot.com boom and for the 9/11 event could also be considered. R code for dummy variables is in Appendix A Section A.3.

A transfer function could also be used to account for a structural shift in the model at some point. In this case, rather than turning the dummy on for the period of disturbance and then off again when the usual circumstances have come to an end, the transfer function is maintained. There are no obvious breakpoints that would suggest a clear chance of a structural change. However, it is possible to check for structural breaks at points like the introduction of the North American Free Trade Agreement (NAFTA) in 1995, the introduction of the Euro in 1999 or September 11. This would also be one way to deal with the real risk of parameter instability.

### 2.3.6 Endogeneity

The second important methodological issue is that of endogeneity. The statistical difficulties that emerge when trying to estimate parameters when there is feedback from the dependent variable onto explanatory variables had already been noted by people like Kouri and Porter as early as 1974 (Kouri and Porter, 1974, pp. 464-465) as part of their criticism of the Branson model (Branson, 1968) and (Branson and Hill, 1971). A more general explanation of issues that arise when the dependent variable is endogenous is provided by Hamilton in an analysis of the estimation of the supply and demand for oranges (Hamilton, 1994, pp. 235-238).

Price and quantity are determined simultaneously and are endogenous if the system is represented by two equations.

$$q_t^d = \beta p_t + \varepsilon_t^d \quad (2.40)$$

For demand, with  $q_t^d$  quantity demanded,  $p$  price,  $\beta$  the parameter to be estimated for the response of price to a change in demand and  $\varepsilon_t^d$ , a *random variable* representing all the other factors that affect demand that have not been included.

$$q_t^s = \gamma p_t + \varepsilon_t^s \quad (2.41)$$

For supply, with  $q_t^s$  the quantity supplied,  $p$  is again price,  $\gamma$  is to be estimated as the response of price to a change in supply,  $\varepsilon_t^s$  is a random variable representing all the other factors that may affect supply but not included here. The equality condition (supply equals demand) means that

$$\beta p_t + \varepsilon_t^d = \gamma p_t + \varepsilon_t^s \quad (2.42)$$

However, if Equation 2.40 or Equation 2.41 are estimated by ordinary least squares (OLS), the estimates of coefficients will be biased as the price is not independent of the error term in either case and therefore the OLS assumptions that  $E[p_t \varepsilon_t^d] = 0$  and  $E[p_t \varepsilon_t^s] = 0$  have been violated.

Re-arranging equation 2.42 gives

$$p_t = \frac{\varepsilon_t^d - \varepsilon_t^s}{\gamma - \beta} \quad (2.43)$$

substituting equation 2.43 back into equation 2.41

$$q_t = \gamma \frac{\varepsilon_t^d - \varepsilon_t^s}{\gamma - \beta} + \varepsilon_t^s \quad (2.44)$$

$$q_t = \frac{\gamma \varepsilon_t^d}{\gamma - \beta} - \frac{\gamma \varepsilon_t^s}{\gamma - \beta} + \frac{(\gamma - \beta) \varepsilon_t^s}{\gamma - \beta} \quad (2.45)$$

and therefore

$$q_t = \frac{\gamma}{\gamma - \beta} \varepsilon_t^d - \frac{\beta}{\gamma - \beta} \varepsilon_t^s \quad (2.46)$$

If equation 2.40 is estimated by OLS, the estimate of  $b_t$  would be

$$b_t = \frac{1/T \sum_{i=1}^T p_t q_t}{1/T \sum_{i=1}^T p_t^2} \quad (2.47)$$

substituting equations 2.43 and 2.46 back into 2.47 gives,

$$\frac{1}{T} \sum_{i=1}^T p_t q_t = \frac{1}{T} \sum_{i=1}^T \left[ \frac{1}{\gamma - \beta} \varepsilon_t^d - \frac{1}{\gamma - \beta} \varepsilon_t^s \right] \left[ \frac{\gamma}{\gamma - \beta} \varepsilon_t^d - \frac{\beta}{\gamma - \beta} \varepsilon_t^s \right] \quad (2.48)$$

therefore

$$\frac{1}{T} \sum_{i=1}^T p_t q_t \xrightarrow{p} \frac{\gamma \sigma_d^2 + \beta \sigma_s^2}{(\gamma - \beta)^2} \quad (2.49)$$

and

$$\frac{1}{T} \sum_{i=1}^T p_t^2 = \frac{1}{T} \sum_{i=1}^T \left[ \frac{1}{\gamma - \beta} \varepsilon_t^d - \frac{1}{\gamma - \beta} \varepsilon_t^s \right]^2 \quad (2.50)$$

therefore .

$$\frac{1}{T} \sum_{i=1}^T p_t^2 \xrightarrow{p} \frac{\sigma_d^2 + \sigma_s^2}{(\gamma + \beta)^2} \quad (2.51)$$

substitute 2.49 and 2.51 back into 2.47

$$b_t \xrightarrow{p} \frac{\gamma \sigma_d^2 + \beta \sigma_s^2}{\sigma_d^2 - \sigma_s^2} \quad (2.52)$$

The estimate of  $b$  is not the price elasticity of demand ( $\hat{\beta}$ ) but an average of the price elasticity of demand  $\hat{\beta}$  and the price elasticity of supply ( $\hat{\gamma}$ ). Therefore, if price elasticity of supply ( $\hat{\gamma}$ ) is zero, the estimate of  $b$  converges to ( $\hat{\beta}$ ) but the larger the price effect on supply, the more biased the estimate becomes.

Sims made an important link between the use of reduced form equations and the problems with forecasting in his seminal paper *Macroeconomics and Reality* (Sims, 1980).<sup>14</sup> This work built on the known difficulties posed by endogeneity, where there is feedback between the dependent variable and the regressors, by suggesting that there would be very few cases where true exogeneity would be present and criticising the large number of implicit assumptions that had to be made to establish supposedly *reduced form* equations. Reduced form is one that depends only on exogenous variables and past realisations of the endogenous variables. However, in establishing these reduced-form equations decisions must be taken about which variables to include and which to exclude. Those excluded are essentially given a zero restriction. Sims was particularly critical of the large-scale, macroeconomic models that were built from a large number of interlocking reduced forms, arguing that the problems of endogeneity and implicit restrictions would be magnified in this case.

<sup>14</sup>The analysis was not original. (Working, 1925) discussed this issue when trying to determine a demand schedule for potato prices, (Haavelmo, 1943, p. 2) analysed the difficulty of solving simultaneous equations when there are stochastic elements, presenting Equation 2.52, and (Liu, 1960), cited by Sims, called for more complete structural models to replace the *underidentified* models that had been cropped due to the statistical difficulty of assessing significance of variables when there is covariance between them. However, Sims emphasised the link between endogeneity and the poor forecasting performance of the existing models and he also proposed a solution, which is used in the work here.

To consider some of these issues in relation to exchange rate forecasting, consider the well-known and often-cited analysis of empirical tests of exchange rate models that was undertaken by Meese and Rogoff, who found that major economic exchange rate models have no better forecasting ability than a random walk (Meese and Rogoff, 1983). The general equation estimated was

$$s = a_0 + a_1(m - m^*) + a_2(y - y^*) + a_3(r - r^*) + a_4(\pi^e - \pi^{e*}) + a_5\bar{T}B + a_6\bar{T}B^* + u \quad (2.53)$$

where, following Meese and Rogoff,  $s$  is the logarithm of the dollar price of the foreign currency,  $m - m^*$  is the ratio of the log of the domestic to overseas money supply,  $y - y^*$  is the ratio of the log of domestic to overseas income,  $r - r^*$  is the short-term nominal interest rate differential,  $\pi^e - \pi^{e*}$  is the expected long-run inflation differential and where  $\bar{T}B$  and  $\bar{T}B^*$  are the cumulative domestic and overseas trade balances. Amongst the empirical work discussed, there are various methods used, including *generalised least squares*, to deal with the serial correlation of the residuals and the assumption that money supply, expected long-term inflation and interest rates are endogenous (Fair, 1970). There is also some allowance made for lagged adjustment.

It is assumed that  $a_1$  is unity in all models, the Frenkel-Bilson monetary model without sticky prices forces purchasing power parity by setting  $a_4 = a_5 = a_6 = 0$ ; the Dornbusch-Frankel model allows prices to adjust gradually by setting  $a_5 = a_6 = 0$ ; while the Hooper-Morton model allows for the real exchange rate to adjust by leaving all the coefficients open. These models are compared with a random walk, a random walk with drift and a VAR. The sample is taken from March 1973 until June 1981. Forecasts from the model are made at one, three, six and twelve month horizons. Using mean error (ME), mean absolute error (MAE) and root mean square error (RMSE), model forecasts are compared to actual exchange rate changes and the random walk forecast. No model achieves a lower RMSE than a random walk at any horizon. Subsequent work by Frankel has extended the tests to monetary and portfolio balance models with limited additional success (Frankel, 1984).

One way that Meese and Rogoff deal with the problem of endogeneity is to use instruments to try to isolate the required effect. To return to Hamilton's orange market example, it is necessary to find a variable that will adjust with the supply curve and not the demand curve. Hamilton suggests that in the market for oranges, the weather may be used (Hamilton, 1994, p. 235). As  $\varepsilon_t^s$  represents all those factors that affect supply other than price, it is possible to run the following regression.

$$\varepsilon_t^s = hw_t + u_t^s \quad (2.54)$$

where  $h$  is the coefficient obtained from the regression which, by definition, is unrelated to  $u_t^s$ . Going back to Equations 2.40 and 2.41,  $\varepsilon_t^d$  represents all those factors that affect demand other than price. The weather should only affect demand via the price (as it affects supply) and therefore, should not be related to  $\varepsilon_t^d$ . Changes in the price that are the result of the weather represent a shift in the supply curve not the demand curve.

If  $p^*$  is the OLS estimate of the relationship between  $p_t$  and  $w_t$ , substitute 2.54 back into 2.43,

$$p = \frac{\varepsilon_t^d - hw_t - u_t^s}{\gamma - \beta} \quad (2.55)$$

and then, as  $p^*$  is the projection of  $p$  on  $w$ .

$$p^* = \frac{-h}{\gamma - \beta} w_t \quad (2.56)$$

as  $\varepsilon_t^d$  and  $u_t^s$  are uncorrelated with  $w_t$ ,

$$p = p^* + \frac{\varepsilon_t^d - u_t^s}{\gamma - \beta} \quad (2.57)$$

Substitute 2.57 back into 2.40,

$$q_t^d = \beta \left( p^* + \frac{\varepsilon_t^d - u_t^s}{\gamma - \beta} \right) + \varepsilon_t^d \quad (2.58)$$

and

$$q_t^d = \beta p^* + v \quad (2.59)$$

when

$$v = \frac{-\beta u_t^s}{\gamma - \beta} + \frac{\gamma \varepsilon_t^d}{\gamma - \beta} \quad (2.60)$$

if  $u_t^s$  and  $\varepsilon_t^d$  are uncorrelated with  $p^*$ ,  $v$  is uncorrelated with  $p^*$ . Now if 2.58 or 2.59 are estimated by OLS, it would provide a consistent estimate of  $\beta$ .

Return to 2.47 and use



$$\hat{\beta}_t^* = \frac{1/T \sum_{i=1}^T p_t^* q_t}{1/T \sum_{i=1}^T (p_t^*)^2} \quad (2.61)$$

$$\hat{\beta}_t^* = \frac{(1/T) \sum_{i=1}^T p_t^* (\beta(p_t^* + v_t))}{(1/T) \sum_{i=1}^T [p_t^*]^2} \quad (2.62)$$

$$\hat{\beta}_t^* = \beta + \frac{(1/T) \sum_{i=1}^T p_t^* v_t}{(1/T) \sum_{i=1}^T [p_t^*]^2} \quad (2.63)$$

$$\hat{\beta}_t^* \xrightarrow{p} \beta \quad (2.64)$$

The process of estimating  $p^*$  from the initial projection of

$$p_t = \hat{\delta}_I w_t \quad (2.65)$$

is called *two-stage least squares* (2SLS) and the exogenous variable  $w_t$  (weather in this case) is called the *instrument* in a method of *instrumental variables* where the instrument is a tool to estimate the relationship between  $q_t$  and  $p_t$ . The instrument must be correlated with the endogenous variable (price in this case) but not with the error term (it only affects demand through price).

However, the big problem that is found in trying to apply this approach to the study of exchange rates is finding an equivalent of the weather for the international capital flows. The aim is to find something that will affect international capital flows but will not directly have an influence on the real exchange rate. For example, an increased US government deficit or a changing in the credit rating could affect the net flow to the US bond market. However, it is very likely that this would also have a direct effect on the exchange rate itself and therefore this instrument would also be related to the error term. US corporate profitability could affect the net flow to US equities and monetary policy expectations could affect speculative flows driven by interest rate differentials, but these are sure also to affect the exchange rate.

Finding truly exogenous variables is not easy. Sims addressed the question of exogeneity in *Money, Income and Causality* (Sims, 1972). Sims suggested that the dependent variable be regressed on past and future values of the explanatory variables and that only if the coefficient on future values appeared to be zero could it be said that the causality was unidirectional. If the coefficients on future values were statistically or economically significant, bidirectional causality should be assumed. This method is part

of the suite of Granger-Sims causality tests that have been used to try to determine cause and effect and to test for exogeneity (Granger, 1969) and (Sims, 1972).

Sims used the method to assess whether money  $M$  could be called *strictly exogenous* in an estimate of quarterly data of money supply and Gross National Product (GNP) for the period 1947 to 1969. As future values of money did not appear to explain GNP he concluded that “The evidence agrees quite well with a null hypothesis that causality runs entirely from money to GNP, without feedback” Sims (1972, p. 541). The result was to find some support for the implicit exogeneity of the money in the *St. Louis Fed reduced form equations*.<sup>15</sup>

However, even here it may just be a matter of degree. Clearly some aspects of monetary growth are a response to changes in economic activity and the conclusion of exogeneity may just be an artifact of the imprecision with which the test is made. At its extreme, as Lucas (1976) argued, even exogenous variables can become endogenised if they become policy variables and start to affect behaviour of economic agents. For example, the relationship between money and economic activity can change if the monetary authorities start to change the stock of money in response to a nominal GNP target.<sup>16</sup> The issue is one that is very relevant to the question of real exchange rates and capital flows because the two key instruments that the monetary authorities have to control the economy are the level of interest rates and direct intervention in the foreign exchange market. In the former case, there will be an effect on interest rate differentials and possibly bond markets; in the latter, there will be a change in the composition of foreign exchange reserves, the central bank balance sheet and possibly also the net flow to international bond markets.

It is hard to make the case that international capital flows are exogenous. Any overseas transaction has to take some account of the expected change in the value of the exchange rate; the performance of the currency will also have an effect on the profitability of exporters, viability of overseas investment projects and macroeconomic variables that are important for the valuation of securities such as the effect of short-term interest rates and inflation on bonds. In addition, the purchase of US government bonds by overseas

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<sup>15</sup>The *St. Louis Fed equations* is the term given to work done using reduced-form equations by the research department at the St. Louis Fed and the broad debate about the role of fiscal and monetary policy in the business cycle. The equations assess the relationship between government spending, money and the economy and the relative importance of fiscal and monetary action. The original article (Andersen and Jordan, 1968) asserted that the effect of fiscal policy on the economy was relatively small and statistically insignificant. The results were controversial and prompted a range of discussion including the argument that endogeneity of the variables meant that the estimates of the parameters established using such techniques were unreliable. Sims' contribution is a small part of this debate.

<sup>16</sup>This is a more formal version of *Goodhart's Law*, which states that statistical regularity will tend to change when a (monetary) variable is used for policy purposes (Goodhart, 1975). It is part of a wider problem of feedback in the measurement and modelling of expectations which was also addressed by Sims (Sims, 1980).

monetary authorities is designed to ensure that a variety of other countries fix their exchange rate against the US dollar. The factors that speculators use to assess future exchange rate movements are surely broad and ever-changing. They must, at some point, include all the variables that have been considered for the capital-flow model.

Granger causality tests take the form

$$y_t = \alpha_0 + \sum_{i=1}^{i=p} \beta_i y_{t-i} + \sum_{j=1}^{j=p} \gamma_j x_{t-j} + \varepsilon_t \quad (2.66a)$$

$$x_t = \alpha_0 + \sum_{i=1}^{i=p} \beta_i x_{t-i} + \sum_{j=1}^{j=p} \gamma_j y_{t-j} + \varepsilon_t \quad (2.66b)$$

where the null hypothesis that  $x$  does not Granger-cause  $y$  is that the estimated value of all  $\gamma$  are equal to zero. An F-test of the null that the real exchange rate (RTWI) does not Granger-cause the other variables is rejected. The confirmation that changes in the value of the real exchange rate tends to lead changes in capital flows suggests a feedback from the exchange rate to capital flows that supports the use of a system-type model.

### 2.3.7 Vector autoregression

This econometric technique proposed by Sims to overcome the problems caused by endogeneity and the implicit restrictions imposed on reduced form equations has come to be known as the Vector Autoregression (VAR). All the left-hand-side or dependent variables are also explanatory variables; a wide range of variables are used; there are no initial restrictions on the parameters, including zero restrictions on the lagged variables. The essence of the VAR is to set up a system that is made up of all the important variables, assume that they are endogenous and that there are significant lags. Exogenous variables can be added, but these are usually restricted to things that are clearly determined outside of the system such as seasonal or special dummies, trends and constants. The variables that will be included in the list of endogenous variables should be determined by economic theory. The lag order is eventually determined by the use of information criteria that will assess whether the addition of extra lags adds more to the explanation than it loses in terms of degrees of freedom.

The explanation below draws on the following texts (Enders, 2010, pp. 297-335), (Hamilton, 1994, pp. 291-350) and (Green, 2003, pp. 586-607). A simple *structural* or *primitive* system with just two endogenous variables and one lag would be.

$$x_t = b_{10} + b_{12}y_t + \gamma_{11}y_{t-1} + \gamma_{12}x_{t-1} + \epsilon_{xt}, \quad (2.67a)$$

$$y_t = b_{20} + b_{22}x_t + \gamma_{21}x_{t-1} + \gamma_{22}y_{t-1} + \epsilon_{yt}, \quad (2.67b)$$

It is assumed that  $\epsilon_{xt}$  and  $\epsilon_{yt}$  are independent of each other, are normally distributed with a constant variance. Though the independence assumption appears quite onerous, it should be remembered that this is independence of innovation. It does not mean that there is no relationship between the two variables ( $x$  and  $y$  here). A shock to either variable will have an effect on the other via the contemporaneous relationship (which is  $b_{11}$  and  $b_{21}$  in Equations 2.67a and 2.67b). As a consequence, this model cannot be easily estimated as there are feedback effects of the sort discussed above ( $y_t$  is related to  $\epsilon_{xt}$  and  $x_t$  is related to  $\epsilon_{yt}$ ). The variables are endogenous. As an alternative to the use of *Instrumental Variables* the structural or primitive equations can be transformed so that ordinary least squares (OLS) can be utilised.

In matrix form, 2.67a and 2.67b can be written as,

$$\begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix} \begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_{xt} \\ \epsilon_{yt} \end{bmatrix} \quad (2.68)$$

A more general characterisation would be

$$Bx_t = \Gamma_0 + \Gamma_1x_{t-1} + \epsilon_t \quad (2.69)$$

Multiplying through by  $B^{-1}$  will give the *standard form of the VAR*

$$x_t = A_0 + A_1x_{t-1} + e_t \quad (2.70)$$

Now with  $A_0 = B^{-1}\Gamma_0$ ,  $A_1 = B^{-1}\Gamma_1$  and  $e_t = B^{-1}\epsilon_t$ , and returning to the equivalent form

$$y_t = a_{10} + a_{11}y_{t-1} + a_{12}x_{t-1} + e_{1t} \quad (2.71a)$$

$$x_t = a_{20} + a_{21}x_{t-1} + a_{22}y_{t-1} + e_{2t} \quad (2.71b)$$

Now the equations can be estimated with OLS because the variables are uncorrelated with the error term. Hamilton shows that this is the equivalent to the Maximum Likelihood Estimator (MLE) (Hamilton, 1994, p. 293). However, though the model can be

estimated with ease, because of the transformation that has been undertaken, the coefficients that are uncovered are not those from the original structural model represented by Equations 2.67a and 2.67b. For the standard form of the VAR (Equations 2.71a and 2.71b), the errors are a composite of  $\epsilon_{yt}$  and  $\epsilon_{xt}$  as  $e_t = B^{-1}\epsilon_t$ . The latter can be used to uncover the components of the structural VAR from the estimation of the standard form. However, some method must be established to deal with the problem of identification. While it is possible to get the estimates of  $A_0$ ,  $A_1$  and  $e_t$  from Equation 2.70, it may not be possible to get all the components of the primitive or structural model unless some restrictions are imposed. The primitive or structural system, made up of Equations 2.67a and 2.67b, contains eight parameters  $b_{10}, b_{11}, b_{20}, b_{21}, \gamma_{10}, \gamma_{11}, \gamma_{21}, \gamma_{22}$  and the variance of  $\epsilon_{xt}$  and  $\epsilon_{yt}$ , while the 2.70 VAR, made up of 2.71a and 2.71b, will provide only six coefficient estimates plus the variance and covariance of the error terms  $e_{1t}$  and  $e_{2t}$ . Therefore, in this case there are only nine estimates for ten parameters and a restriction will have to be made if everything is going to be uncovered. In general,  $K(K-1)/2$  restrictions will be required, where  $K$  is the number of endogenous variables in the VAR.

### 2.3.8 Identification

There are a wide variety of restrictions that can be placed on Equations 2.67a and 2.67b. There is a whole industry that has built up to find VAR restrictions. These generally begin with a reference to economic theory. For example, it is possible to assume that some of the coefficients are equal to particular values. If it were assumed that there were no contemporaneous relationship between  $x$  and  $y$ ,  $b_{11}$  in Equation 2.67a could be set to zero; if the contemporaneous relationship between  $x$  and  $y$  is assumed to be symmetrical, Equations 2.67a and 2.67b can include  $b_{11} = b_{21}$ .

One standard way to identify the VAR is to use a *Cholesky decomposition* which forces the error variance-covariance matrix to become an upper triangle and therefore makes  $K(K-1)/2$  restrictions as required. This will equate the number of unknown parameters with the number of equations by imposing, virtually arbitrary, restrictions on the model. In the example above, for Equation 2.68 it would be assumed that  $b_{21}$  is equal to zero. This imposes the restriction that  $x_t$  does not have any contemporaneous effect on  $y_t$  in Equation 2.67b. Setting the restriction by using the Cholesky decomposition in this way is somewhat *ad hoc* or *naive* and goes some way back towards the unjustified or unsupported restrictions that were at the heart of Sims' original criticism of the endogeneity modelling problem (Sims, 1980). One of the main practical issues is that the results may change according to the order that the variables are placed into the

TABLE 2.3: SVAR Restrictions

	CNB	CNE	CNFDI	COT	RTWI	SPREAD	S1
CNB	1	NA	0a	0b	0c	NA	0d
CNE	NA	1	NA	0e	NA	0f	NA
CNFDI	0g	NA	1	0h	NA	0i	0j
COT	NA	0k	0l	1	NA	0m	NA
RTWI	0n	NA	NA	NA	1	NA	NA
SPREAD	NA	0p	0q	0r	NA	1	0s
S1	0t	NA	0u	NA	NA	0v	1

The table shows the individual equations in the VAR and the restrictions that are placed on some of the coefficients to identify the system. Reading across the page, the first row reads CNB as the dependent variable, NA for CNE meaning that this coefficient can be estimated, there is a zero restriction placed on CNFDI and the letter identifies the explanation for the restriction in the paragraph below.

VAR. Therefore, one way to assess the resilience of the results is to shuffle the variables and to compare the findings across different specifications. That is what is done here.

It would be much better, if possible, to use economic theory to suggest restrictions that can be imposed on the  $B$  matrix. There is a wide literature that assesses different methods of making these restrictions. For example, Sims proposed a six-variable VAR including variables like GNP, money supply, interest rates, inflation, investment and unemployment and made 17 restrictions that the system was *over-identified*, meaning that there are more equations than unknown coefficients to be estimated (Sims, 1986), while Bernanke makes a number of explicit restrictions to support his assertion that the relationship between money and income is intermediated by credit rather than being the result of money illusion or causality running from income to money (Bernanke, 1986). It is also possible to place a restriction on the moving average vector of structural errors to analyse the temporary and permanent components of GNP in a two variable VAR where one additional restriction is needed for identification (Blanchard and Quah, 1987). In this way the error-covariance matrix ( $\varepsilon_t$ ) rather than the  $B$  matrix is restricted in Equation 2.69.

The Sims-Bernanke approach is adopted here. There are seven variables in the model being estimated. This means that twenty one restrictions ( $K(K - 1)/2$ ) are needed for system identification. It is now possible to consider the economic arguments for restrictions and to impose these on the model. For example, in this paper, there will be seven variables which can be represented by seven equations along the lines of Equations 2.67a and 2.67b where there is a seven-by-seven  $B$  matrix like that in Equation 2.69 and Table 2.3 is the first matrix of Equation 2.68. Table 2.3 gives an overview of of the restrictions suggested.

### 2.3.9 VAR restrictions

The following are the explanations for the twenty-one restrictions that are imposed on the VAR. Note that these are contemporaneous restrictions (same quarter), a lagged effect is still allowed. The equations are read across rows, with the dependent variable normalised to unity, coefficients on independent variables that are to be estimated are labelled "NA" in Table 2.3, as they are in the R code, and the zero restrictions are labeled alphabetically. The matrix does not have to be symmetric; for example, a change in cumulative net foreign direct investment to GDP (CNFDI) may affect speculative sentiment in the current quarter, as the confidence expressed by international investors may encourage speculative activity, but that does not mean that an increase in speculative sentiment has to affect CNFDI which may be expected to be influenced by factors that are more long-term or fundamental in their nature. R code for the restricted matrix is presented in Appendix A Section A.8. It will be evident that the B matrix is set up like Table 2.3.

Reading across the row for each equation in turn. The cumulative net bond equation (CNB) is restricted by imposing a coefficient of zero on the influence of foreign direct investment (a), cumulative official treasuries (b), real exchange rate (c) and sentiment (d). Though the exchange rate and speculative sentiment could increase net bond flows, it seems more likely that this would happen at the short end of the yield curve (and therefore would be better captured by the money market proxies SPREAD or S1 ) and, as noted in (Siourounis, 2004, p. 3) and (Hau and Rey, 2006), most of the international bond flows appear to be hedged against foreign exchange gains and losses. The cumulative net equity equation is restricted only at the cumulative official treasuries (e) and the interest rate spread (f). Lower relative rates could inspire a more positive attitude towards corporate profits, but rate changes could just as likely be a response to broad-based economic weakness that would not be conducive to profitability. The restrictions on the FDI equations are on bond flows (g), official treasuries (h), the interest rate spread (i) and sentiment (j). As foreign direct investment is assumed to be a more long-term commitment, it seems likely that short-term relationship with other variables will be modest; the longer term coefficients can play a more prominent role. The flow of Official Treasuries (COT) is most likely to be a response to an appreciation of the US dollar and therefore should not be significantly affected by things like equity (k) and FDI (l) flows, unless indirectly. The real exchange rate is allowed to be affected by all the other variables outside of net bond flows (n). The interest-rate spread, which presumably is largely a function of central bank policy, is restricted against net equity (p), net FDI (q), official purchase (r) and sentiment (s). The exchange rate and net bond flows are allowed to have some influence. Finally, the sentiment equation is restricted on bonds (t), FDI (u) and the spread (v), but is allowed to be affected by equity and the

exchange rate. This allowed for some positive spillover from more optimistic attitudes towards the economy, which may affect the flow of money to the stock market or into real investments. It also allows for positive feedback from a change in the value of the exchange rate to speculative sentiment.

It is, of course, possible to argue about some of the restrictions that have been imposed here. However, at least the restrictions are out in the open, can be debated and can be assessed against the available data evidence. This marks an improvement on the *ad hoc* or *naive* methods. It is of course possible to run the model, assess the outcome and then make adjustments to the restrictions. However, this would increase the risk of *data mining* or *over-fitting* and it is not done here. However, as a robustness check, three models are assessed: the first is one that is restricted using the Cholesky decomposition (called System One); the second takes a random ordering of the variables and again restricts the coefficients on the lower triangle to be zero (called System Two); the final version uses the structural restrictions noted above (System Three). If all three methods give similar results, there should be greater confidence that the outcome is not just a function of the ordering of the variables or the assumptions that have been made.

## 2.4 Results

The main results for System Three are presented in Figure 2.4 where it is evident that the most dramatic and significant contribution to the change in the real exchange rate comes from the two types of speculation that are analysed. *Impulse Response Functions*, to be discussed more fully in Section 2.4.4 below, show that a one unit innovation or shock to the S1 series, equal to a ten percentage point change in the net position of speculators relative to the total speculative position, will have on average a positive effect of close to 4% on the real trade-weighted exchange rate over the next eight quarters. The 95% confidence intervals, denoted by the red, dashed lines, reveal that it is very likely that there is a positive effect. For speculative flows that are linked to the interest rate differential, a one-unit or one hundred basis-point improvement in US interest rate advantage tends on average to have an effect of increasing the US real trade-weighted index by about 10%. Here there is more uncertainty and there are times when the effect is quite minimal.

For the other major flows, there is a great deal more ambiguity. The effect of a one-unit increase in the net cumulative bond position relative to GDP (equivalent to about \$35bn at the beginning of 2010) is close to zero over the following four quarters and slightly negative beyond that point. The impulse response functions show a range of possible outcomes that are centred around zero. The average effect of an innovation



to the net inflow to US equities of one percentage point of GDP or about \$35bn is on average zero but the confidence intervals are wide, suggesting that sometimes the equity inflow is associated with an appreciation of the real exchange rate and sometimes with a depreciation. The net flow associated with foreign direct investment is very similar, but slightly more positive, to that of equities. The action of overseas central banks, cumulative official treasuries (COT), is associated with a positive effect of an average 4% over the next four quarters. Here the causation is likely to be running from the exchange rate to inflows as the overseas central banks respond to US dollar weakness by buying dollars and US government bonds to help to maintain their exchange rate pegs. The width of the confidence intervals indicates that there are many occasions when the capital flow associated with central bank intervention does not have the desired effect and weakness in the US real trade-weighted index continues.

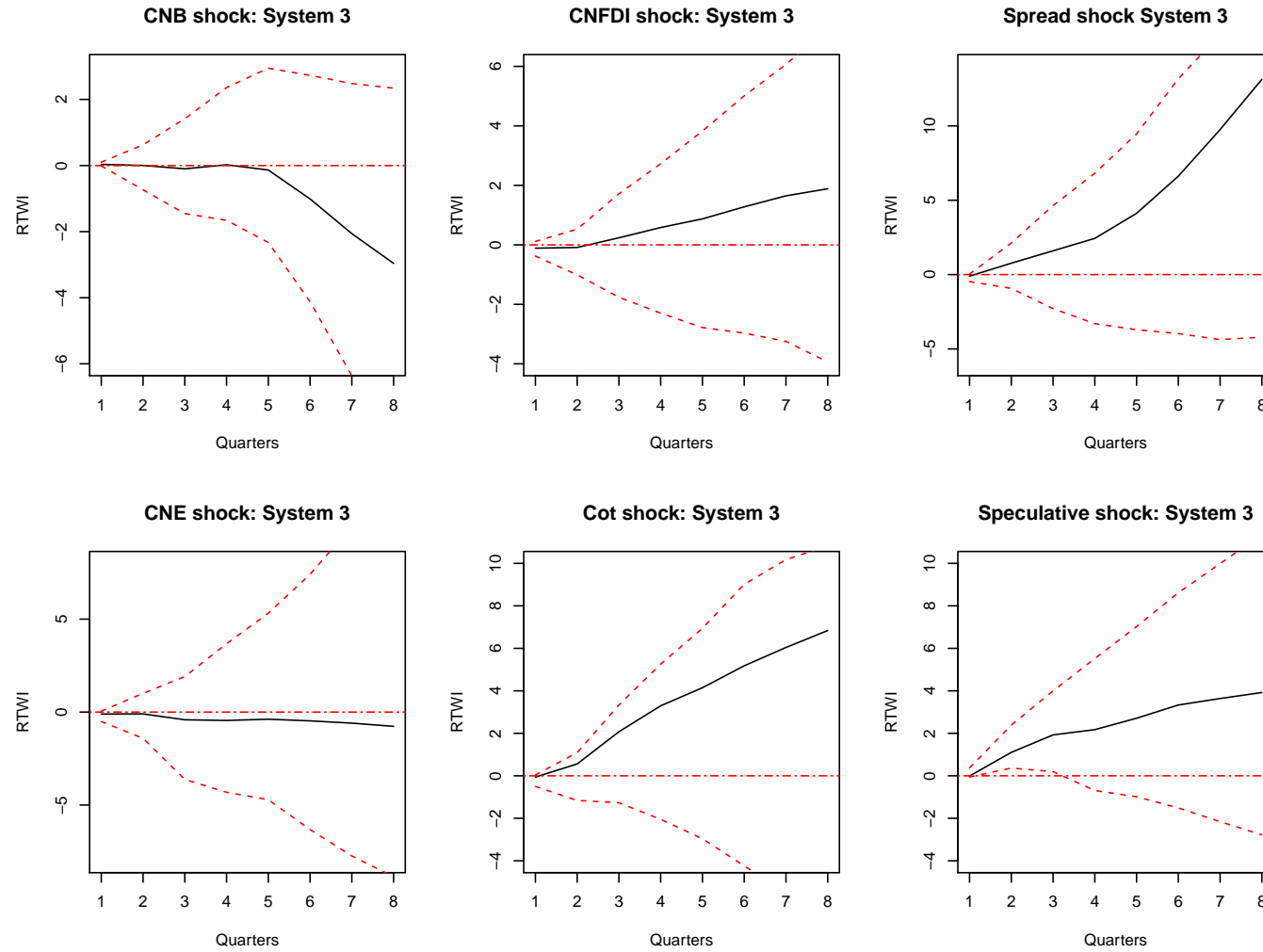
The overall impression is one where speculation has a much more precise and significant effect on the real exchange rate than the other capital flows. It is clear that speculation can have a effect that is not just short-term in nature and that this can have a real effect on the economy. A very similar pattern is noted in the impulse response functions that are derived from the other Systems (see Figures 2.9 and 2.10 and Section 2.4.6 below). The results are robust to alternative specifications. This increases the confidence in the results as it appears that it is not the method of identifying the VAR or the restrictions that have been imposed having a major effect on the outcome.

The rest of this section provides more detail of the analysis behind the results briefly presented here including the model selection, diagnostic tests and the creation of impulse response functions. The statistical analysis is carried out in the R environment (R Core Team, 2013).<sup>17</sup>

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<sup>17</sup>See <http://www.R-project.org/> for more details. The packages `xtables`, `dse` and `vars` were primarily used for compiling tables in La Tex and for running the VAR analysis (R Core Team, 2013), (Dahl, 2012), (Pfaff, 2008*b*) and (Pfaff, 2008*a*)

FIGURE 2.4: Impulse Response Functions for RTWI for System Three



### 2.4.1 Model selection

There are a number of different models to be assessed. There are various ways that the exchange rate (nominal or real), interest-rate spread (SPREAD1 or SPREAD2) and sentiment (S1 or S2) can be measured. There are also the three proposed solutions to the non-stationary current account series and also the possibility of the addition of exogenous variables to the VAR. The three dummy variables have already been set up for specific period of volatility in international capital flows can be included if they add explanatory power. The issue of a structural break has also been considered and there is also some room for seasonal dummies. In addition, the VAR can include a constant or a trend.

Table 2.4 presents the key information for the baseline model selection process. The three main models are identified by the inclusion of the net cumulative current account (CCA), the change in the net cumulative current account (DCCA) or the absence of the net cumulative current account ("No Current Account"). Models are tested with and without dummy variables. The log likelihood and the Akaike (AIK) and Bayesian information criteria (BIC) are reported along with a number of diagnostic tests. See Appendix A Section A.7 for full details of the R code used to select variables from the raw data files and for carrying out the diagnostic tests.

Table 2.4 shows a comparison of the different models that are proposed. Information criteria are used for model selection and for choosing the length of the lags to include. The Likelihood function is the probability that the parameters of the model are observed given values of the variables in the system and a probability density function. Parameters can be adjusted to maximise the likelihood. In which case, it is usually easier to use the log of the likelihood function. However, the more parameters are added to the model, the higher the Likelihood function as each new series is sure to add something. Therefore, in order to guard against over-fitting, it is usual to place a penalty on the use of additional explanatory variables.

TABLE 2.4: Model Selection

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
CCA	Yes	Yes	No	No	No	No	No	No
DCCA	No	No	Yes	Yes	No	No	No	No
No CA	No	No	No	No	Yes	Yes	Yes	Yes
Dummy	No	Yes	No	Yes	No	No	Yes	Yes
Lag Length	4	4	4	4	1	4	1	4
Lag Length: AIC	3	3	3	3	1	1	1	3
Lag Length: BIC	1	1	1	1	1	1	1	1
Log Likelihood	-1693.94	-1627.99	-2365.93	-2305.49	-1598.27	-1413.18	-1555.74	-1358.10
AIC	19.4501	18.6721	33.7877	33.0450	14.7446	14.7887	14.2961	14.1583
BIC	21.6783	21.6529	36.1546	36.108	16.4275	16.5043	16.5399	16.4895
Roots	Good	Good	Good	Good	Good	Good	Good	Good
Serial Correlation. (p-value)	564.23 (0.00)	575.54 (0.00)	567.54 (0.00)	589.07 (0.00)	314.02 (0.00)	389.15 (0.00)	338.09 (0.00)	394.06 (0.00)
Heteroskedasticity. (p-value)	3060 (0.00)	3060 (0.00)	3060 (0.00)	3060 (0.00)	2576 (0.00)	2492 (0.00)	2576 (0.00)	2492 (0.00)
Normality (p-value)	990.0 (0.00)	36.81 (0.00)	1438.00 (0.30)	18.49 (0.00)	2401 (0.00)	1469 (0.00)	210.00 (0.00)	32.43 (0.00)

The models are versions of Equations 2.71a and 2.71b estimated with OLS. CCA, DCCA and No Current Account identifies the three main class of model (with the net cumulative current account, the change in the net cumulative current account and without the current account variable). Dummy indicates whether the dummy variables are included. Lag length is the lag length used and the following rows indicate the lag length indicated by the Information criteria (Akaike Information Criterion (AIC) (Akaike, 1981) or Schwartz Bayesian Information Criterion (BIC) (Schwarz, 1978). Log Likelihood is the log likelihood of the VAR estimation. “Roots” checks for stability with the result of a test that the roots of the coefficients of the autoregressive polynomial lie outside the unit circle. Serial correlation, heteroskedasticity and Normality are the residual tests of the null hypothesis that normal, independent and identically distributed. Serial correlation is tested using the multivariate Portmanteau and Breusch-Godfrey test; heteroskedasticity is tested using the ARCH-LM test; the test of normally distributed errors is the multivariate Jarques-Bera test of the null that all the residuals are normally distributed.

There are a number of ways that the Likelihood function can be adjusted to penalised taking additional variables into account. The two used in this study are the Akaike Information Criterion (AIC) (Akaike, 1981) and the Bayesian Information Criterion (BIC) (Schwarz, 1978). The AIC is

$$AIC = 2k - 2\ln(L) \quad (2.72)$$

where  $k$  is the number of parameters in the model and  $L$  is the maximised value of the likelihood function. The BIC is

$$BIC = k\ln(n) - 2\ln(L) \quad (2.73)$$

with  $n$  being the number of observations in the model.

The AIC tends to apply a small penalty to additional parameters while the BIC is less generous. As a result it is often the case that the two methods can suggest different solutions. The AIC is likely to favour a model with more explanatory variables and the BIC is likely to suggest something more parsimonious. This is the case in Table 2.4 where AIC indicates that that Model 8 with dummy variables and four lags (but no current account) is the best fit while the BIC suggests that Model 5 is the best, with no current account, no dummies and only one lag.

### 2.4.2 Model specification and diagnostics

The preferred model, according to the range of information and diagnostics outlined in Table 2.4 is the one that does not include the current account, has four lags and uses the three dummy variables, SPREAD2 and S1. A model with a linear trend and a constant is the one that produces the lowest values of the AIC and BIC. The summary information on model 8 reveals that the system is stable as the roots of the autoregressive coefficients are all within the unit circle. The dummy variables are significant.

There is some concern that the diagnostic tests for the preferred model indicate that there is serial correlation of the residuals, hetroskadasticity and that the errors are not normally distributed. (Juselius, 2007, p.47) reports simulation studies that have shown that the statistical inference for VARS is much more susceptible to parameter instability, autocorrelation and residual skew than it is to hetroskedasticity and kurtosis. Each of these can be considered in more detail in turn.

There are two tests of serial correlation. The first is the *Lagrange Multiplier* test that is sometimes called the *Breusch-Godfrey* test after its authors (Breusch, 1979) and (Godfrey, 1978). The test is based on an initial estimation of the autocorrelation of the residuals.

$$u_t = A_0 y_{t-1} + A_1 y_{t-2} \dots + B_0 u_{t-1} + B_1 u_{t-2} \dots + \varepsilon_t \quad (2.74)$$

Once the lag length is determined, the null is a test of whether all the B values are equal to zero. Formally, the test is

$$LM_h = T(K - \text{tr}(\Sigma_R^{-1} \Sigma_e)) \quad (2.75)$$

where  $\Sigma_R$  and  $\Sigma_e$  are the covariance matrices of the restricted and unrestricted models respectively. Asymptotically, the test statistic has a  $\chi^2$  distribution with degrees of freedom equal to the lag length multiplied by the square of the number of endogenous variables. (Edgerton and Shukur, 1999) present a small-sample adjustment that is used here. See (Pfaff, 2008a, p. 29) for full details. The results of the test are presented on line 12 of Table 2.4. This shows that in each case the null hypothesis that all the residuals are different from zero is rejected. This is a little surprising as the *correlograms* of the estimated residuals from each of the equations do not show any serial correlation in any of the equations (see Figure 2.5. These are constructed as the *autocorrelations* of the residuals of each of the estimated equations. The autocorrelations are constructed as the ratio of the covariance between the current residuals and each lag normalised to the estimated variance of the residuals. Therefore the covariance is,

$$\sum_{i=1}^{i=j} (e_t) \hat{e}_{t-i} = T^{-1} \sum_{t=1}^{t=T} (e_t - \bar{e})(e_{t-i} - \bar{e}) \quad (2.76)$$

where  $j$  the order of covariance to be estimated, and the variance is

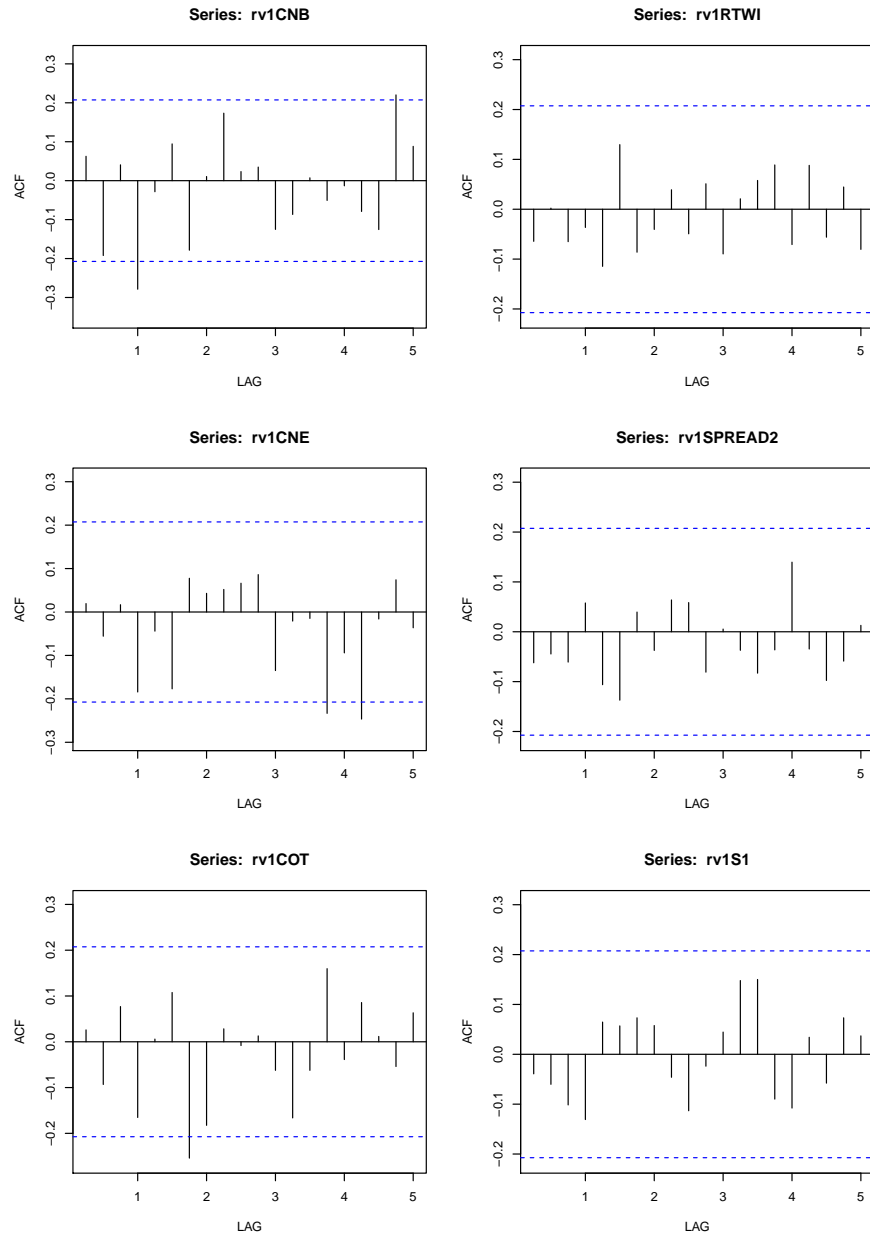
$$\hat{\sigma}_e^2 = T^{-1} \sum_{t=1}^{t=T} (e_t - \bar{e})^2 \quad (2.77)$$

See (Harvey, 1993, pp. 13 - 14) for more details.

According to the assumptions that were used to construct the VAR, these covariances should be zero, though this will not be the case in the sample. To test the null hypothesis that the assumption is correct, confidence intervals are drawn according to the formula  $\frac{z_{1-\alpha/2}}{\sqrt{N}}$  where  $z$  is the quantile function from the standard normal distribution,  $\alpha$  is the confidence level (usually set at 5%) and  $N$  is the number of observations. This is an

approximation and assumes a normal distribution. The limits for a 5% confidence are drawn in Figure 2.5 in blue.

FIGURE 2.5: Autocorrelation of residuals



The test of heteroskedasticity is based on the following regression.

$$vech(\hat{u}_t \hat{u}_t') = \beta_0 + \beta_1 vech(\hat{u}_{t-1} \hat{u}_{t-1}') \dots \beta_q vech(\hat{u}_{t-q} \hat{u}_{t-q}') + v_t \quad (2.78)$$

Where  $vech$  is the half-vectorisation of the symmetric matrix  $(\hat{u}_t \hat{u}_t')$ .<sup>18</sup> The null hypothesis of no heteroskedasticity takes the form  $H0 := \beta_0 = \beta_1 = \beta_2 = \dots = \beta_q = 0$  with the test statistic.

$$VARCH_{LM}(q) = \frac{1}{2}TK(K+1)R_m^2 \quad (2.79)$$

where

$$R_m^2 = \frac{2}{K(K+1)}tr(\hat{\Omega}\hat{\Omega}^{-1}) \quad (2.80)$$

With  $\Omega$  the variance-covariance matrix from Equation 2.78. The test is distributed as  $\chi^2(qK^2(K+1)^2/4)$ . See (Hamilton, 1994) for more details. The test statistic is recorded in line 14 of Table 2.4. This shows some evidence of heteroscedasticity in the preferred model. However, the univariate tests indicate that this comes from the SPREAD2 equation. The null of uniform variance cannot be rejected for any other series. This is also evident from the time series plot of the residuals (see Figure 2.6).

Heteroskedasticity could be addressed by some sort of adjustment such as taking logs or using the Box-Cox transformation (Box and Cox, 1964). However, with many of the capital flows negative, it would be necessary to transform the data first by adding sufficient to take them into positive territory. This would change the relationship between different capital flows and would affect the reading of the results.<sup>19</sup>

The Jarque-Bera Test is used to test whether the residuals from the regression are normally distributed (Jarque and Bera, 1980), (Jarque and Bera, 1981) and (Jarque and Bera, 1987). The test takes the form.

$$JB_{mv} = s_3^2 + s_4^2 \quad (2.81)$$

where  $s_3$  is the *sample skew*, defined as

$$s_3^2 = Tb_1b_1'/6 \quad (2.82)$$

and  $s_4^2$  is the sample kurtosis,

$$s_4^2 = T(b_2 - 3K)'(b_2 - 3K)/24 \quad (2.83)$$

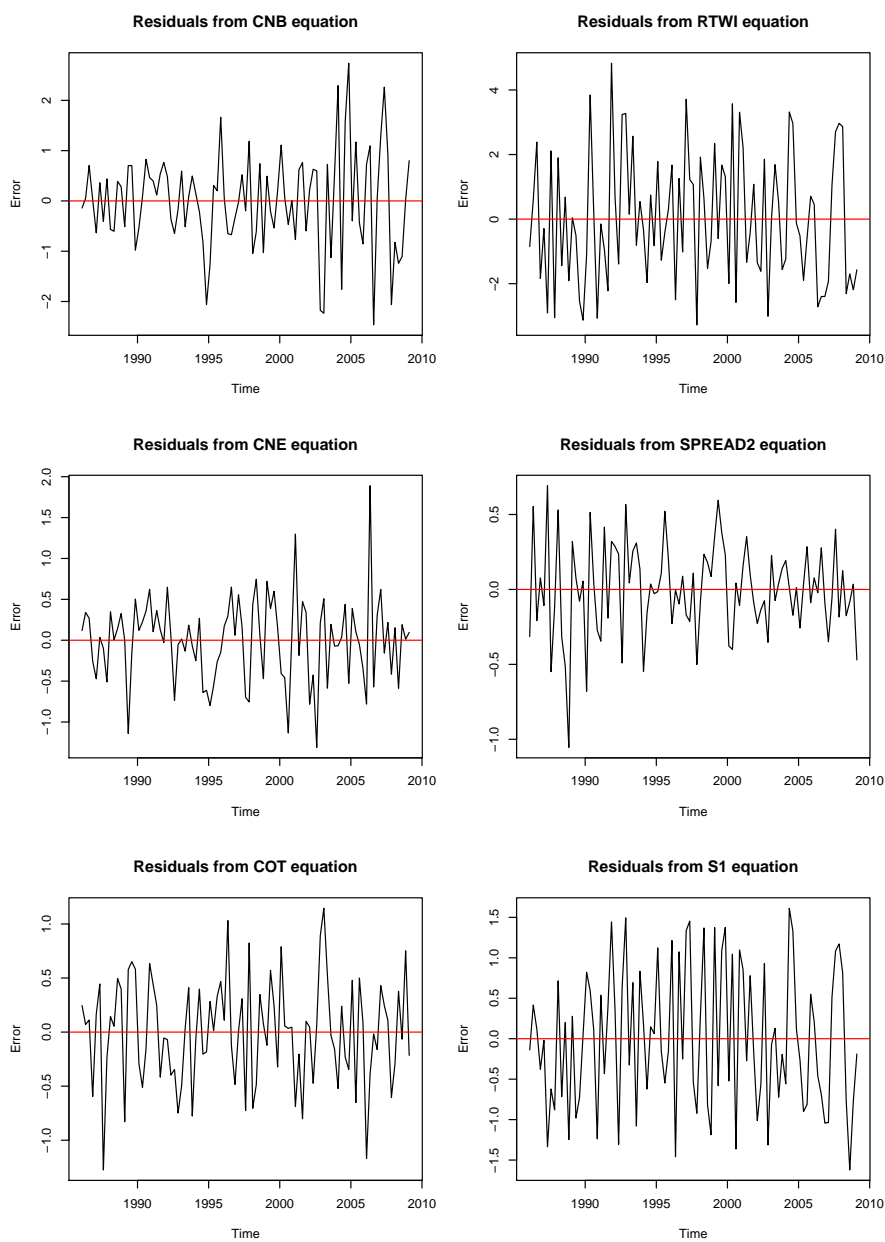
where  $b_1$  and  $b_2$  are the third and fourth non-central moment vectors and  $K$  is the number of endogenous variables (Pfaff, 2008a, p. 31). The tests are presented separately in row denoted normality of Table 2.4. It can be seen that the null hypothesis that the

<sup>18</sup>Half-vectorisation is the stacked lower triangle. For example,  $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$  would be  $\begin{pmatrix} a \\ c \\ b \\ d \end{pmatrix}$ .

<sup>19</sup>The transformation should involve adding sufficient to the raw data to take them into positive territory. Logs can then be taken and the data analysis carried out on the transformed figures. Once results are achieved, the data can be transformed back to original values for the interpretation.

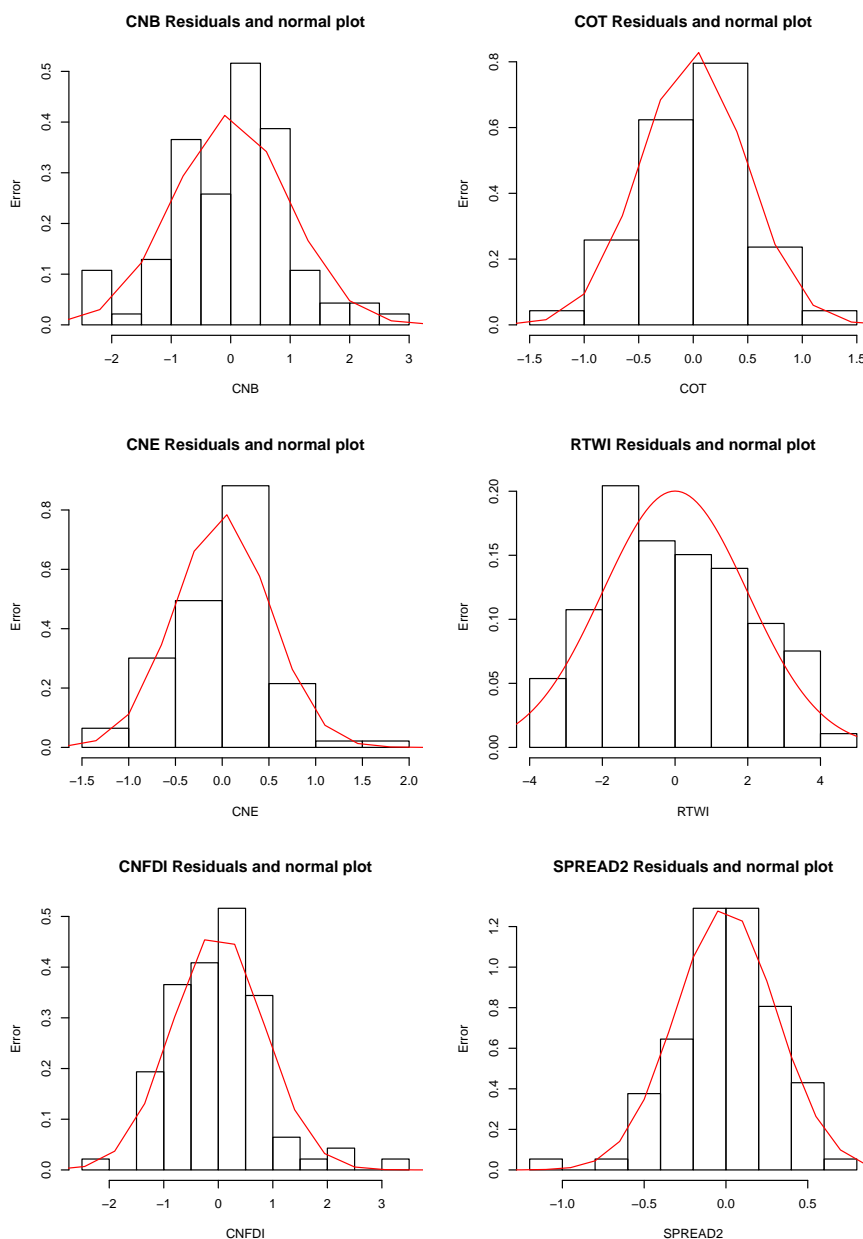


FIGURE 2.6: Time Series of Model Residuals



distribution is free from skew is not rejected but the null of normal kurtosis is rejected. The univariate tests reject the null of normality for the CNE and CNFDI series. This is also evident in Figure 2.7.

FIGURE 2.7: Histogram of model residuals



### 2.4.3 Parameter stability

One of the problems with use of the VAR methodology is the assumption that the parameters are stable over time. Given the tremendous changes that have taken place in the international financial markets, this assumption is not likely to hold. It is evident from Figure 2.6 that there has been a large increase in the size of the international capital flows that are associated with net international bond flows. The increase in official purchase reflects the increase in activity from central banks trying to fix their

exchange rates. One way to deal with this would be to use a model that incorporates time varying parameters. There are examples of these *state space* or *Bayesian Vector Auto Regression* models, but these are not followed here.

An *Empirical fluctuation process* is used to test for model stability. The *generalised fluctuation test* uses an empirical model to construct boundaries that mark the limit of what can be considered stable. The test is on the null hypothesis that the estimated coefficients of the VAR are stable over time.  $H_0 := \beta_1 = \beta_2 = \beta_3 \dots + \beta_T = \beta$ . As common, the residuals are investigated for departures from the assumptions of the model. Investigating the cumulative sum of the ordinary least square residuals (OLS-CUSUM) is more sensitive to small changes or gradual changes in the underlying parameters of the model (Brown et al., 1975). The residuals can be standardised or squared for different forms of the test. The recursive residuals are calculated as

$$\hat{u}_i = \frac{y_i - x_i' \hat{\beta}^{(i-1)}}{\sqrt{1 + x_i' (X^{(i-1)} X^{(i-1)})^{-1} x_i}} \quad (i = k + 1, \dots, n), \quad (2.84)$$

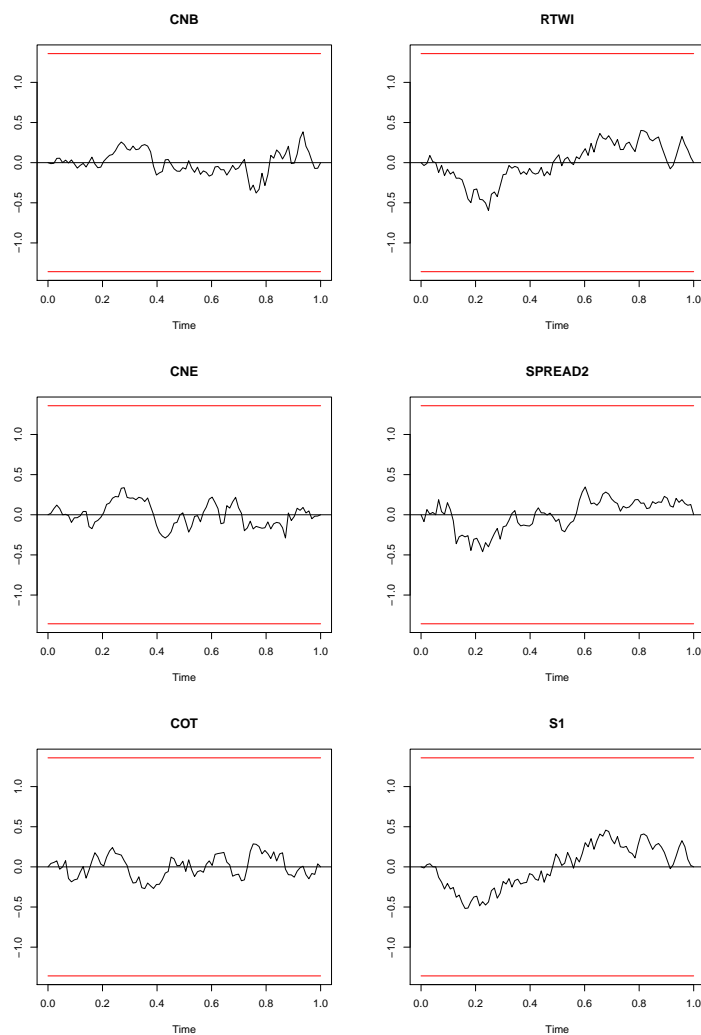
where each estimate  $\hat{u}_i$  is on the series up to point  $i$ ,  $X^{(i-1)} = (x_1, x_2 \dots x_{i-1})$ . Under the null hypothesis the  $\hat{u}_i$  fluctuate around zero with an independent distribution of  $N(0, \sigma^2)$ .

These should fluctuate around zero. If there is a structural break, there will be a deviation from zero that breaks the defined boundary at the point of the break. The OLS-CUSUM empirical fluctuation process is defined by

$$W_n^0(t) = \frac{1}{\hat{\sigma} \sqrt{n}} \sum_{i=1}^{nt} \hat{u}_i \quad (0 \leq t \leq 1), \quad (2.85)$$

The test for stability is based on a departure from zero that is as probable as the power of the test to be applied ( $\alpha$ ). If the evolution of the squared residuals is assumed to be a normal Gaussian process,  $E[W_n^0(t)] = 0$ ,  $V(W_n^0(t)) = i - k$ . The standard deviation of the process is  $\sqrt{i - k}$ . It is usual to define the boundary above and below zero half way between  $k$  and  $T$  with probability equal to  $\alpha$  to define the rejection of the null that the model is structurally stable. In this case,  $\alpha$  is set at 0.05 and is identified by the red, dashed lines in Figure 2.8. See (Zeileis et al., 2002) for more details on the test and its implementation.

FIGURE 2.8: Cumulative sum of residuals stability test



#### 2.4.4 Impulse response functions

Once the base VAR model has been decided, it can be used to assess how variables in the system interact. This is most usually done by creating *Impulse Response Functions* (IRF). These are the graphical representations of the effect of a one unit shock or innovation on one part of the system to any other part of the system. The IRF show how the system deals with disturbances. Technically, this is achieved by using the moving average (MA) version of the VAR and then applying some restrictions to ensure that the shocks can be identified.

The *Wold moving average representation* is used to turn a stable<sup>20</sup> AR process into one

<sup>20</sup>Stability requires that roots of the AR process,  $I - A$  in this case, lie outside the unit circle such that the AR element is less than unity. This has been checked by noting that the roots of the characteristic

that is MA. See (Harvey, 1993, p. 17), (Hamilton, 1994, pp. 64 - 70) or (Enders, 2010, pp. 307-311) for full details.

Starting from the standard VAR representation of Equation 2.70,

$$x_t = A_0 + A_1 x_{t-1} + e_t \quad (2.86)$$

by iterating backwards, this becomes

$$x_t = A_0 + A_1(A_0 + A_1 x_{t-2} + e_{t-1}) + e_t \quad (2.87)$$

so

$$x_t = (I + A_1)A_0 + A_1^2 x_{t-2} + A_1 e_{t-1} + e_t \quad (2.88)$$

after n iterations

$$x_t = (I + A_1 + \dots + A_1^n)A_0 + \sum_{i=1}^n A_1^i + A_1^{n+1} e_{t-n-1} \quad (2.89)$$

and therefore, given that  $A_1$  is less than one as a result of the stability assumption, shocks will have a diminished impact over time as  $A_1^n$  will tend to zero as n tends to infinity. Meanwhile,  $(I + A_1 + \dots + A_1^n)A_0$  is the mean value of the endogenous components. Therefore,

$$x_t = \mu + \sum_{i=0}^{\infty} A_1^i e_{t-i} \quad (2.90)$$

Where  $\mu$  is the mean level of  $y$  and  $z$  in the original Equations 2.67a and 2.67b.

Once the estimates of  $A_1$  have been made, they can be used to assess the effect of a shock or innovation from one series in the VAR on any of the others. However, as discussed in Section 2.3.8 the system is underidentified and therefore some restrictions have to be imposed if the original, structural relationships are to be assessed. In this case, the identification requires that  $A_1$  be replaced by the  $B^{-1}A_1$ . Which would be

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polynomial are outside the unit circle, see (Harvey, 1993, p19-20) for more details. All the unit roots for all the equations have been checked. See line "Roots" in Table 2.4.

$$x_t = \mu + \sum_{i=0}^{\infty} \Phi_i \varepsilon_{t-i} \quad (2.91)$$

when

$$\Phi_i = \frac{A_1^i}{1 - b_{12}b_{21}} \begin{bmatrix} 1 & -b_{12} \\ -b_{21} & 1 \end{bmatrix} \quad (2.92)$$

because the IRFs are now based on the structural errors rather than those of the standard form. Now it is evident that a one-unit shock to  $\varepsilon_t$  will increase  $\mathbf{x}_t$  by  $\sum_{i=0}^{i=n} \Phi_i$  where  $n$  is the number of periods to look forward.

However, if the system is underidentified (as discussed in Section 2.3.8) this will not be possible because not all the components of  $\Phi_i$  will be available. This is where it becomes necessary to make some restrictions to ensure that the system is identified.

Therefore, if  $b_{21}$  is set to zero (ideally because it is deemed plausible due to economic theory), there will be no contemporaneous relationship between a shock to  $y_t$  and  $z_t$ . However, there will still be lagged effects as  $y_{t-1}$  will affect  $z_t$ . The impulse response function will trace out the effect of a shock to one variable on another variable in the system. Because the system is assumed to be stable these shocks will gradually diminish over time. For example, if the auto-regressive coefficient is 0.8%, meaning that the initial shock on a univariate series would increase the dependent variable  $y_t$  by one unit contemporaneously, 0.8% in the period after the shock and by 0.64% two periods after the shock.

The path of the shock can be displayed in a diagram to show the average effect that is expected given the estimated parameters. However, it must be noted that the parameters are estimated with some imprecision and therefore it is usual to also draw some confidence intervals around the path to show the range of possible outcomes that the system suggests is most likely. Therefore, the IRFs show the most likely effect that a shock to one variable will have on one of the other variables and also the range of possible outcomes.

### 2.4.5 Confidence intervals

There are two methods for constructing the confidence intervals. The first is to assume that the error in estimating the coefficients of the system is normally distributed and to use this together with the estimate of the standard error to draw 95% confidence

intervals in the usual way. However, with multicollinearity within the system and some evidence that some of the error terms are not normally distributed (see Section 2.4.2), it is better to use the underlying data to assess the precision of the IRFs by using the *bootstrap method*.

The bootstrap first presented by Efron (Efron, 1979) is a modification or simplification of the *jackknife* method which samples from the sample. While the jackknife systematically excludes one element of the sample, bootstrap takes a random sample from the sample with replacement. In this way the sample is taken as the population and repeated estimates are made of the parameters of interest allowing empirical estimates of the qualities of the estimation to be made.

In this case, the *residual bootstrap* is used. This involves using a random draw of the residuals from the estimated system, calculating estimated values of the endogenous variables and then re-estimating the coefficients of the system before calculating the IRF. If this is done 100 times, the empirical distribution can be used to identify the central 95% (or any other level of precision that is required) of the estimates and use this to define the confidence intervals.

In a simple univariate system,

$$y_t = b_0 y_{t-1} + e_t \quad (2.93)$$

can be estimated to get values of  $\hat{b}_0$  and  $\hat{e}_t$ . These are then used to construct  $\hat{y}_t$  from the estimates ( $\hat{y}_t = \hat{b}_0 y_{t-1} + \hat{e}_j$ ) where  $\hat{e}_j$  is drawn randomly (with replacement) from the sample of  $\hat{e}_t$ . These estimates of  $y_t$  are used to make a new estimate of the system parameters and these are used to calculate new IRF. The process is repeated a large number of times.

The one complication with the multivariate system is the likelihood that shocks to the system may not be independent and in this case it would be better to randomly draw sets of shocks or innovations or to draw one innovation and use that to calculate the contemporaneous errors. There were one thousand bootstraps in this study. The confidence interval was set at 95% so that once the IRF are ranked the 50<sup>th</sup> marks the 5% confidence interval and the 950<sup>th</sup> marks the 5% confidence interval.<sup>21</sup> See Figure

<sup>21</sup>in the R package VARS (Pfaff, 2008b) and (Pfaff, 2008a) the function IRF is used to create impulse response functions from the standard or structural VAR. Options for the function allow estimation of bootstrap or standard confidence intervals. If bootstrap is selected, the number of draws can be specified. The larger the number of samples, the more precise the estimate but the greater the computational cost. See Appendix A Section A.9 for R code that will calculate the IRF from each of the estimated VAR models.

2.4, 2.9 and 2.10 for IRF and confidence intervals for the three systems that have been estimated.

### 2.4.6 Alternative models

As has been discussed in Section 2.3.8, there are some questions about the use of the naive method of identifying the standard VAR model so that the structural IRF can be estimated. In particular, the ordering of the endogenous variables becomes important and this feels unsatisfactory. The Structural VAR method that imposes theory-related restrictions is more satisfying but there remains a risk that the system will be misspecified if the restrictions turn out to be incorrect.

As a result, it was decided that there would be three different systems used to identify the VAR: System One will force the B matrix to be a lower triangle based on the initial order of the endogenous variables (the order is that of Table 2.3); System Two is the same but the order of the variables is selected randomly (see Appendix A Section A.10 for more details of the method, the R code and outcome of this random selection); System Three is the Structural VAR (SVAR) and the restrictions fully discussed in Section 2.3.9. If the three different systems produce three different results then it can be concluded that the method used for identification plays a large part in the results. This would raise doubts about the reliability or robustness of the results. However, the results are very similar. The IRF for the three systems are presented in Figures 2.4, 2.9 and 2.10 respectively.

The aim of this study is to get some understanding of the forces that can drive the real exchange rate from its equilibrium level. Therefore, the main focus here is the effect of an innovation from capital flows to the real exchange rate, and therefore these are the main IRFs that have been drawn. The IRF show the effect of a one-unit shock or innovation for one component of the system to all the other parts of the system (see Section 2.4.4 for a full discussion of the construction of IRFs and the confidence intervals). Remember, when considering the economic significance of these shocks, that in the standard model, capital flows are measured as percentage of nominal GDP which is \$3.6 trillion in the first quarter of 2010. Therefore, a shock or innovation to bonds (CNB), equity (CNE) or FDI (CNFDI) is the equivalent of about \$35bn at present. A one-unit change in the exchange rate index represents an adjustment of about 1% given the index fluctuates more-or-less around 100. An innovation for the Spread series means a 1-percent or 100 basis point increase in US short-term interest rates relative to those in the rest of the world. An innovation for the speculative-sentiment index means that there has been a



ten-percentage point increase in speculators holding US dollars with a short position in either Euro, GBP, CHF or JPY.

It is possible to look at the relationship between some of the other components of the system. For example, IRF of the effect of a one-unit shock to the flow associated with speculative sentiment has a near 1% positive effect on the net inflow to the US bond market and for FDI but has very little effect on net equities. A shock to sentiment has close to % cumulative effect on the interest rate spread. This, together with the information about the relationship between speculative sentiment and FDI, suggests that this speculative sentiment reflects some broad attitude towards the US economy and economic conditions. As would be expected, when there is a shock to speculative momentum there is an outflow of official funds from the US bond market: overseas central banks do not need to support their currencies by buying US dollars and bonds when there is positive speculative sentiment to support the US dollar. It is reassuring that these IRFs are coherent and consistent with economic theory.

#### **2.4.6.1 System three: structural VAR**

As discussed in Section 2.4, Figure 2.4 shows the impulse response of a one unit shock from each of the variables in the VAR on the RTWI using System Three for the identification. The most significant findings are that a one-percentage-point increase in the relative interest rate spread has a cumulative effect of over 10% on the RTWI over the two years following this shock and that this effect is most likely to be between -5% and 12%. This is a series that is designed to capture short-term money market flows, including those associated with the carry trade<sup>22</sup> attempt to take advantage of the breakdown in UIP. It is notable that the effect of the interest-rate spread is large and significant even when other flows that may be affected by interest rates, such as bond or equity, are taken into account. The effects are consistent with evidence from Chapter 4 that UIP does not hold. The evidence is also consistent with the Dornbusch over-shooting model that was discussed in Section 2.2.3. This model suggests that there will be an immediate jump in the exchange rate in favour of the currency with the increase in relative interest rates so that there can be a subsequent reversal to provide a capital loss to offset the income gains from the interest-rate differential (Dornbusch, 1976). However, it is evident from the IRFs that the adjustment is not instantaneous and there is scope to achieve some initial capital gains as the investment currency appreciates to augment the income gains from the relatively high interest rate. The pattern is consistent with the idea that increased interest rates can encourage carry trade activity that will have a positive

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<sup>22</sup>The carry trade is discussed more fully in Chapter 4 but basic ideas is that there is borrowing in a relatively low interest rate currency and investment in a relatively high interest rate currency with the aim of making more on the interest rate differential than is lost in the exchange rate adjustment.

near-term effect on the exchange rate that would undermine UIP in the short-run but may increase the risk of sharp reversals further out. The carry trade will be discussed more fully in Chapter 4.

The speculative sentiment series may also capture some of the carry trade effect as well as momentum and other speculative activity. Figure 2.4 shows that, using the identifications of System Three, a ten percentage point increase in speculative sentiment (S1), meaning the net position of speculators relative to total speculative positions, has an average 4% effect on the real exchange rate over the next 2 years. In the short-run (out to three quarters) the effect is positive in about 90% of the cases. This is the strongest results (in terms of statistical significance) from all the IRFs reported here. The result indicates that speculative activity can have real effects, even outside the very short-run. Given the effect of the real exchange rate on other parts of the economy, it indicates that speculative activity can have real effects on economic activity.

The influence of the other types of capital flow on the real exchange rate are less clear cut. This may not be surprising given the method employed and the nature of these capital flows. The VAR tries to find parameters for the relationships between the series that are stable for the whole of the period under study. Though the analysis of the stability of the system that was conducted was reasonably encouraging (see Figure 2.8 for the graph of the cumulative sum of the residuals) given the tremendous changes that have taken place in international financial markets between 1986 and 2010, it is very likely that relationships have changed over time. This is part of the reason that the confidence intervals are so wide. One way to deal with this would be to allow the coefficients to change over time by estimating a model with time-varying parameters (TVP). For an example of a Bayesian Vector Auto Regression (BVAR) that uses state-space methods for TVP see (Del Negro and Otrok, 2008). There are fuller details in (Koop and Korobilis, 2009). This is an extension that will be made in future research.

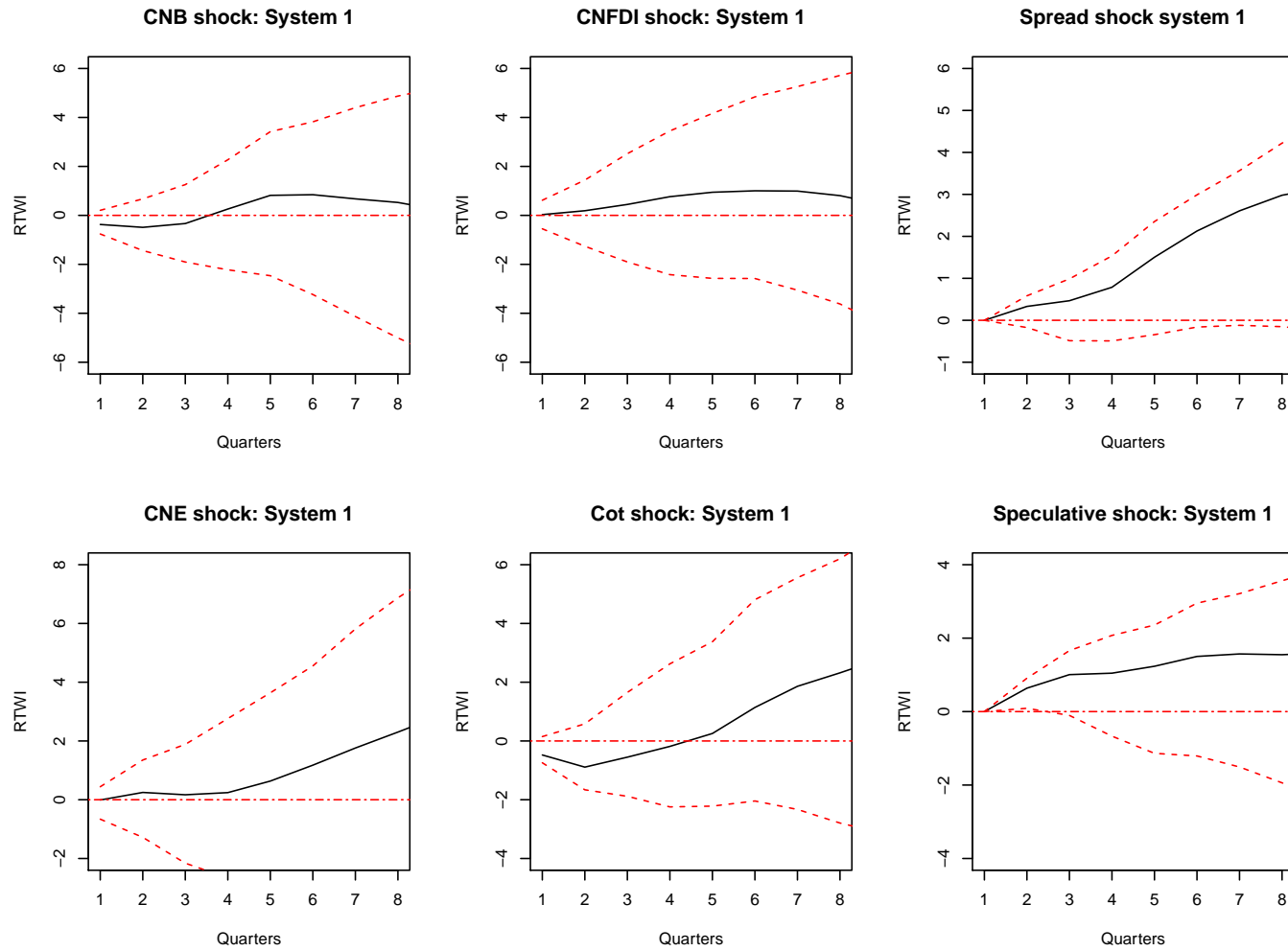
When using System Three for identification, the influence of net bond flows on the real exchange rate is minimal. The effect of a one unit innovation on net international bond flows (CNB) could be between -2% and +2% but is on average close to zero. The result is the same as that found in (Siourounis, 2004). The findings are consistent with the belief that international bond portfolios tend to hedge their activity. This means that for a capital inflow that comes from the bond market, there is an offsetting outflow in the form of a forward rate agreement or swap that will set the price at which the foreign currency receipts will be translated back into domestic currency. In this case, there should be no net effect. (Siourounis, 2004, p 3) cites a survey in (Hau and Rey, 2006) of proprietary data from a *fund of funds* that reports international bond flows to over 100 funds are hedged in more than 90% of the cases compared to just 12% in equities.

For the identification of System Three, a shock to the net international flow of equity (CNE) has virtually no effect on average over the 2 years. However, the confidence intervals are wide (between plus and minus 7%) indicating a variety of effects at different times. The result is something of a contrast to the much more positive relationship established between equity flow and the exchange rate that was found in (Hau and Rey, 2006) and (Siourounis, 2004). These each found a large and significant effect on the exchange rate from equity flows. The limitations of the VAR method outlined above may be at work here. The other studies used nominal rather than real rates and did not include any variables to represent speculation. As such, it may be the case that other studies are picking up some of the effects of speculation when they find that net equity flows have a significant effect on the exchange rate.

An innovation in the net flow of foreign direct investment (CNFDI) has a small, positive but imprecise effect on the real exchange rate. Intuitively, the effect of net foreign direct investment is likely to be more ambiguous given the uncertainty about what it means for exchange rate flows. There are two main ways that international transactions of this category can be completed: paying cash and paying with equity. In the first case there could be a foreign exchange transaction if the acquiring company does not have existing resources or ability to borrow in target currency; in the latter case there is no foreign exchange change unless the receivers of the script sell it to change foreign currency proceeds back into domestic currency. There are also leads and lags and timing issues that suggest a lot of imprecision in the estimation of the effect of this type of flow on the real exchange rate.

An unexpected increase in net official purchase of US bonds (COT) has a positive effect on the US real exchange rate. This indicates that overseas central banks are able to reduce the upward pressure on their currencies through their intervention in the foreign exchange market (buying US bonds in the process).

FIGURE 2.9: Impulse Response Functions for RTWI for System One

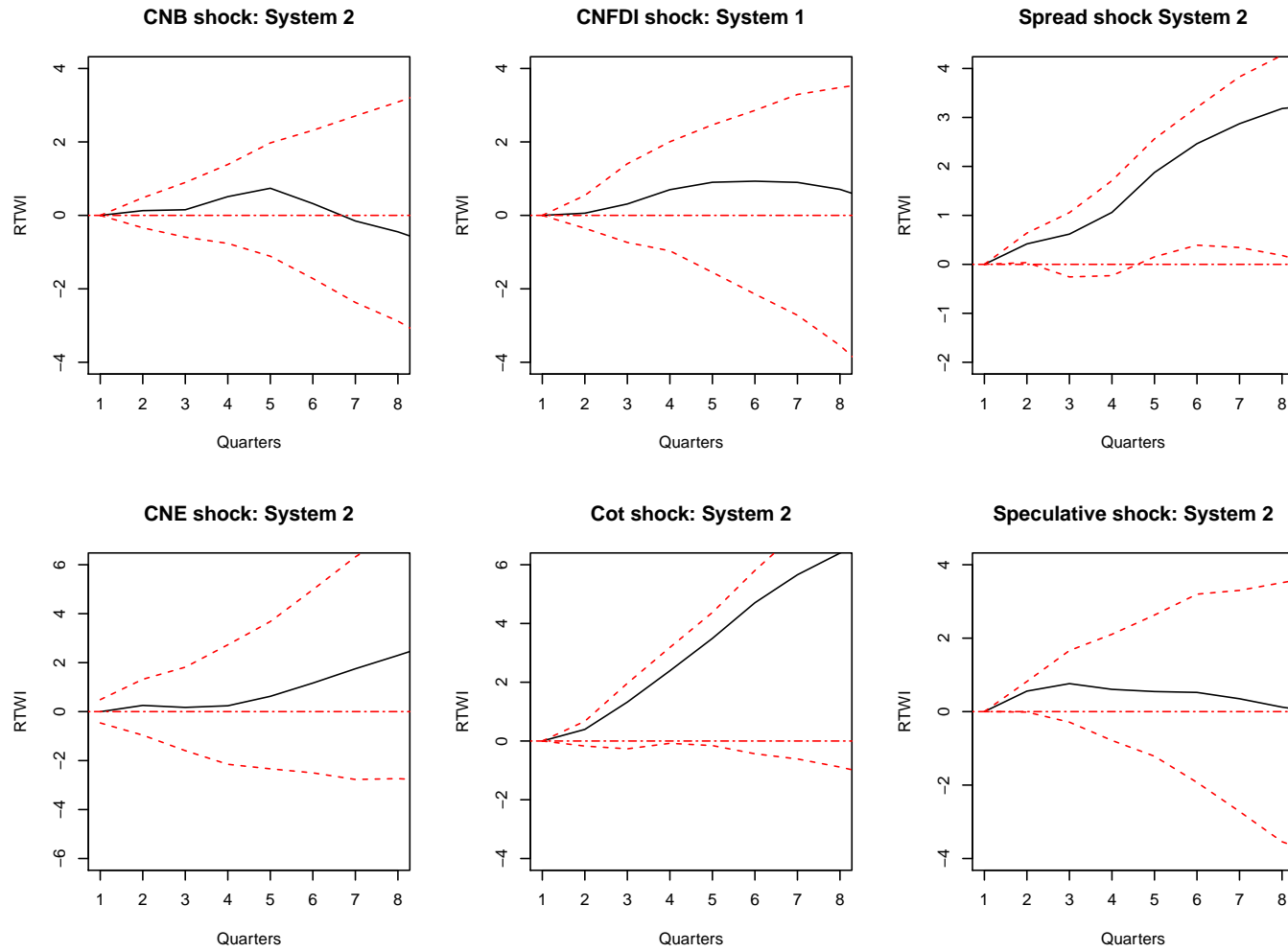


### 2.4.7 Comparison of identification methods

It is encouraging that the broad patterns identified in the IRFs remain very similar no matter which of the three methods is used to identify the system (see Figures 2.4, 2.9 and 2.10 for IRFs created with Systems 1, 2 and 3 respectively). The speculative effects related to sentiment and interest rate differentials are unequivocally positive in all three cases. The other major effect that is identified is that of the positive relationship between the official purchase of treasuries and the exchange rate. The different methods of identifying the system all indicate that the other capital flows have a very uncertain effect on the real exchange rate.

The one difference that is evident in the IRF from the three different system is that for System One the initial impact of a positive shock to the purchase of bonds by foreign official institutions is negative and then turns positive in line with the other two systems. This may be the result of reverse causation as it is most likely that the foreign exchange intervention will take place at times of US dollar weakness as, by definition, this is the time when overseas currencies are appreciating against the US unit.

FIGURE 2.10: Impulse Response Functions for RTWI for System Two



## 2.5 Speculation has real and significant effects

A model of international capital flow and the real exchange rate has been presented. A VAR has been used to estimate the parameters of the system, using data that has been collected from a variety of sources, and these estimated parameters are used to create IRFs that show how the system returns to stability once it has been hit by a shock. Unlike most attempts to assess the relationship between capital flow and the exchange rate, this model includes a role for speculation, and some methods have been proposed here to measure speculative activity. These measures seek to capture two types of speculative activity: sentiment driven and interest rate driven.

The IRFs that have been presented suggest that deviations from PPP can be explained by innovations in net international capital flows and that, contrary to some of the other investigations of this issue, the type of flow that has the most pronounced and significant effect is that associated with speculation. If the assumption is made that PPP is the fundamental value, this means that speculation is the key factor that is driving the exchange rate away from equilibrium. However, the nature of the method used here, derived from the microstructure literature and focused on orders, means that the underlying motivation of the financial flows is not known. It is assumed to include any of those factors that have been left out of the model in the pursuit of parsimony. The reason that speculators become more positive about the US dollar is not known. It may be benign, part of the process of price adjustment, with changes in the underlying fundamentals requiring a need for a change in the real exchange rate (as was discussed in Section 2.2.4), it may be that these changes in the real exchange rate are not justified by economic fundamentals and the speculative activity is upsetting the equilibrium and causing an imbalance.

The type of information that is behind the speculative activity is important. If speculation is informed, it is part of the process of *price discovery*, it is an important part of ensuring that exchange rates reflect economic fundamentals, and it speeds the process that aligns prices with fundamentals; if speculation is uninformed, it is distorting prices and providing false signals. Looking at Figure 2.1 it is clear from the time series graph of the real exchange rate (RTWI in row 2, column 2 of the figure) that there have been some substantial changes in the value of the US real exchange rate. The very large appreciation that is evident in the period between 2000 and 2005 may have been a reaction to fundamentals. It is not possible to determine that from the methods used in this chapter.

The appreciation of the US real exchange rate may be the cause of a number of significant US economic problems: the deindustrialisation of the US economy, the problems faced

by the auto industry and increase in economic inequality. The rise in the US current account deficit has been part of the story of global imbalances and consequent increase in international capital flows contributing, in some eyes, to the sub-prime crisis and financial shock (see Footnote 3 for detail). As such, an investigation of the informational content of speculation is of major importance.

The next two chapters will explore speculation in more detail. Chapter 3 will assess the informational content of speculation with an assessment of speculative sentiment and momentum trading. This is the sort of activity that variable S1 is designed to capture in the capital flow system. Chapter 4 will look in detail at speculative activity that is associated with the *carry trade* and will seek to understand more about the sort of returns that are achieved by that action.



## Chapter 3

# The Informational Content of Speculation: An Event Study

### 3.1 Introduction

There is a fundamental schism in the literature between those that view speculation as uninformed noise activity that can run in waves when affected by common decision-making bias or social influences, and those that view speculation as activity informed by fundamental knowledge that will stabilise markets. In the former case, there is a risk that speculative activity will drive prices away from fundamental value as price changes and sentiment feed off each other. At its most extreme, speculation in this interpretation is likely to turn into a bubble that may burst in a cascade where the previous run-up in price and sentiment is swiftly reversed. However, the alternative view of speculation as an activity that is driven by fundamental knowledge and information would suggest that speculation acts to limit overshooting and divergence from fundamental value, thereby reducing volatility. This second view says that it is the absence of speculators and the liquidity that they provide that encourages excess price movement and volatility. The aim of this chapter is to use the foreign exchange market to assess the relationship between intensity or weight of speculation and the movement of prices. If speculators are uninformed, their most extreme sentiment and their greatest weight in market activity should tend to cause overshooting and presage bubble-bursting, reversals and a crash; if speculators are informed, activity will drive prices towards fundamental value and equilibrium where volatility and crash risk should be reduced.

### 3.1.1 Fundamental value

Fundamental or intrinsic value is a difficult concept to apply to foreign exchange. There is a weight of empirical evidence that standard economic models are not very effective in explaining the behaviour of exchange rates. As already discussed in Chapter 2 Section 2.3.6, Meese and Rogoff found that in out-of-sample forecasts, a random walk performed as well as the four major economic models of foreign exchange behaviour that were employed (Meese and Rogoff, 1983). These findings have been repeated in a number of similar, subsequent studies (Frankel, 1984), (Frankel and Froot, 1990*b*), (Lyons, 1995) and (Sarno and Valente, 2006). In the previous chapter, the fundamental value of the exchange rate was assessed to be PPP. However, even there the real exchange rate was not stable (see Figure 2.1 and view the variable RTWI to see the evolution of the US real trade weighted index over the period 1985 to 2010). Therefore, while the law of one price and purchasing power parity generally determines exchange rates in the long-run for currencies of countries at a similar level of economic development, in the short to medium-term there is still no robust economic model that can consistently explain exchange rate movements, let alone provide a forecast.

As discussed in Section 1.3.1, noise-trading is the label attached to that trading or investment where decisions seem to have been made with no reference to fundamental information; activity is like a random noise. This chapter provides an investigation into the effect of speculation in the foreign exchange market. It seeks to assess the relationship between sentiment, speculation, information and exchange rate prices. The DeLong-Summers model of noise trading is calibrated against daily and weekly returns for major foreign exchange rates (De Long et al., 1990). Little support for the hypothesis that extreme levels of sentiment or extreme levels of speculative activity convey information about the future direction of prices is found. This is something of a contrast to the evidence that has been found in some other markets. See (De Bondt and Thaler, 1985), (Chopra et al., 1992) and (Stein, 1989) amongst others (discussed more fully in Section 3.2.1.1 below). The results of the experiment carried out here suggest that it is not sufficient just to measure the intensity of speculative sentiment or the weight of speculators to determine the divergence from intrinsic value and that the relationship between speculation and price is rather complex. There is evidence here against the idea of speculation as purely noise. Rather, it appears that speculation is part of the price discovery process.

## 3.2 Literature review

In many ways this is a study about how efficient the market is in processing information, specifically whether the presence of speculators improves or reduces the efficiency with which information is processed. As such, there must first be some discussion of information and ideas about the efficiency with which it is incorporated into asset prices.

Bachelier is responsible for the first structured study of informational efficiency in his 1900 doctoral analysis of the behaviour of French government bond, future and option prices (Bachelier, 1900). His is apparently the first analysis that suggested that the evolution of securities' prices was a *Martingale*, meaning that past events do not help to predict the future value, that the expected future value is equal to the current value and that the process is a *fair game* for which the probability of winning or losing is equal. A *random walk* is a slightly stronger construct as each step is an independent and identically distributed random variable. However, a martingale may contain past information about the higher moments. So there may be, for example, volatility clustering. Brownian motion is named after the Scottish botanist Robert Brown and refers to the random movement of particles suspended in a liquid or gas. See (LeRoy, 1989) for an overview of market efficiency, random walks and Martingale processes. Bachelier studied a set of bond prices and found that the potential returns of these 19<sup>th</sup> century French government bonds could be represented by a probability distribution where the mean was zero once the gravitation towards parity at maturity and seasonal cycle of 'dirty prices' with accrued interest had been accounted for.

“ The determination of these fluctuations depends on an infinite number of factors; it is, therefore impossible to aspire to mathematical prediction of it. Contradictory opinions concerning these changes diverge so much that at the same instant buyers believe in a price increase and sellers in a price decrease.”

(Bachelier, 1900, p. 17)

Bachelier's ideas received little immediate attention and remained dormant until renewed interest in the process describing securities prices developed in the 1950s. However, others were tentatively pursuing similar investigations. In the 1930s Working assessed the empirical evidence for random behaviour of stock and commodity prices (Working, 1934) and U.K. statistician Kendall studied the performance of weekly price data from the Dow Jones (Kendall, 1953). Among those taking an interest in the subject were Roberts, who scorned the *patterns* that were identified by professional investors while

making the case for a focus on the change in price of securities rather than the price itself. What we now call *returns* were, argued Roberts, much more random than price levels. He calibrated a model of random shocks to the price change, using the RAND Corporation's random number text (RAND, 1953) and created graphs that were remarkably close to those produced by real stocks. Nonetheless, Roberts warned his research would not prevent people from using past data to try to make investment decisions as "chance behaviour itself provides 'patterns' that invite spurious interpretations" (Roberts, 1959, p. 2).

Towards the end of the decade, Osborne made the direct comparison between the price movement of stocks and the activity of small particles through the analysis of prices of a selection of stocks from the American and New York stock exchanges. The data were collected from *The Wall Street Journal* by a research company called F.W. Stephens for the period from 1924 to 1956. The log of the price ratio for a range of different time periods and their distribution was compared to what would have been expected from something evolving with Brownian motion. By plotting the ratio over time, Osborne showed that changes in the log of the price ratio was close to being normally distributed. Osborne argued that the securities prices jumped around to find the point where buyers and sellers were balanced and overall opinion about the direction of prices was close to zero. Therefore, the evolution of prices was a like a sequence of independent random variables that were the consequence of transactions taking place. The distribution function for this sequence of random variables was, according to Osborne's study, normal with a zero mean and a variance that increased steadily with time. Osborne concluded that the random nature of price changes would ensure that buyers and sellers could only make a standard return on average (Osborne, 1959).

Samuelson provided a theoretical foundation for the idea that securities prices would follow a random walk. Starting with a series of simple axioms, he deduced that competitive markets would drive securities prices towards the expected value, where the expected value is defined as the projected mean of the process underlying the evolution of the price. This introduced the idea of a *Martingales* or the notion that the expected value of a security or financial asset would be equal to its current value. If that is not the case, rational investors in a competitive market will take advantage of the deviation by buying when it is below the expected value and selling when it is above and, as a result of this activity, would drive the price towards the expected level and, in the process, remove the opportunity to make profits. Using the backward iteration of expectations, the theory states that a stock price should equal the expected present value of future dividends. This work provided the underpinning and stimulus for another wave of empirical examinations but rests, of course, on the assumptions made about the competitive nature of

markets and the ability of investors to form expectations about the future (Samuelson, 1965).

Amongst these empirical investigations, Cootner tested Bachelier's ideas on a range of financial markets, most notably the forward market for grain (Cootner, 1960) and Fama found that the returns of stocks in the Dow Jones Industrial Average were very close to the benchmark of a random walk (Fama, 1965). At this point the term *Efficient Market Hypothesis* (EMH) became more widely used. Jensen described market efficiency as

“A market is efficient with respect to information set  $\Omega_t$  if it is impossible to make economic profits by trading on the basis of information set  $\Omega_t$ ”.

(Jensen, 1978, p. 95).

More formally,

$$E[R_{t+1}, Q_{t+1} | \Omega_t] = 0 \quad (3.1)$$

where  $E$  is the expectations operator,  $Q_{t+1}$  is the risk premium at time  $t + 1$ ,  $R_{t+1}$  is the return at time  $t + 1$  and  $\Omega_t$  is the information set at time  $t$  (Jensen, 1978, p. 95). Jensen also said “I believe that there is no other proposition in economics which has more solid empirical evidence supporting it than the Efficient Market Hypothesis” (Jensen, 1978, p. 93). Jensen was, however, identifying a number of inconsistencies and anomalies that had been uncovered and was anticipating a revolution that would overthrow the theory. He was anticipating the paradigm shift that was to follow.

### 3.2.1 Failures of market efficiency

Questions about the EMH had emerged gradually with doubts about some of the assumptions that Samuelson had used in the construction of his theory and with a rising number of indications that financial asset prices did not evolve in a totally random fashion. There were three main strands to the question that arose: empirical evidence that the price of securities did not follow a random walk made up of a series of independent and identically distributed random variables; questions about the effects of institutional structures of financial markets on price; the criticism of VNM expected utility theory as a valid model of investment decision-making.

### 3.2.1.1 Empirical evidence

The empirical evidence that has been gathered about the nature of the returns to securities reveals two primary issues. The first is that serial correlation or trends are evident and the second is the leptokurtic and skewed distribution of these returns. The former is the most damaging to the idea that financial markets can be informationally efficient as it suggests, contrary to the implications of the EMH, that future price changes could be partially foreseen by the movement of past price changes.<sup>1</sup> The evidence seems to support the notion that prices can evolve in trends, and that there are times when positive price developments are more likely to be followed by further positive developments and that there are other times when positive price developments are more likely to be followed by a negative outcome.

There are a number of studies that find evidence that the reaction of stocks to information is less than instantaneous. Ball and Brown seems to be the first study that identifies the upward drift in cumulative abnormal returns after some positive earnings news and downward drift in cumulative abnormal earnings after negative earnings news (Ball and Brown, 1968). Bernard provides a summary of the evidence that stocks react slowly to earnings announcements. He cites twenty examples of “post earnings announcement drift” (Bernard, 1993, p. 303). Part of this under-reaction comes from simply failing to identify what current earnings mean for subsequent quarters. Bernard argues that the evidence is firmly on the side of earning reactions being too small and taking on average six months to be fully digested (Bernard, 1993, p. 305).

Jagadeesh and Titman tested the theory that there is momentum or serial correlation in the stock prices by creating portfolios that bought stocks that had performed well and sold those that had performed poorly over a period of between three months and one year before the selection date. The portfolios record positive abnormal returns initially, but these returns start to disappear beyond the 12 month horizon. The most successful strategy buys stock based on their performance over the previous 12 months and holds for a further 3 months. The return here is 1.3% per month (Jagadeesh and Titman, 1993).

Jeremy Stein also finds evidence of overshooting in the options market, what he calls “the systematic tendency to overemphasize recent data at the expense of other information when making projections” (Stein, 1989, p 1011). Here the term structure of

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<sup>1</sup>This of course depends on the assumption of *risk neutrality* and the notion that investor decisions will be determined by the first two moments of the distribution of expected returns. If the return distribution is skewed or fat tailed or there is serial correlation in the conditional variance of the returns, there may be unexplored opportunities to reduce risk or to increase risk-adjusted returns. As will be further assessed in Chapter 4 the third and fourth moments of the distribution of returns can be extremely important in assessing the level of risk.

implied volatility is inconsistent with rational behaviour or the pricing model. Implied volatilities on the longer term options move almost step-in-step with the shorter ones despite the evidence of mean-reversion and swift decay of volatility shocks, suggesting an overreaction to news that spreads from the short end, where it is appropriate, to the long end, where it is not. Short-term spikes in volatility are likely to be reversed, meaning that the long-dated options should be less affected than the short-dated options.

For a longer investment period, there is some evidence of negative serial correlation. Eugene Fama and Kenneth French studied stock returns over the period of 1926 to 1985 and found slow mean-reversion or negative autocorrelation for return periods beyond one year. This is similar to the cut-off period for positive momentum found in (Jegadeesh and Titman, 1993), suggesting some sort of threshold around 12 months. Fama and French assert that up to forty percent of the 3-to-5 year return variation for small firms is explained by this mean reversion and up to twenty-five percent of the return variation of larger firms over the same time horizon (Fama and French, 1988).

De Bondt and Thaler investigate the issue of overshooting by building *winning* and *losing* portfolios based on the best and worst performing stocks each year. They use data from the Center for Research in Securities Prices (CRSP) on securities from the New York Stock Exchange for the period between January 1930 to December 1982. They then compare the performance of the two portfolios to assess whether there is evidence that investors have contributed to an overshooting of the *winning* stocks and an undershooting of the *losing* stocks. They reject the hypothesis that the returns from the two portfolios are the same and find that on average, over the three years following the portfolio contraction, the *losing* portfolio returns 25 percentage points more than the *winning* portfolio (De Bondt and Thaler, 1985).

The idea that over-and-under shooting can be used to identify securities that have caught up in a wave of positive or negative sentiment has been repeated a number of times. De Bondt and Thaler used the performance over the previous year to identify *winners* and *losers*, other have broken the portfolios into size-adjusted and beta-adjusted components to test the suggestion that the returns recorded are just a compensation for increased risk (Chopra et al., 1992). The main findings are that smaller firms account for the bulk of the gains but that overshooting is still evident. There are other examples where a variety of measures, including the price-earnings ratio (Basu, 1977) and cash flow to price (Chan et al., 1991) have been used to assess the level of over-shooting. It is shown that book-to-market and cash-flow ratios have the most positive impact on positive returns. Lakonishok, Shleifer and Vishny provide an overview of *contrarian* investment strategies (Lakonishok et al., 1994). This whole area is closely linked to the debate about the relative merits of *value* and *growth* stocks, with ample evidence from academic and

practitioners that while growth stocks outperform value in the short-run, in line with the evidence of momentum, there are frequent reversals as over-reactions are reversed.

### 3.2.1.2 Normal distribution

The indications that the distribution of financial security returns are likely to be leptokurtic and skewed would not necessarily undermine the EMH as long as the distributions were independent. However, this evidence that the distribution of returns is not normal, reinforces the view that standard analysis of investment based on the first two moments of the return distribution may not be adequate to understand risk. This is something that will be more fully investigated in Chapter 4 with a study of the carry trade. In addition, if there is a pattern to the evolution of the higher moments over time, which appears to be the case, this can also suggest that there may be informational inefficiencies that can be exploited to make abnormal returns.

For example, volatility clustering means that a period when the returns to financial assets exhibit a high variance is much more likely to be followed by another period with high volatility than one where the volatility returns to some average level. The creation of autoregressive conditional heteroscedasticity (ARCH) and general autoregressive conditional heteroscedasticity (GARCH) models have been designed to understand this process and provide greater precision about the effect that a shock to volatility will have on the system. See (Engle, 1982) for the original model, (Bollerslev, 1986) for the generalised version, (Engle et al., 1987) for an application to time-varying risk premia and (Hamilton, 1994, pp. 657 - 665) for a fuller overview of the subject.

Lo and MacKinlay directly tested the random walk hypothesis for weekly stock returns for the period between 1962 and 1985. The main aim of the study was to compare the ratio of different variances under the random walk assumption. They found significant positive serial correlation for the market return index at weekly and monthly holding periods, indicating that returns were not independent. The variance of a monthly return should be four times that of a weekly return if the evolution of price is a random walk. However, there were clear deviations from this benchmark. Asset price returns do not follow a random walk. (Lo and MacKinlay, 1988).

In 1959 Osborne found that returns were nearly normally distributed. However, the quantile plots that he produced showed that there were slightly more extreme readings than would be expected (Osborne, 1959). This was a finding that was repeated by a number of other studies. With computer power lacking and measurement imprecise, these findings of a small deviation from normality were initially ignored. Paul Cootner



had already found that extreme returns were more likely to be recorded at the daily frequency than at the monthly level. This, he suggested was related to the increased ability of speculators to take action at the lower frequency to limit extreme price movement (Cootner, 1962). However, the mathematician Benoit Mandelbrot rejected this idea, suggesting that the discrepancy between the evidence from the different frequencies was due to sample size (there being much more high-frequency data). It was not what he had found with cotton prices. Mandelbrot had made his own investigation of cotton prices and suggested that serial correlation in the returns was a significant problem and that an alternative distribution would be more appropriate for the returns as there were a number of extreme readings (Mandelbrot, 1963) and (Mandelbrot, 1971).

### **3.2.1.3 Institutional features**

One explanation for this serial correlation of returns is that information is absorbed into price through the process of trading and that this may cause a delay and therefore a gradual adjustment of price. This idea is supported by research that was conducted by John Campbell, Sanford Grossman and Jiang Wang, which compared serial correlation with the volume of trading (Campbell et al., 1993). If a lack of trading causes information to be more gradually absorbed into price, there should be a negative relationship between trading volume and the degree of serial correlation. This study found that for individual and stock indices, serial correlation declined with aggregate trading volume. If this is correct, an increase in trading will increase market efficiency and points to a positive role for speculators.

(Lo and MacKinlay, 1990) argue that one reason for the serial correlation in prices is the asynchronous trading system and the time lag between some stocks reacting to market news. In other words, it could be that the underperforming stocks have not yet reacted to the news that the outperforming stocks have already incorporated. However, this idea is rejected by Jagadeesh and Titman as a result of their method of decomposing returns into market and specific factors (Jagadeesh and Titman, 1993, p. 73). Indeed, Jagadeesh and Titman argue that the momentum that they find in stock price returns is consistent with delayed price reaction to firm-specific news (Jagadeesh and Titman, 1993)

### **3.2.1.4 Decision-making**

As discussed in Section 1.3.2 there are alternative views of the decision-making process. Knight, Shackle, Keynes and others had suggested that that not all decisions could be subjected to a quantifiable, probabilistic approach. In addition, Simon updated the

idea of *economic man* with *global rationality* to something that was consistent with the actual quality of information and computational capacities of economic agents. Simon questioned the model of the *economic man* with stable preferences, clear and voluminous information and computational skill. Simon introduced the term *bounded rationality* to express the limits to VNM rational-decision-making: there is only a certain amount of information that can be processed and probably only a certain amount of information that is available (Simon, 1955, p. 99). Simon wanted to use psychological evidence to support his ideas, but found it lacking at that time. However, as more experimental work on the psychology of decision-making was carried out, empirical support was provided for many of the themes that Knight, Shackle, Keynes and Simon had already proposed.

### 3.2.1.5 Behavioural finance

In 2002 Daniel Kahneman shared the Nobel prize in economics for the work that he did with Amos Tversky. The Nobel committee cited the application of experiments and surveys to question the assumptions of economic rationality and the model of VNM expected utility and to build a more empirically-based theory of how decisions are made as a justification for the award (Kahneman and Tversky, 1979) and (Kahneman, 2012). Kahneman and Tversky present *Prospect Theory* which is an alternative to the VNM expected utility theory (see Section 1.2.3 for an overview of that benchmark case). The theory was developed from the results of a large number of experiments that Kahneman and Tversky carried out to ask people what would be their decision given a choice of alternatives. Kahneman and Tversky then compared their results to those that would be expected from a VNM expected utility model.

Kahneman and Tversky developed a *decision-weighting function*  $\pi = \pi(p)$  which had a similar effect as the adjustments that Keynes makes to standard probability estimates using  $q$  to cover risk aversion and  $w$  to cover uncertainty (see Section 1.3.2). The essential difference between Prospect Theory and the VNM expected utility benchmark are that people underweigh outcomes that are probable compared to certainties, which contributes to relatively high risk-aversion in choices involving sure gains and risk-taking in choices involving sure losses (Kahneman and Tversky, 1979, p. 263). In practical terms, for investors, this encourages the phenomenon of selling winners early to lock in gains and holding on to losers for too long, gambling in the face of adverse consequences. In addition, the people making decisions in the experiments conducted by Kahneman and Tversky are concerned about changes in wealth rather than the level of wealth itself. According to Kahneman and Tversky, this explains why people are prepared to purchase insurance that will cover losses that are a relatively small proportion of their

wealth, losses that they could presumably self-insure without the administration costs of a formal insurance company (Kahneman and Tversky, 1979, p. 286).

More relevant for this study are the *heuristics* or short-cuts to decision-making that have been identified by Kahneman, Tversky and other psychologists. A range of investigations reveal that people deal with the problem of limited information and limited cognitive processing power by using these heuristics that will economise on time and effort. The heuristics allow decision to be made quickly with a limited amount of information. However, they may also create some systematic biases in decision-making that can ensure that, in some situations, investors will make systematic mistakes in their evaluations. If the mistakes are systematic, they should be identifiable and susceptible to exploitation by informed investors. There are a wide range of heuristics that have been suggested, but this study will pay particular attention to *conservatism* and *representativeness*.

Conservatism is the tendency that people have to be cautious about changing their mind. It is very similar to the *convention* noted by Keynes in the *General Theory* where he asserts that

“In practice we have tacitly agreed, as a rule, to fall back on what is, in truth, a *convention*. The essence of this convention - though it does not, of course, work quite so simply - lies in assuming that the existing state of affairs will continue indefinitely, except in so far as we have specific reason to expect a change.”

(Keynes, 1936, p. 152)

There is a certain scepticism about new information and a caution about changing an established opinion. The Psychologist Edwards describes his findings relative to the benchmark of Bayesian decision-making.

“An abundance of research has shown that human beings are conservative processors of fallible information. Such experiments compare human behavior to the outputs of Bayes’s theorem, the formally optimal rule about how opinions (that is, probabilities) should be revised on the basis of new information. It turns out that opinion change is very *orderly*, and usually proportional to number calculated from Bayes’s theorem - but it is insufficient in amount. A convenient first approximation to the data would say that it takes anywhere from two to five observations to do one observation’s worth of work in inducing a subject to change his opinions.”

(Edwards, 1982, p. 359)

Different investors will interpret information in different ways and will require varying levels of evidence to convince them that they should change their opinion about the value of an investment. This is likely to lead to a more gradual adjustment of securities prices to new information than would be expected if there were an immediate absorption of information into price as suggested by the EMH. If investors are conservative in their decision-making, there will tend to be a gradual adjustment to information that would be consistent with trends and serial correlation in returns to securities that could be used to enhance returns. If there are trends, there are inefficiencies in prices that can be exploited.

Another decision-making short-cut that has been identified by a number of psychological experiments is *representativeness*. This is the tendency to estimate the probability of an event by reference to its similarity to the parent population or similarity to the process that generated the parent population. Base effects tend to be downgraded or ignored. Kahneman presents the example of an accident that takes place in a town that has two taxi companies: 85% of the cabs are green and 15% are blue. A witness identifies the taxi involved in the accident as being blue and tests of the witness reveal that she is correct in her assertion 80% of the time. What is the probability that the accident was caused by a blue cab? Most people put the probability in the range of 80% to 50% but it is actually 41%.

By Bayes' Rule (see Section 1.2.3 for derivation).

$$P(B|I) = \frac{P(I|B)P(B)}{P(I)} \quad (3.2)$$

where  $P(B|I)$  is the probability that the car was blue conditional on it having been identified as blue.

$$P(I|B) = 0.80 \text{ as there is 80\% accuracy}$$

$$P(B) = 0.15 \text{ 15\% blue cabs}$$

$$P(I|B)P(B) = 0.80 \times 0.15$$

$$= 0.12$$

$$P(I|G)P(G) = 0.2 \times 0.85$$

$$= 0.17$$

$$P(I) = P(I|B)P(B) + P(I|G)P(G) \text{ as B and G are the only options}$$

$$P(I) = 0.12 + 0.17$$

$$P(B|I) = 0.41$$

(Kahneman and Tversky, 1980)

There is too much influence from the immediate information about the witness and too little about the bigger picture. The information about the proportion of blue and green cars is ignored. However, Kahneman and Tversky reveal that if the thought experiment is changed so that the participants are told that green taxis are involved in 85% of the accidents, the information is regarded as relevant and it is incorporated into the decision-making process and probability estimates are very close to those of the Bayesian calculation.

Therefore, the representativeness heuristic also means that there is a departure from VNM expected utility outcomes and therefore some systematic biases that could be exploited by informed investors. This is consistent with the way that stock analysts over-react to new information (De Bondt and Thaler, 1990) and more generally to the sort of myopic focus on the short-term that Keynes spoke about in Chapter Twelve of *The General Theory* (see Section 1.3.1 for fuller details). It tends to lead to overshooting, over-reaction and the creation of bubbles.

### 3.3 Methodology

The aim of this study is to test whether the noise-trader model provides an appropriate explanation for speculators' activity in the foreign exchange market and whether it can be used more generally to gain an understanding of speculative behaviour. This will involve three steps: the first is to assess the price implication of the noise-trader

model, in particular the price performance when speculative activity becomes extreme; the second will involve measuring speculative activity in the foreign exchange market; finally, it will be assessed whether extreme speculative activity in the foreign exchange market is consistent with the noise-trader model. If the speculative activity that is seen in the foreign exchange market produces results that are like the noise-trader model, it can be said that speculation is noise trading as Keynes asserted, if not it may be more informed as suggested by Friedman. See Section 1.3.1 for detail of these two views.

The noise-trader model used in this study is from De Long, Shleifer, Summers and Waldeman (De Long et al., 1990). This is a derivative of the Samuelson overlapping generations model with two-period agents making a portfolio choice (Samuelson, 1958). There are two assets: a safe asset ( $s$ ) which pays a set dividend ( $d$ ) and is in perfectly elastic supply; the risky asset ( $u$ ) also pays the same dividend but is not in elastic supply. There are two types of investor or trader: sophisticated traders ( $i$ ) who know the fundamental value of the risky assets and noise-traders ( $n$ ) who misperceive the fundamental value. In the absence of noise-traders, the assets are substitutes. Each trader chooses their portfolio in the first period ( $t$ ) to maximise their utility on the basis of their belief about the price of the unsafe asset in the second period ( $t + 1$ ). The representative noise-trader mistakes the price of the risky asset by a random variable

$$\rho_t \sim N(\rho^*, \sigma_{\rho^2}) \quad (3.3)$$

where  $\rho^*$  is the average mistake of the noise-traders and  $\sigma_{\rho^2}$  is the variance of the misperception. Assuming an exponential utility function or constant absolute risk aversion<sup>2</sup>, each type of investor chooses the proportion ( $\lambda$ ) of the risky asset to hold to maximise utility.

$$E(U) = \bar{w} - \gamma \sigma_w^2 \quad (3.4)$$

where  $\bar{w}$  is end of period wealth,  $\gamma$  is a measure of absolute risk aversion and  $\sigma_w^2$  is the variance of wealth. Utility is a function of risk and return. This depends on holdings of the risky asset. For the informed trader this is,

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<sup>2</sup>Though (Tobin, 1958) used a quadratic utility function to show that investor preference could be defined by just the mean and the variance of the returns, the increasing absolute risk aversion this implies does not seem to be a suitable property as it implies people become more unwilling to take risk as they become more wealthy ((Hicks, 1962) and (Arrow, 1965). Constant absolute risk aversion is the (Pratt, 1964), (Arrow, 1965) measure based on  $u(c) = 1 - e^{-\gamma c}$  where the *coefficient of absolute risk aversion*  $A(c) = -\frac{u''(c)}{u'(c)} = \gamma$ . This is a standard device.

$$E(U) = c_0 + \lambda_t^i [r + {}_t p_{t+1} - p_t(1+r)] - \gamma(\lambda_t^i)^2 ({}_t \sigma_{p,t+1}^2) \quad (3.5)$$

where  $c_0$  is the endowment, following the notation in the original paper,  ${}_t p_{t+1}$  is the expected price of the risky asset at  $t+1$ , conditional on information at time  $t$  and  ${}_t \sigma_{p,t+1}^2$  is the expected variance of the misperception conditional on information at time  $t$ .

For the noise-trader utility is

$$E(U) = c_0 + \lambda_t^i [r + {}_t p_{t+1} - p_t(1+r)] - \gamma(\lambda_t^i)^2 ({}_t \sigma_{p,t+1}^2) + \lambda_t^i (\rho_i) \quad (3.6)$$

where the only difference from that of the sophisticated trader is the addition of the final term, which adds utility through the noise-traders' misperception of the expected return from holding  $\lambda_t^i$  of the risky asset.

Maximising utility with respect to the share of the risky asset in the portfolio of the informed ( $\lambda_t^i$ ) and noise-traders ( $\lambda_t^n$ ) respectively,

$$\frac{\delta(U)}{\delta \lambda} = 0 \quad (3.7a)$$

$$\lambda_t^i = \frac{r + {}_t p_{t+1} - (1+r)p_t}{2\gamma({}_t \sigma_{p,t+1}^2)} \quad (3.7b)$$

$$\lambda_t^n = \frac{r + {}_t p_{t+1} - (1+r)p_t}{2\gamma({}_t \sigma_{p,t+1}^2)} + \frac{\rho_t}{2\gamma({}_t \sigma_{p,t+1}^2)} \quad (3.7c)$$

with the only difference between the two being the final term of equation 3.7c which represents the misperception.

The old sell their holdings to the young so that demand of the young must equal unity. Equations 3.7b and 3.7c above imply that

$$(1-\mu)\lambda_t^i + \mu\lambda_t^n = 1 \quad (3.8a)$$

where  $\mu$  is the proportion of noise-traders to total in the market.

by substitution and re-arranging

$$(1 - \mu) \left[ \frac{r + {}_t p_{t+1} - (1 + r)p_t}{2\gamma({}_t \sigma_{p,t+1}^2)} \right] + \mu \left[ \frac{r + {}_t p_{t+1} - (1 + r)p_t}{2\gamma({}_t \sigma_{p,t+1}^2)} + \frac{\rho_t}{2\gamma({}_t \sigma_{p,t+1}^2)} \right] = 1 \quad (3.8b)$$

$$1 = \frac{r + {}_t p_{t+1} - (1 + r)p_t}{2\gamma({}_t \sigma_{p,t+1}^2)} + \frac{\mu \rho_t}{2\gamma({}_t \sigma_{p,t+1}^2)} \quad (3.8c)$$

$$p_t = \frac{1}{1 + r} [r + {}_t p_{t+1} - 2\gamma({}_t \sigma_{p,t+1}^2) + \mu \rho_t] \quad (3.8d)$$

In words, the price is a function of the discounted value of the future dividend, the expected capital gain and the misperception of speculative noise-traders, less the perceived risk. To obtain a more general solution, it is possible to substitute for future expected price, so

$$p_t = \frac{1}{1 + r} \left[ r + \frac{1}{1 + r} \{ r + {}_t p_{t+2} - 2\gamma({}_t \sigma_{p,t+2}^2) + \mu \rho_t \} - 2\gamma({}_t \sigma_{p,t+1}^2) + \mu \rho_t \right] \quad (3.9)$$

If this is repeated, the price becomes the discounted value of the future dividends, the expected capital gain and the general misperception of noise-traders less risk.

$$p_t = 1 + \frac{\mu(\rho_t - \rho^*)}{1 + r} + \frac{\mu \rho^*}{r} - \frac{2\gamma}{r} ({}_t \sigma_{p,t+1}^2) \quad (3.10)$$

In words, the deviation from the true fundamental value of unity is a result of the discounted value of the noise-traders' misperception of the price ( $p_t - \rho^*$ ), multiplied by the weight of noise-traders in the total ( $\mu$ ) plus a perpetuity of the average noise-trader misperception ( $\frac{\mu \rho^*}{r}$ ), adjusted for the risk. This risk is a function of the volatility of the price which, from equation 3.10 is a result of the variability of the misperception of speculative noise-traders. All but the second term in equation 3.10 are constants, and if the variance of the price one period ahead is equal to the variance of the misperception,

$${}_t \sigma_{p,t+1}^2 = \frac{\mu^2 \sigma_\rho^2}{1 + r^2} \quad (3.11)$$

the final price equation becomes.

$$p_t = 1 + \frac{\mu(\rho_t - \rho^*)}{1 + r} + \frac{\mu \rho^*}{r} - \frac{2\gamma \mu^2 \sigma_\rho^2}{r(1 + r)^2} \quad (3.12)$$



De Long and the others use the utility function to compare the outcomes for the two types of investor for different realisations of the parameters. They note four effects: the *Friedman Effect*, which is the tendency of informed investors to push prices back towards fundamental value; *Price Pressure* as the way that speculative noise-traders buy more and drive the price higher as they become more bullish; *Hold More*, whereby the noise-traders hold more of the risky asset; *Create Space* is the added risk that is caused by an increase in the variability of noise-trader belief. The Friedman Effect and Price Pressure tend to reduce noise-trader utility as they work to create losses or reduced gains for noise-trader positions; Hold More and Create Space can increase noise-trader utility and profits (De Long et al., 1990, pp. 14-15). A number of important ideas flow from the model. The main findings are that noise-traders will not necessarily disappear as Friedman had suggested (Friedman, 1953). While noise-traders will tend to get less utility than sophisticated traders, this does not necessarily drive them from the market. The noise-traders expected to get higher utility due to their misperception. The reduction in utility comes mainly from the fact that they are not compensated for taking risk that they are not aware of. This is consistent with the type of over-confident, entrepreneurial misperception discussed in Section 1.3.2 in relation to the returns to speculation. If the noise-traders become aware of the risk that they are taking they are less likely to undertake the activity.

De Long and the others test a variety of specifications that include modest switching from one style of investment to another and changes in the weight of new traders after previous performance. Some result in the disappearance of noise-traders while others suggest that they can become more dominant. The model also explains the importance of investment with a long-term horizon as this is the only way that *noise-trader risk* can be overcome. If agents live for more than two periods, fundamental investors can make an arbitrage between safe and risky assets, driving the price back to fundamental value. Therefore, investors or traders with a reputation that will allow resources and time to consider the long-term would be able to take full advantage of the noise-traders' misperception. The model relies crucially on the institutional or psychological myopia.

Noise-traders drive the price in the direction of their mis-perception. The second and third terms in Equation 3.12 show the deviation from fundamental value due to the fact that the noise-trader mis-perception is not equal to zero but equal to  $p^*$ . This means that the mis-perception is not random but biased in a positive fashion. If the mis-perception is random, we are back to the random walk with noise-traders adding liquidity on each side of the market and the informed traders able to take advantage of any deviation of the price from its fundamental value. There is still some risk that the outcome will be different from the fundamental value, because the noise-traders may still become more extreme in their misperception, but on average informed traders will make

profit if they act. This deviation in the price is what De Long and co-authors call price pressure. While there is no fundamental risk in this model, price pressure causes risk for which there is no compensation and which is assumed by the noise-traders. This is rather similar to the risk created by speculators in the Keynes models where additional uncertainty, in the Knightian sense, encourages more investors towards self-perpetuating myopic behaviour.

### 3.3.1 The implications of the noise-trader model

The aim of this study is to test the implications of the noise-trader model. There are two parameters from the noise-trader price Equation 3.12 that can be used to measure the amount of speculation: the price misperception ( $\rho$ ) and the weight of noise-traders in the market ( $\mu$ ). The aim of this section is to identify the returns that are implied by the noise-trader model when either the intensity of the misperception or the weight of noise-traders is increased to extreme levels so that this can be used as a benchmark against which foreign exchange market activity can be judged.

To understand what the noise-trader model of speculative behaviour means for foreign exchange rates, a *Monte Carlo* simulation is carried out with a variety of mis-perceptions and noise-trader weights. Two time series are created. The first series is based on a random noise-trade misperception, ( $\rho^*$ ). This is called the Misperception Model (MPM). The second is based on a random weight of noise-traders ( $\mu$ ) and is called the Random Weight Model (RWM). The simulation creates a 1000 period price series from Equation 3.12. The dividend paid on the risky asset ( $r$ ) is posted at 10%; the risk-aversion parameter ( $\gamma$ ) is assumed to be 0.3 (in line with that suggested in (Forbes, 2009, p. 127)); starting from a price of 100, the average noise-trader mis-perception ( $\rho^*$ ) is a random variable in the first simulation with a mean of 4 and a variance ( $\sigma_{\rho^*}^2$ ) of 2, and has a fixed value of 4 in the second simulation; the weight of noise-traders ( $\mu$ ) is 50% in the first case but is modelled as a two-period moving average of a normal random variable centred at 50% with a standard deviation of 20% and equally weighted average of its previous value (starting at 50%) to allow smooth adjustment, in the second simulation.

A 1000 period prices simulation is created for each model and the returns for these series are calculated as the log change in price. Those periods when mis-perception or the weight of speculators is *extreme* are identified as those that are at or above the ninety-fifth percentile. These extremes are the *event* for an event study (see Section 3.3.5 for full details of the event study method) and the returns following the extreme are recorded. The simulations are created with software package R (R Core Team, 2013) using the code in Appendix B Section B.2. The package *eventstudies* (Shah et al.,

2011) aligns the defined events (in this case the extreme noise-trader activity) so that descriptive statistics and other analysis can be carried out on the period after the event has occurred. Descriptive statistics for the whole series of returns and for those when misperception or weight of noise-traders are presented in Table 3.1. The process is then repeated for one thousand simulations of each model so that confidence intervals can be established for the estimates of the descriptive statistics.

### 3.3.2 The results of simulation

The results of the simulation are recorded in Table 3.1. It shows that the mean return to an investment strategy in the whole of the sample is very close to zero. However, for each of the extreme readings, there are large negative returns to follow. This is consistent with the structure of the model: noise-traders drive price above intrinsic value and subsequent returns will be negative; the more extreme the misperception or the weight of uninformed speculative noise-traders in the market, the greater the negative return that is likely to be recorded.

TABLE 3.1: Results of the Monte Carlo Simulation of the Noise-Trader Model

	Base Case	Extreme (MPM)	Extreme (RWM)
Mean	-0.00	-0.90*	-0.49
Standard Deviation	0.98	0.49*	0.42*
Skew	-0.07	-0.16	-0.78*
Kurtosis	-0.14	-0.38	-0.35
Number	1000	50	50

Descriptive statistics for the De Long Noise-Trader model (De Long et al., 1990). The Base Case measures the benchmark as returns from prices generated by Equation 3.12 for the whole sample. The MPM measures returns after a period of extreme sentiment when the misperception of noise-traders ( $\rho$ ) is equal to or above the 95th percentile of all the misperceptions; the RWM measures the returns following a recording of extreme weight of noise-traders ( $\mu$ ) is equal to or above the 95th percentile of all noise-trader realisations. The asterisk denotes significantly different from zero at the 95th confidence interval. R Code used to create table is in Appendix B Section B.2.

### 3.3.3 Measuring the intensity of speculative sentiment

The measurement of speculative intensity must identify how strongly speculators believe that the market will move in a particular direction. In the absence of a daily survey of speculators, this study uses *risk-reversal skew* as an objective measure of speculative

sentiment rather than surveys of opinion.<sup>3</sup> This is the relative price of currency put and call options for the same strike price. The *Put-Call-Parity* in the Black-Scholes option pricing model assumes that these will be the same (Black and Scholes, 1973). While the Black-Scholes model is the basis for valuing options, where the price of a non-dividend paying stock trades at a discount to the forward rate equal to the risk free rate, the forward rate in a currency option is determined by the relative interest rate differential between the two currencies. The Garman-Kohlhagan adjustment that accounts for the difference in interest payments on the two currencies is used. The spot discount is determined therefore by the relative interest rate differential for the appropriate maturity (Garman and Kohlhagan, 1983). This model allows the market practice of pricing options from the volatility implied by the model. In other words, the Garman-Kohlhagan is used to extract the volatility that is implied by a specific option price given the strike and other parameters.

As noted above in Section 3.1.1 determining the fundamental value of exchange rates has proved to be extremely difficult. As PPP is, at best, a medium-term phenomenon and given the finding by Meese and Rogoff about the superiority of the random walk relative to other economic models and accepting for the moment the EMH, it will be assumed that the forward rate is the best estimate of the future value of the exchange rate. Any forecast which deviates from the forward rate will in this case be counted as a misperception and the further away from the random walk the greater the misperception.

4

This study uses a unique dataset of *risk-reversals* for eleven major currency pairs. This is the only period for which the data currently exist. The risk-reversal data is very difficult to obtain in an over-the-counter market like foreign exchange where there is no centralised exchange to record and collect information, generally being the property of

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<sup>3</sup>There are a number of surveys of investor opinion that are regularly conducted by financial service information companies. However, these are disparate and, in many cases, unsystematic, and it is not clear whether they measure speculative sentiment or investor opinion more generally. The Wall Street Journal runs an annual survey of investor opinion, but this is focused mostly on US equities. The *Economist* magazine also solicits opinion, but in a relatively unstructured and *ad hoc* fashion. In the foreign exchange market, there is a broad set of market forecasts that was collected by the financial services company *MMS International* (formerly Money Market Services) which polled a broad range of financial market participants on key exchange rates for one and four week forecast horizons. Frankel and Froot found that the median forecast from the MMS survey exhibited trend-following behaviour at the one to three week horizon while there is mean-reversion beyond that point. Frankel and Froot also assess the 'Financial Report' that has been produced by *The Economist* magazine and *Currency Forecasters Digest* and find a wide dispersion of opinion and express some concern about the aggregation of such divergent forecasters (Froot and Frankel, 1989) and (Frankel and Froot, 1987).

<sup>4</sup>As will be discussed more fully in Chapter 4 and was briefly covered in Section 2.2.2, the expected exchange rate should be equal on average to the forward rate once any risk premia has been taken into account. Though it will be seen that UIP and the assumption that the future exchange rate is on average equal to the interest rate differential does not hold, the fact that daily data is being used here and the attention is on the most extreme divergences from UIP suggests that this will not greatly affect the results.

quoting institutions. The risk-reversals are the average prices quoted at 10:00 GMT by major banks on the Thomson-Reuters composite option pages (OPT1) for the period between January 2 1996 and September 6 2002. The risk-reversals are the spread of implied volatility for a 1 month 25 delta at-the-money call option relative to the equivalent put. A call option is the right to buy and a put option is the right to sell. The delta of an option measures the effect of a change in the spot price on the value of the option. This can range from zero for deeply out-of-the-money options to unity for deeply in the money strikes. The at-the-money delta is 50 as there is a 50:50 chance of the option being exercised. The benchmark for option risk-reversals is 25 delta. This is a measure of how far the option is out of the money or how far the strike is from the forward rate.

If the exchange rate trajectory is expected to follow a random walk with drift towards the 1 month forward, implied volatility on the put and the call for the same delta should be equal. Any deviation from this equivalence is an indication that a deviation from the random walk with drift is implied in the market price of options.<sup>5</sup> Therefore, the relationship between implied volatility for calls and implied volatilities for puts for the same delta and maturity can be taken as an indication of how much more expensive calls are relative to the equivalent put or as the market bias towards puts over calls or, in this case, as an indication of market sentiment. The larger the absolute level of the risk-reversal skew, the greater the relative price and, in equilibrium, the greater the belief, expressed through the action of market participants or the inventory of market-makers, that there will be a deviation from the forward rate. If extreme deviations or speculations are noise they should presage a sharp reversal. If speculation is informed, this is part of the price discovery process and extremes may be followed by calm conditions around a new equilibrium.

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<sup>5</sup>If the risk-reversal for a 1-month USD/CAD is quoted at 0.15-0.28% and the implied volatility is 8.50%, the market-maker would be willing to buy the 1-month 25 delta USD-put-CAD-call at 8.65% and sell the USD-call-CAD-put at 8.50%. The dealer pays 0.15%. Alternatively, the dealer would sell a 25 delta call at 8.78% and buy the USD-call-CAD-put at 8.50%, earning 0.28% (Kapner, 2006).

TABLE 3.2: Descriptive Statistics for Daily Exchange Rate Returns: 2 January 1996 to 6 September 2002

Statistic	AUD	EURGBP	EURSEK	GBP	CHF	EURCHF	EURJPY	EUR	CAD	JPY
Number	1685	1675	1716	1667	1674	1674	1675	1668	1683	1675
Mean	-0.0174	-0.0187	0.0011	0.0025	0.0120	-0.0039	-0.0072	-0.0172	0.0084	0.0076
Median	0.0000	-0.0298	0.0000	0.0000	0.0114	0.0000	0.0000	-0.0253	0.0000	0.0188
Standard deviation	0.7241	0.5542	0.0438	0.0489	0.6819	0.0277	0.8416	0.6338	0.0363	0.8170
Max	5.8301	3.0543	2.1633	2.2573	3.5086	1.6477	4.0879	2.4136	2.2170	5.1788
Min	-3.4666	-2.2858	-2.2900	-2.2701	-3.6525	-1.8466	-8.2848	-2.2901	-2.9707	-10.6573
Skewness	0.1206*	0.2923*	0.0432	-0.0452	-0.1423*	-0.4046*	-0.7388*	0.1738*	-0.1095	-1.7237*
Kurtosis	4.17*	1.88	2.43*	1.48	1.96	5.84*	7.08*	1.12	5.11*	21.52*

Continuously compounded returns (multiplied by 100) for period 2 January 1996 to September 2002 for US dollar per unit of Australian dollar (AUD), UK sterling per unit of Euro (EURGBP), Swedish Crown per unit of Euro (EURSEK); US dollar per unit of UK sterling (GBP); Swiss franc per unit of US dollar (CHF); Swiss franc per unit of Euro (EURCHF); US dollars per unit of Euro (EUR); Canadian dollars per unit of US dollar (CAD); Japanese yen per unit of US dollars (JPY). The asterisk (\*) means that the estimate is significantly different from zero at the 5% level using t-statistics for the mean and the standard error of skew and standard error of excess-kurtosis respectively. Codes for table available in Appendix B Section B.4.

Table 3.2 shows descriptive statistics for the exchange rate data used in the study. There are daily data for the period between January 1996 and September 2002. This is the period for which risk-reversal data are available. The series are of slightly different lengths as there are some gaps in the risk reversal and exchange rate data as a result of holidays and market closures. From the raw data continuously compounded returns are calculated and multiplied by 100. The first thing of note is that the mean return does not appear to be statistically different from zero. This is what would be expected if, as has been identified in many studies, exchange rates follow a random walk. This apparent stability hides some significant changes that are taking place below the surface. For example, the Japanese yen records an appreciation of 10.66% on one day. Most of the exchange rate series appear to be skewed in some way and there is also evidence of kurtosis in many cases. An asterisk is used to denote statistical significance at the level of 95% confidence. A t-test is used for the mean; a *standard error of skew* and a *standard error of kurtosis* are used for the skew and kurtosis respectively. These are calculated as  $SES = \sqrt{\frac{6n(n-1)}{(n-2)(N+1)(N+3)}}$  and  $SEK = \sqrt{\frac{n^2-1}{(n-3)(N+5)}}$ , with the assumption that this estimate is distributed normally, the skew or kurtosis is considered significant if it is more than two standard errors from zero. The statistics are generated using the code in Appendix A Section B.4.

TABLE 3.3: Descriptive Statistics for Risk Reversals: 2 January 1996 to 6 September 2002

Statistic	AUD	EURGBP	EURSEK	GBP	CHF	EURCHF	EURJPY	EUR	CAD	JPY
Number	1702	1697	1719	1691	1374	1339	1697	1692	1701	1697
Mean	-0.37	0.15	0.71	-0.08	-0.28	-0.38	-0.48	0.19	0.12	-0.74
Median	-0.30	0.10	0.80	-0.10	-0.15	-0.30	-0.10	0.10	0.15	-0.55
Standard Deviation	0.38	0.37	0.51	0.33	0.49	0.36	1.02	0.49	0.25	1.02
Max	0.45	1.72	1.90	1.00	1.05	0.50	1.70	2.05	1.45	2.05
Min	-1.70	-0.80	-0.30	-1.35	-2.05	-1.80	-4.03	-1.15	-0.65	-4.00
Skewness	-0.50*	1.27*	-0.23*	0.33*	-0.79*	-0.58*	-0.93*	0.68*	0.23*	-0.51*
Kurtosis	0.02	2.29*	-1.67	0.72	0.69	0.19	0.15	0.96	1.83	-0.03

Daily risk reversal skew. Risk reversal is the premium of implied volatility for calls relative to the equivalent put (equal distance to the strike price, 25 delta in this case). A figure above zero means that calls are more expensive (in volatility and price terms) than puts. A figure below zero means that puts are more expensive. The asterisk (\*) means that the estimate is significant at the 5% level using t-statistics for the mean and the standard error of skew and standard error of excess-kurtosis respectively. These are calculated as  $SES = \sqrt{\frac{6n(n-1)}{(n-2)(N+1)(N+3)}}$  and  $SEK = \sqrt{\frac{n^2-1}{(n-3)(N+5)}}$ , with the assumption that this estimate is distributed normally, the skew or kurtosis is considered significant if it is more than two standard errors from zero.



Table 3.3 gives the descriptive statistics for the risk-reversal data. The statistics are generated using the R code in Appendix B Section B.4. For a neutral risk-reversal, a reading of zero, there would be no price preference for calls or puts at the similar delta. The figures show that, in contrast to the average returns, there are often average skews that are different from zero. The most significant of these are the positive bias for EUR-GBP and a negative bias for USD-JPY. The latter may be related to hedging activity by Japanese exporters. While this could suggest that implied volatility is an imperfect measure of speculative activity, note that extreme readings are based on quantiles of the distribution and therefore an underlying hedging-induced shift in the mean of the distribution should not affect the results. In other words, if the extreme is denoted by the 90th percentile, it does not matter if the mean is zero and this comes at 0.8 or if the mean is 0.2 and this comes at 1.0.

### 3.3.4 Measuring the proportion of speculators

Recording speculative activity in an over-the-counter market like foreign exchange is extremely difficult. However, there are some exchange-traded currency derivative markets in the US, and participants in these markets are required to report their positions to the US regulators. The Commodity Futures Trading Commission (CFTC) was set up by Congress in 1974 to regulate commodity future and options markets. The CFTC collect weekly information about the open positions held by private entities in the US derivative markets. A sub-set of this information is released to the public each week as the *Commitment of Traders Report* (CoT). The weekly release has been in place since September 30, 1992. Before that the data were released every two weeks. The CoT is released each Friday and details the positions outstanding the previous Tuesday (CFTC, 2012).

The CFTC require traders to categorise themselves as being either commercial (C) or non-commercial (NC). Commercial traders must have some underlying business interest in the security, commodity or instrument that they are trading. These could be seen as natural hedgers. Non-commercial accounts are generally considered to be speculators. See (Sanders et al., 2004) and (Wang, 2004) for examples of previous use of this data in this fashion.

The administrative requirements are more onerous for non-commercial accounts but the CFTC have the right, which they use, to re-categorise parties if they are not happy with the self-selection. Positions are either long or short, meaning that they will receive or deliver the underlying; for non-commercial accounts there are also *spreading* positions which are simultaneous holdings of long and short positions in different maturities of

the same contract, taking a position on the spread between two maturity dates. These are assumed to be speculators. The CFTC data also report *Open Interest* (OI) which is the record of outstanding open positions.

If it is assumed that futures and cash markets are two separate markets and that most participants have a preference for one or the other and therefore do not frequently switch; if it is also assumed that the nature and level of speculative activity in the futures market is an indicator of what is happening in the broader spot market, it will be possible to use this data, which measures speculative activity in the futures market to assess the intensity and level of speculative activity in the foreign exchange market more generally. In other words, the futures market is used as a sample of the entire foreign exchange market. This is important because, unlike many other financial markets, it is the cash foreign exchange market that dominates in terms of activity and liquidity. The futures market is relatively small (BIS, 2010).

It could be argued that this is a biased sample as it is a US market. Though international financial markets are global in nature, there is some evidence to support this claim. For example, there is a tendency to have a positive holding of the overseas currency as this is a hedge for exporters. Nonetheless, as was argued with the risk-reversals, it is the relative rather than absolute position of the signal that will determine the extreme and therefore if the US sample is proportionate to the population, sample signals can still be regarded as measuring an extreme. If the distribution of the sample itself is different from the population this is a problem, but there is no evidence that this is the case.

The data used run from September 30 1998 when the data started to be released on a weekly basis and continue up to December 31 2008. This date is shortly before this part of the research was started. The Euro data runs from March 3 1998 to December 31 2008. There are two gaps in the Swiss Franc data for September 14 2004 and September 21 2004. The absence of these data seems to be a result of problems with the CFTC database. The contracts are for EUR 100,000; GBP 62,500; JPY 12,500,000; CHF 100,000 and CAD 100,000. For the CoT data, two series are created: S1 measures the net long non-commercial positions relative to total non-commercial positions and S2 measures the net long non-commercial positions relative to open interest. Table 3.4 given an overview of the descriptive statistics for the returns on the weekly foreign exchange rates that are relevant for the futures market data. There are no significant differences from the daily data that is used in the risk-reversal part of the study recorded in Table 3.2. Once again, the mean return is very close to zero. This is consistent with the idea that exchange rates follow a random walk. The distribution of returns are skewed for some pairs and often fat-tailed (identified with an asterisk where statistically significant

TABLE 3.4: Descriptive Statistics for Weekly Exchange Rate Returns: 30 September 1998 to 31 December 2008

Statistic	EUR	JPY	GBP	CHF	CAD
Number	522	849	849	847	849
Mean	0.0351	0.0337	-0.0202	0.0233	0.0018
Median	0.0650	-0.0800	0.0000	0.0000	-0.0200
Standard deviation	1.4063	1.6355	1.2755	1.5418	1.0558
Max	8.7900	11.6700	5.7200	8.3400	10.0100
Min	-4.2400	-15.0400	-6.4100	-5.7100	-5.0900
Skew	0.27*	-0.06	-0.34*	0.31*	0.78*
Kurtosis	2.76*	12.58*	2.07 *	1.82	11.59*

Continuously compounded returns multiplied by 100 for US dollar per unit of Euro (EUR), US dollar per unit of Japanese Yen (JPY), US dollar per unit of UK Sterling (GBP), US dollar per unit of Swiss Franc (CHF) and US dollar per unit of Canadian dollar (CAD) for the period 30 September 1998 to 31 Dec 2008; An asterisk (\*) means that the estimate is significantly different from zero at the 5% level of statistical significance using t-statistics for the mean and the standard error of skew and standard error of excess-kurtosis respectively. These are calculated as  $SES = \sqrt{\frac{6n(n-1)}{(n-2)(N+1)(N+3)}}$  and  $SEK = \sqrt{\frac{n^2-1}{(n-3)(N+5)}}$ , with the assumption that this estimate is distributed normally, the skew or kurtosis is considered significant if it is more than two standard errors from zero.

as either a t-test or a test of the standard error of skew or standard error of kurtosis as calculated above).

Table 3.5 shows the descriptive statistics for the two measures of speculative sentiment. The first (S1) is measured as the net non-commercial long and non-commercial short proportionate to the sum of non-commercial positions long and short positions; (S2) is measured as the net non-commercial long and spreading positions proportionate to open interest. The first captures directional speculation and, as can be seen from a number of minimums, this can reach 100%. The second records the weight of speculation relative to everything else in the market. The former is more sensitive, as can be seen by the range and the standard deviation; the second is usually above zero because there are always some spreading positions that seek to take advantage of calendar spreads and other strategies.

TABLE 3.5: Descriptive Statistics for S1 (Speculative Sentiment) and S2 (Speculative Weight): 30 September 1998 to 31 December 2008

Statistic	EUR		JPY		GBP		CHF		CAD	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Number	522	522	849	849	849	849	847	847	849	849
Mean	31.31	43.43	-23.90	44.21	2.76	41.68	-21.14	46.13	6.68	41.23
Median	42.75	39.56	-33.30	43.56	11.15	38.88	-37.32	42.88	7.44	39.81
Standard deviation	41.94	16.13	51.49	12.17	60.59	16.46	60.76	15.73	55.26	15.33
Max	95.67	86.06	87.43	84.50	96.15	89.45	100.00	92.49	100.00	86.63
Min	-100.00	11.15	-99.83	12.88	-100.00	9.10	-100.00	14.61	-90.08	11.89
Skew	-0.88*	0.55*	0.33*	0.57*	-0.17	0.76*	0.45*	0.65*	0.02	0.50*
Kurtosis	0.18	-0.57	-1.14	0.64	-1.45	0.15	-1.25	-0.15	-1.35	-0.28

S1 is the first sentiment indicator, calculated as ratio of net non-commercial long less non-commercial short to the sum of non-commercial long and short positions multiplied by one hundred. S2 is the second sentiment indicators, calculated as the ratio of net non-commercial long to net non-commercial short plus spreading to open interest. An asterisk (\*) means that the estimate is significantly different from zero at the 5% level using t-statistics for the mean and the standard error of skew and standard error of excess-kurtosis respectively. These are calculated as  $SES = \sqrt{\frac{6n(n-1)}{(n-2)(N+1)(N+3)}}$  and  $SEK = \sqrt{\frac{n^2-1}{(n-3)(N+5)}}$ , with the assumption that this estimate is distributed normally, the skew or kurtosis is considered significant if it is more than two standard errors from zero.

### 3.3.5 Event studies

The event studies method was introduced briefly in Section 3.3.1 with a description of how the extreme speculative sentiment and extreme speculative positions in the DeLong model could be used to analyse future returns. Fuller explanation is provided here. Event studies are used to find the effect of a particular event on the performance of an asset price or security. It is often suggested that James Dolley was the first to employ the event study when looking at the effect of a stock split on the price of securities.<sup>6</sup> Dolley took a sample of 174 stocks splits for all common stocks listed on the New York Stock Exchange during the period 1921 to 1931, and using what he called a case study, examined the process of stock splitting. Price information was taken from *Poor's Manual* and *Moody's Manual* as well as the *New York Times*; a survey was sent to all the companies that were involved and (remarkably) 63 of the 111 questionnaires were returned completed. The analysis of the price change was a very small part of the study. Dolly found that of the 95 stock splits that he had been able to compile a time series for, 57 subsequently rose and 26 fell (Dolly, 1933).

However, Dolly only looked at the market reaction the day after the stock split. This was some time after the stock holder meeting that would have ratified the decision of the management. Myer and Bakay argued that, if stocks tend to rise after a stock split, it would be best to buy the stocks when the announcement is made and before the split takes place and that, therefore, the price adjustment is likely to be spread over a number of days. They decided to measure the price action from a point eight weeks before the formal acceptance of the decision by the stock-holders. They measured the price change between the base date and the meeting and tried to account for other influences on the price by recording the ratio of the stock price to the Standard and Poor Industry average, thereby providing the first attempt to separate the specific returns from those of the market. An additional measure of the price ratio was also taken eight weeks after the formal meeting. For the splits that occurred between 1945 and 1946 they found that 62 of the 70 stocks exhibited a positive price performance between the base date and the meeting, during the subsequent time there was some reversal with only 55 of the stocks still showing a net gain between the base and the closure point eight weeks after the announcement meeting (Myers and Bakay, 1948).

Fama, Fisher and Roll use the event study method to conduct a much more systematic assessment of the effect of stock splits on security returns (Fama et al., 1969). Fama later said that the method was secondary to his desire to show off the new dataset that he had

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<sup>6</sup>A stock split is when the number of shares are doubled and the value of each share is cut in half. This is usually done to prevent the price or cost of each share rising too far beyond the means of the small investor.

helped to construct. This was one of the first uses of the Center for Research in Security Prices (CRSP) data. Nonetheless, the Fama study is considered to be the benchmark of Event Studies and it is the framework that is largely followed in the current work.

The event is identified and the time at which the event occurs is marked as time zero (or  $t_0$ ). Returns to the reference security in a window before and after the event are recorded and compared to the normal or expected returns. Therefore,

$$AR_{i\tau} = R_{i\tau} - E[R_{i\tau}|X_\tau] \quad (3.13)$$

Where  $AR_{i\tau}$  are the abnormal returns for security  $i$  at time  $\tau$ ,  $R_{i\tau}$  are the actual returns to security  $i$  at time  $\tau$ ,  $E[R_{i\tau}]$  are the expected returns for security  $i$  at time  $\tau$  conditional on the information  $X_\tau$  and  $\tau$  is the time relative to the event. Estimating the normal or expected returns is one of the key challenges of an event study. It is usually tackled in one of two ways: the security can be assumed to take a mean return or, as in the case of the paper by Fama and the others, a market model can be used. The original market model just takes a constant relationship between security returns and the market estimated by a linear regression. Subsequent models have added additional factors.

The mean return is calculated as

$$\mu_{R,i} = \frac{1}{n} \sum_{j=1}^{j=n} R_{ij} \quad (3.14)$$

where  $R_{ij}$  is the return to security  $i$  at time  $j$  and  $n$  is the number of total number of observations to that

$$E[R_{i\tau}|X_\tau] = \mu_{R,i} + \varepsilon_{i,\tau} \quad (3.15)$$

with  $\varepsilon_{i,\tau}$  being a random variable that is assumed to be normally distributed with a zero mean and a standard deviation of  $\sigma_{R,i}$ . The simple market model is estimated by

$$R_{i,j} = \alpha + \beta_i R_{m,j} + \varepsilon \quad (3.16)$$

Where the  $\beta_i$  is the relationship between the market return  $R_{m,j}$  and the return on the security of interest  $R_{i,j}$  and  $\varepsilon$  is a random variable that represents all the idiosyncratic factors that affect the returns to the security.

The lack of any clear benchmark for currency returns and the fact that theoretically exchange rate returns should be on average equal to the forward rate, have made the case for a mean model. The seminal event studies have used equities and a market model. The expected return is zero and any returns that differ from that are identified

as abnormal. Theoretically, the forward rate should be used but given the high frequency of the data, the interest rate differential is ignored. The evidence about returns in Tables 3.2 and 3.4 suggests that this is not likely to be a major problem.

### 3.3.6 Analysis of events and abnormal returns

The aim of the study is to assess the effect of extreme speculative positions on future returns to ascertain the informational content of these extremes. Therefore, the events that will be used to assess abnormal returns are the extreme readings on sentiment and the extreme presence of speculators. Any reading above the ninety-ninth percentile or below the first percentile is deemed to be extreme. For the risk reversal skew, as a secondary test, a reading above the ninety-fifth and below the fifth percentile is also established as an event. The Event Studies R package was used to manage the data see (Shah et al., 2011) for fuller details on the package and its use. The cumulative abnormal returns for the whole of the event window (CARW) and the cumulative abnormal returns for after the event (CARA) were recorded. These cumulations are just the summation of the continuously compounded returns over the appropriate period.

The R code that is used to produce the results in Tables 3.6 and 3.7 is in Appendix B Section B.5. The date of the events, 1st, 5th, 95th or 99th percentile, reading of the risk-reversal skew or the level of speculative positions, are identified and the exchange rate returns for the window around the event are aligned so that the average for each event and each event day can be calculated. For example, in Table 3.6 the analysis of the event that the risk-reversal skew for the EUR vs the US dollar is an extreme low (measured as being equal to the 5th percentile or lower), all 106 cases of this extreme for the period under study are aligned and the average cumulative returns for the whole window (CARW - one day before and after the event in column four) and the post-event window (CARA - the event and the day after the event) are calculated. A *bootstrap* is conducted. This means that a sample of size 106 (in this case), with replacement, is drawn from each of the event days and new means are calculated for the CARW and CARA. If 95% of the means that are calculated after drawing random samples from the array of windows are above or below zero, it is assumed that the figure is statistically different from zero, and this is represented by an asterisk in the table.

## 3.4 Analysis of the results

Table 3.6 shows the result of the event studies that were carried out on extreme risk reversal. For each exchange rate the second column distinguishes between extreme high

and extreme low, the third column identifies the number of extreme events that were recorded and the next two are the cumulative average returns for the whole window (CARW) and the cumulative average returns for the period of the event and afterwards (CARA). The windows were chosen to correspond to one day and one week of trading. However, Figure 3.1 makes it clear that altering the size of the event window does not change the findings to any significant degree.

Looking down the seventh column (the 4-day CARW) shows the average cumulative return for the period from four days before the extreme event to the four days after the extreme for extreme sentiment highs and lows of each currency pair. The extreme highs are (in this case) those points when the risk-reversal skew is at or above the 95th percentile. It should not be surprising to see that the extreme highs are associated with positive returns, which appear in many cases to be significantly different from zero (where significance is identified as more than 95% of 1000 random bootstrap samples taken from the events being above zero). It is clear that, as speculators become more extreme in their opinion, prices are driven in the direction of sentiment. It shows that the spot price is following the option risk-reversal skew and, as Figure 3.1 reveals, it would be even more pronounced if the event window just ran from the starting point to the event. The findings here are consistent with the evidence that orders and sentiment drive prices (Evans and Lyons, 2002), (Sanders et al., 2004) and (Wang, 2004).

What is more interesting is whether knowledge about the extreme reading at time  $t = 0$  provides any information about future returns. If it is known that speculative sentiment is at the extreme, does this mean that it is more likely that there will be a reversal? Is there an inefficiency? This information is provided in columns 5, 8, 11 and 14 of Table 3.6. A reversal is indicated by a significant negative reading for highs or positive reading for lows. Looking, for example, at the four-day window in column 8, it is clear that the extreme risk reversal skew does not provide any information about future returns. Of the eighteen cases using the 95% th percentile to identify an extreme, ten show a continuation, rather than a reversal, that is not significantly different from zero; one shows a significant continuation; five show reversals that are not significant; only two show significant reversal (EURCHF in each case). For the more extreme event when the 99% the percentile is used to measure the extreme, there is an even more mixed picture. Just over half the cases with the four-day window show a reversal (8 of 18), but only 2 of these are statistically significant.



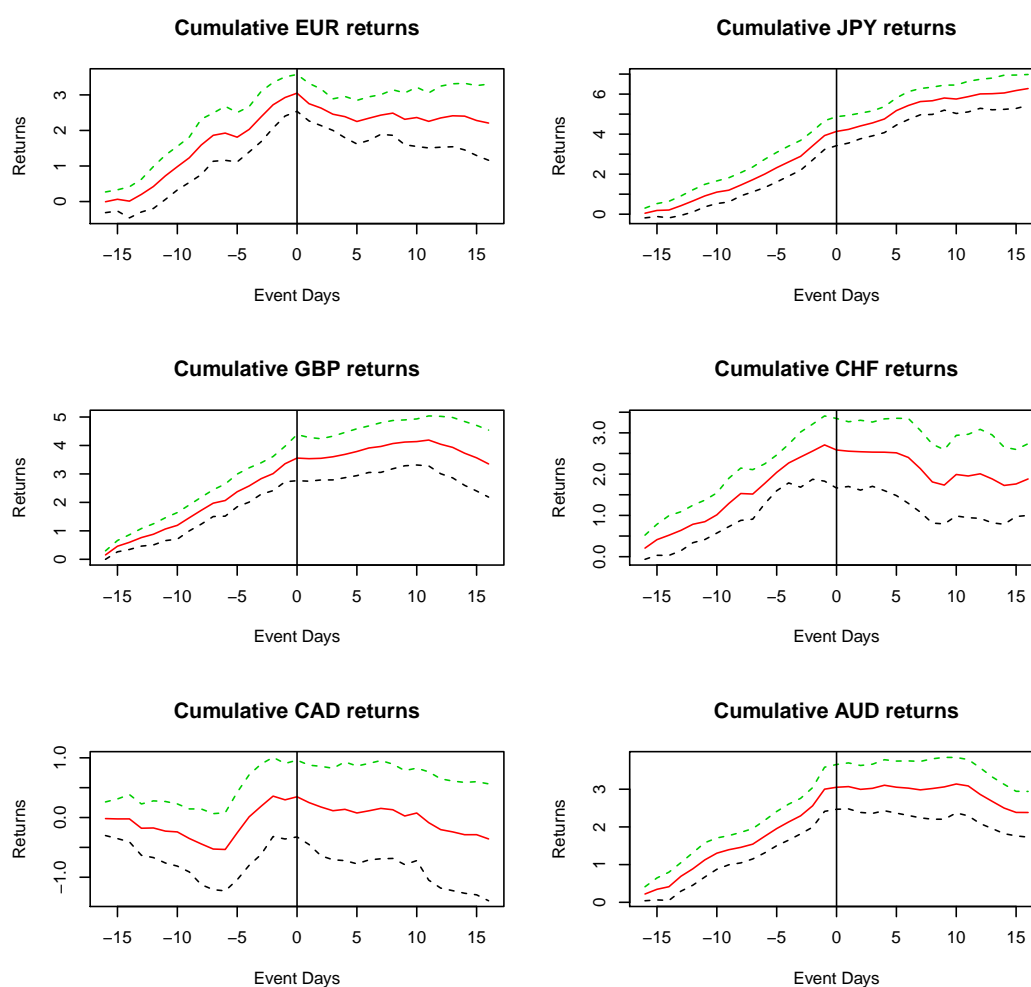
TABLE 3.6: Event Study: Cumulative Abnormal Returns and Extreme Risk Reversal

		5th and 95th percentile						1st and 99th percentile					
		1 day		4 day		1 day		4 day					
		N	CARW	CARA	N	CARW	CARA	N	CARW	CARA	N	CARW	CARA
EUR	Hi	87	0.4103*	0.1586	87	0.9442*	0.1505	22	0.0309	-0.1748	22	0.5781*	-0.5387*
	Lo	106	-0.3313*	-0.0933	106	-0.0816*	-0.1991	21	0.3040	0.1820	21	0.7935*	0.4377
JPY	Hi	90	0.4860*	0.1341	90	1.5158*	0.2531	20	0.8227*	0.3078*	20	2.4337*	0.8284*
	Lo	90	-0.3168	0.0945	90	-1.3532*	0.1984	17	-1.6990*	-0.9347*	17	-3.6751*	-1.2556*
GBP	Hi	96	0.3303*	0.1903*	96	0.8966*	0.2547	21	0.5252*	0.1774	21	1.3131*	0.3284
	Lo	97	-0.1894	0.0312	97	-0.8031*	0.1500	24	-0.2630	-0.0866	24	-0.6660	0.1888
CHF	Hi	80	0.0065	-0.0565	80	0.5624*	0.1322	18	-0.0022	-0.1518	18	0.4887	-0.1768
	Lo	75	-0.3716*	-0.1125	75	-1.0071*	-0.0219	18	0.0064	0.1704	18	-0.8661*	0.7631
CAD	Hi	113	-0.0038	-0.0489	113	0.1872	-0.1951	24	-0.1081	-0.0462	24	0.3935*	-0.1592
	Lo	97	-0.1422*	-0.0571	97	-0.2896*	0.0035	26	-0.2008	-0.0146	26	0.1185	0.4560*
AUD	Hi	101	0.2539*	0.0125	101	0.8728*	0.0875	33	0.5099*	0.0682	33	1.1501*	0.1046
	Lo	138	-0.4384*	-0.1711	138	-1.14935*	-0.2714*	20	-0.4334	0.0563	20	-1.7360*	0.1914
EURJPY	Hi	95	-0.0504	-0.1103	95	-0.0128	-0.2579	23	-0.2932	-0.4188*	23	-0.8203	-1.0195
	Lo	97	-0.4746*	-0.1647	97	-1.6757*	-0.4595	20	-1.3630*	-0.6976*	20	-3.6849*	-1.1999*
EURGBP	Hi	91	0.1544	0.0696	91	0.5176*	0.0979	28	0.2048	0.1195	28	0.4146	-0.0645
	Lo	122	0.0451	0.0996	122	-0.3097*	0.2903*	21	-0.07523	-0.0780	21	-0.4120	-0.1290
EURCHF	Hi	77	0.1183*	0.0690	77	0.3444*	0.0749	31	0.1482*	0.0739	31	0.4993*	0.1816*
	Lo	94	-0.0344	0.0194	94	-0.1596	0.1952*	24	-0.3626*	-0.1483	24	-0.7573*	0.0875

Where Hi means extreme high in the risk-reversal skew and Lo means extreme low in the risk reversal skew; extreme is calculated as being equal or above the 95th or 99th percentile or equal or below the 5th or 1st percentile respectively; CARW is the cumulative abnormal return for the whole window, before and after the extreme event, and CARA is the cumulative abnormal return for the period after the event, which is the event day and the window; abnormal return is anything that is different from zero; the asterisk denotes significantly different from zero, where statistical significance means that more than 95% of 1000 random bootstraps from the events are above or below zero respectively.

The results do not appear to be a function of the percentile that is used to measure the extreme event or the size of the window that is selected. For example, using R code that is available in Appendix B Section B.5, these parameters can be easily changed. Additional cases were run using percentiles at 80% and 99.5%. For the event window, figures 3.1 and 3.2 show the cumulative abnormal returns for the major exchanges rates relative to the US dollar across a 16 day event window. Figure 3.1 shows the extreme highs for as a 99<sup>th</sup> percentile and figure 3.2 shows the extreme low for as a 10<sup>th</sup> percentile. The figures reveal the mean cumulative return (in solid red) and the 95% confidence intervals (dashed blue). The only case where there seems to be any evidence of a reversal is for the extreme low risk-reversals on the Canadian dollar.

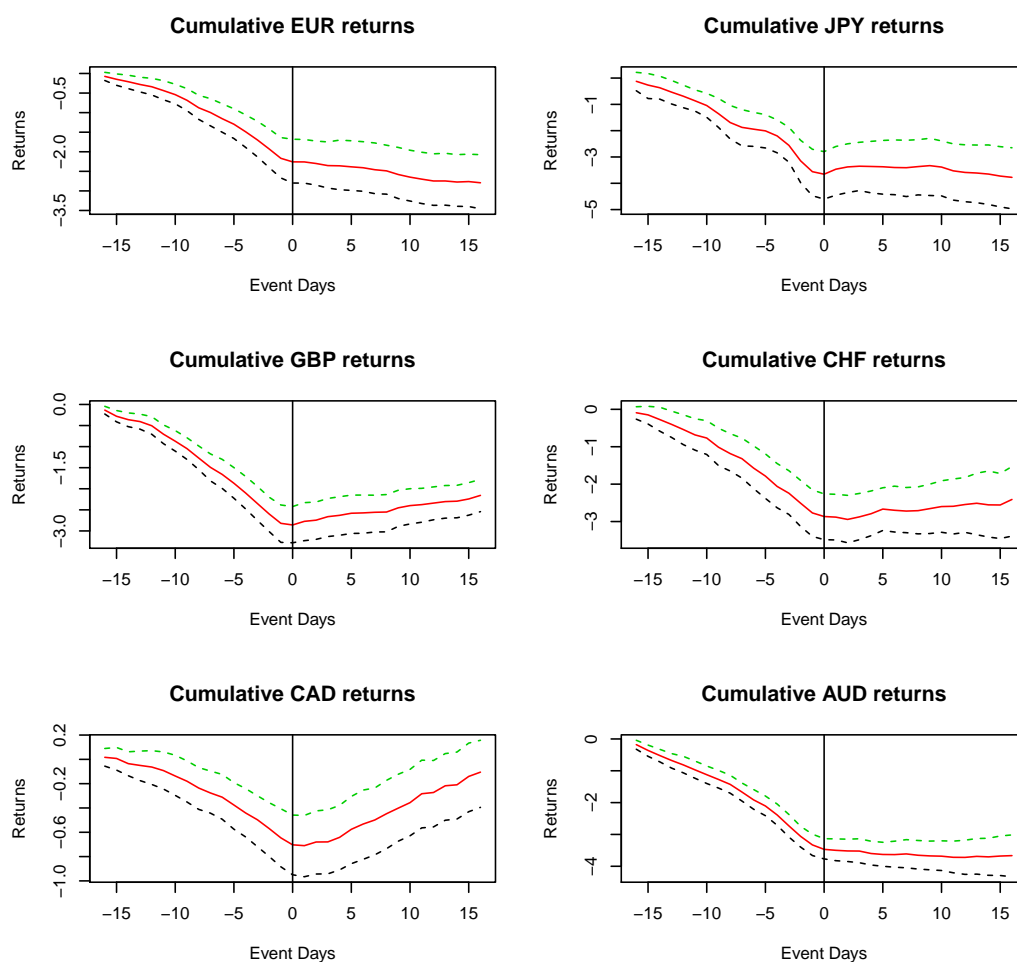
FIGURE 3.1: Event Study: Extreme (High 99th percentile) Risk Reversal Skew and 16 day event window



Again, the most prominent observation is positive association between sentiment and returns. Intuitively, this is not surprising. However, it does suggest that foreign exchange prices are not always driven by a random walk. There is clear evidence here of serial

correlation in the returns. As sentiment rises (as measured by the increase in the risk-reversal) there is a price appreciation. However, the adjustment is not instantaneous. This is an example of the sort of trending behaviour that is common in the literature (as reported in Section 3.2.1.1). It is likely to be at least partially explained by the sort of gradual adjustment to information that was identified as being a consequence of the conservatism heuristic in Section 3.2.1.5 on behavioural finance.

FIGURE 3.2: Event Study: Extreme (Low - 10th percentile) Risk Reversal Skew and 16 day event window



However, it does indicate that the evolution of exchange rates are not a random walk. There is evidence here that prices gradually respond to information, as would be the case if decision-making is following a *conservatism* heuristic or if there were institutional features. The positive (or negative) expectations that are evident in the risk reversal skew do not seem to represent a deviation or a mis-pricing that will be reversed. Rather they seem to be part of the price-discovery process.

The second heuristic that was discussed in Section 3.2.1.5 was representitiveness. This

was the tendency of decision-makers to focus on the immediate and to forget base probabilities. It would suggest that investors would think too much about the new information that has driven prices towards a new equilibrium in Figures 3.1 and 3.2 not sufficient to the broad background where other currencies may be more or less attractive. In practical terms, it suggests that there will be overshooting and that this overshooting will cause reversals when it becomes extreme. There is little evidence here of any reversal. After the extremes are reached, there seems more likely to be a period of consolidation or a fluctuation around the new equilibrium. This is what would be expected if speculation were part of the process of getting information into the price. Once this has taken place, there is consolidation.

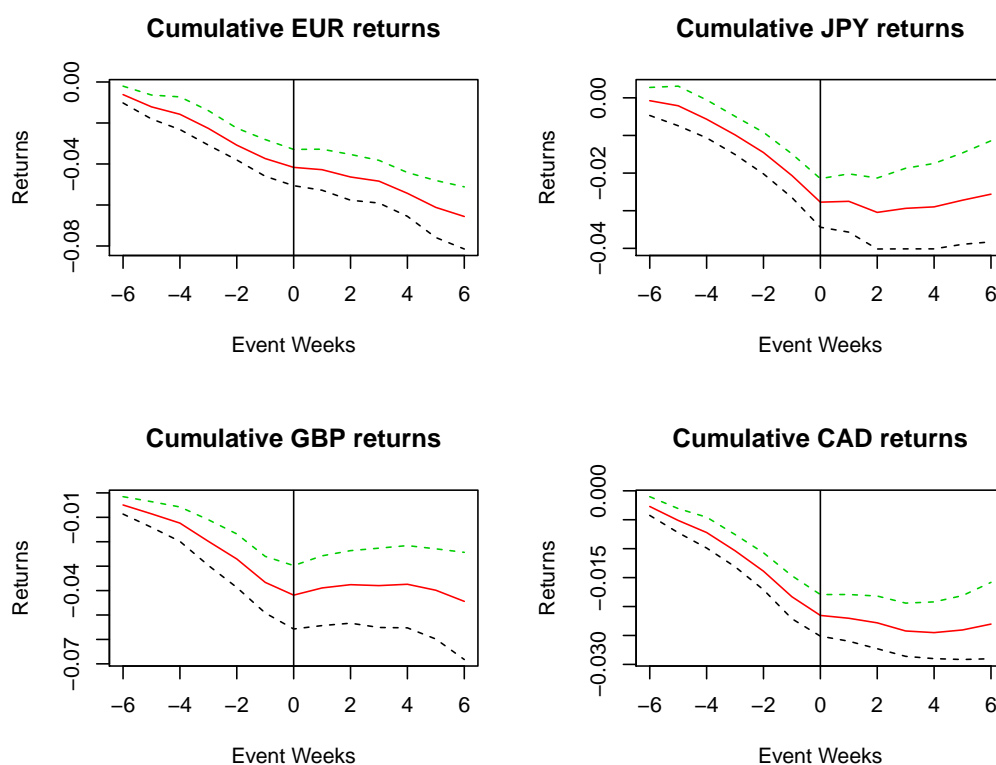
TABLE 3.7: Event Study: Cumulative Abnormal Returns and Extreme Speculative Positions

		S1 - Net Long per Speculators						S2 -Net Long per Open Positions					
		2 week			4 week			2 week			4 week		
		N	CARW	CARA	N	CARW	CARA	N	CARW	CARA	N	CARW	CARA
EUR	Hi	27	2.9415*	1.3163*	27	3.8059*	1.7341*	27	1.0974*	0.2896	27	1.7667*	0.0419
	Lo	27	-2.4258*	-1.2512*	27	-3.9235*	-1.9254*	27	-2.5122*	-1.0607*	27	-4.4478*	-1.9285*
JPY	Hi	43	1.9749*	0.7286*	43	2.8628*	0.7909	43	2.2463*	1.0554*	43	3.7125*	1.4443*
	Lo	43	-2.2014*	-1.1312*	43	-3.2488*	-1.5758*	43	-2.0605*	-0.9791*	43	-2.6865*	-0.8318
GBP	Hi	43	0.7102	-0.2116	43	1.0172*	-0.7902*	43	1.2916*	0.2370	43	1.6912*	0.0126
	Lo	43	-0.6979*	0.2902	43	-1.5330*	0.1014	43	-1.8993*	-0.1415	43	-2.8830*	-0.0768
CHF	Hi	43	1.4400*	-0.0988	43	2.8665*	-0.0993	43	2.5260*	0.5074	43	3.6060*	0.2158
	Lo	43	-2.1816*	-0.9770*	43	-3.3030*	-0.09798*	43	-1.2605*	-0.3070	43	-0.16021*	0.0670
CAD	Hi	43	1.8658*	1.0195*	43	3.5298*	1.8319*	43	2.0160*	0.8788*	43	3.0995*	0.9921*
	Lo	43	-1.3238*	-0.5548*	43	-1.9151*	-0.7859*	43	-1.2462*	-0.4505*	43	-1.9390*	-0.6195*

Where Hi means extreme high in the sentient index, either S1 which is the measure of net long non-commercial (speculative) positions per number of speculators) or S2 which is the measure of net long non-commercial (speculative) positions per open interest (total outstanding open positions); high and low are above the 95th percentile or below the 5th percentile respectively; CARW is the cumulative abnormal return for the whole window, before and after the extreme event, and CARA is the cumulative abnormal return for the period after the event, which is the event day and the window; abnormal return is anything that is different from zero; the asterisk denotes significantly different from zero, where statistical significance means that more than 95% of 1000 random bootstraps from the events are above or below zero respectively.

Table 3.7 shows the results from the event studies that were carried out using speculative positions as reported to the US regulators. The table works in a similar way to Table 3.6. The first column is the exchange rate, defined as units per US dollar. The table is then split into two parts. The first part uses the measure S1 which is the net non-commercial (speculative) positions relative to total non-commercial (speculative) positions; the second is S2 as the net non-commercial position relative to open interest or the total outstanding open positions. Therefore, the first captures the balance of speculative positions while the second captures the balance of speculative positions relative to the whole market. If speculators become more prevalent or dominant in the market, this will show up in S2 but not S1. S1 is more sensitive to changes in sentiment and more volatile.<sup>7</sup> Each of these sections is broken into the results for a 2 week window and a 4 week window. Each of these has the same pattern. There is a row for extreme high and extreme low which represents extreme long positions or extreme short positions; the first column identifies the number of cases; CARW is the cumulative abnormal return for the whole event window; CARA is the cumulative abnormal return for the period after the event to the end of the window.

FIGURE 3.3: Event Study: Extreme (95th percentile), Non-commercial net per OI (S2), 6 week event window

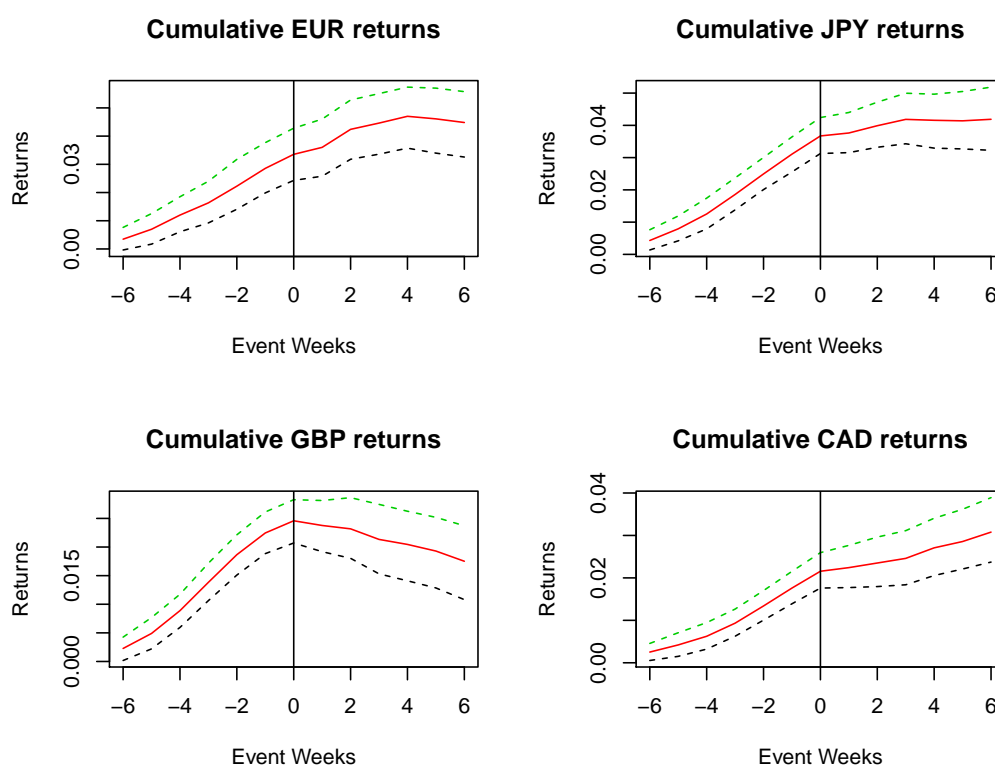


<sup>7</sup>When the same data are used in the model for international capital flows in Chapter 2, it is found that S1 tends to provide a better fit for the module of capital flow and the real trade weighted index.

Once again, there is a very strong association between returns and the movement of speculators. For the 4-day window and the S1 and S2 measures, every one of the currencies studied, high and low, had a mean cumulative return for the whole of the event window that was in the same direction as sentiment. When re-sampled a thousand times, more than ninety five percent of the means calculated were greater than zero in all cases but one (GBP). Once again there is evidence here of momentum and of speculator positions following the movement of prices.

However, there is little evidence that these speculators are driving prices to extremes with their extreme behaviour. Sixty percent of the S1 cases still show a significant abnormal return in the direction of the extreme 4 weeks after the extreme has been reached; only thirty percent of the cases show a reversal and in only one of those do ninety five percent of the re-sampled means remain above zero. For S2 it is even more extreme, with ninety percent of the cases showing a continuation and forty percent of them being significant. Again the evidence is consistent with the gradual adjustment of prices to information.

FIGURE 3.4: Event Study: Extreme (90th percentile), Non-commercial net long (S1), 6 week window



The R code for all the event window figures is available in Appendix B Section B.6. This merely takes the data that was used to construct Tables 3.6 and 3.7 and puts it in graphical form. The event windows are stretched to give a clear view of the evolution

of exchange rates around the event. Confidence intervals are added. Once event objects `FX.exc` have been created, parameter for exchange rate, extreme measure, quantile, window length and the high or low indicator can be changed for alternative assessments of speculative extremes. Adjustments to these parameters show that these results are not a function of the choices presented in the main text. They are robust to alternative specifications.

Figure 3.3 shows the performance of the cumulative abnormal returns around a six week event window where the event is the net low (short) speculative positions relative to total activity (open interest) at or below the (5%) level. This means that the speculators are inclined to be short the non-domestic (US dollar) currency. While the Euro continues to move lower after the extreme short positions, the other major currencies seem to reveal a period of consolidation that is consistent with the settlement around an equilibrium after a period where information is being absorbed. The contrast between the Euro and the other currencies may be associated with the fact that there is a smaller dataset for the Euro due to its more limited lifespan. Figure 3.4 shows the abnormal returns around extreme high (90th percentile and long position). There is some tentative evidence of continuation for speculative positions in the Canadian dollar and signs of reversal for UK sterling. However, the Euro and the Japanese yen move sideways after the event. There is no clear pattern after the extreme and therefore no information.

### 3.5 Speculation and foreign exchange returns

This chapter has sought to measure speculation and to use this measure to discover more about the relationship between speculation, information and asset prices. The measurement of speculation takes two forms: a measurement of the intensity of belief with the risk-reversal skew, and a measurement of speculative positions. Neither of these is ideal, in the sense of being a random sample from a population. However, the option prices reveal the intensity of feeling through the weight of money in a speculative part (options) of a speculative market (foreign exchange). The commitment of traders report records only speculators in the US futures market. However, this is an important market, there is no reason to believe that US or speculators in the futures market are systematically different from those in the rest of the world and presumably if there were a major difference there would be an arbitrage opportunity between the two markets.

As was evident with the analysis of the real exchange rate and international capital flow in Chapter 2, there is strong evidence that speculation affects prices and that this effect is gradual rather than instantaneous. This suggests a market inefficiency that would reward momentum-based trading. It is no wonder therefore that (Taylor



and Allen, 1992), reporting a survey conducted by the Bank of England, found that of the Chief foreign exchange dealers contacted in London in November 1988, 90% of them attached some weight to *technical analysis*, a method that is fundamentally based on finding trends in asset prices. The survey found that the importance of technical analysis became greater at shorter horizons. This has not disappeared. The importance of momentum trading and technical analysis has not waned with time. Neely and Weller show that gains from technical trading rules still generate excess returns and attribute this to behavioural biases (Neely and Weller, 2011). It seems that speculation forms part of the process of price discovery, but this process is not instantaneous as would be expected in the purest form of the EMH.

The notion that speculation is at least partially informed is supported by the fact that there is little evidence from the event studies conducted here that speculation causes overshooting or bubbles. When speculation is extreme, whether measured by intensity of belief or weight of speculative positions, future returns are as likely to be positive as negative. There is no informational content as there would be if speculation was pure noise. In the simulation of the De Long model, extremes are more likely to be followed by reversals. In the foreign exchange market, that is not the case. There are some large price crashes in the dataset, as shown by the descriptive statistics of the returns. For example in Table 3.2 it is seen that on one day there is a 10.65% appreciation of the Japanese yen and Table 3.3 shows a week when the Canadian dollar falls by 10%. However, the measures of speculative sentiment or the weight of speculation are not particularly high in either of these cases. Indeed, an analysis of the top 1% of positive and negative foreign exchange returns in the dataset reveals that sentiment and positions for this group were very close to the average of the whole set. This would be consistent with a model where extreme price movement was a function of new information rather than the structure of existing positions.

The evidence here, that speculation is associated with serial correlation in the returns but cannot be used in a systematic way to determine reversals, has important implications for speculative activity. It means that the largest returns will be to those that identify the trend at the earliest opportunity. This means that speculators must be prepared to act as swiftly as possible, probably when there is a high level of uncertainty and a lack of information and where any scrap of additional news is highly valued. The risk that actions by other speculators, most notable by their effect on price, will be construed to contain information exacerbates the likelihood of feedback effects. The need to be able to take action before others has reached the most extreme form in the activity of *high frequency trading* (HFT), where decision times are measured in nanoseconds and there is advantage in gaining spacial proximity to exchanges. HFT is all about getting a larger

share of the inefficiency in pricing information by trading or investing closer to where the information is released.

These findings have implications for speculators, economic modellers and policy makers. Speculators may jump on the trend, but they do not know by looking at how popular that trend is when to get off. They need other signs to tell them that the trend has reached its conclusion or equilibrium has been achieved. For the modellers, there is confirmation of the need for feedback effects and evidence that reversals cannot be systematically identified from high levels of speculative positions. It may suggest another trigger for bursting bubbles; it may, for example, suggest that this reversal has to be modelled as stochastic element or pure shock. For policy makers, there is no escape from the requirement to look at economic fundamentals when deciding whether bubbles are building in asset markets. The presence of speculators is no guarantee that there is excess. The speculators may be just part of the adjustment to new information. However, the combination of high level of speculation and divergence from fundamentals is likely to create the greatest risk.

## Chapter 4

# The Carry Trade, Uncovered Interest Parity and Crash Risk

### 4.1 Introduction

This chapter takes a closer look at one particular mode of speculative activity that takes place in the foreign exchange market. The *carry trade* is the attempt to take advantage of deviations from *uncovered interest parity* (UIP). UIP is one of the fundamental theories of international financial economics. UIP asserts that, given the free flow of capital, the expected change in an exchange rate over a specific period should be equal to the interest rate differential for the two currencies for the same period. If this is not the case, there is an opportunity to make an abnormal return, using the carry trade, by borrowing one currency and investing the proceeds in the other. A large body of evidence and the activity of speculators, who it appears trade on information, suggests that UIP does not hold.

In the carry trade, speculators are betting that the depreciation of the investment currency against the funding currency will be less than the interest rate differential. There are two main explanations for why the carry trade is so popular:<sup>1</sup> there may be an inefficiency in the market's processing of information (see Section 3.2 for a fuller discussion of the efficient market hypothesis (EMH)) that will allow abnormal returns to be generated by this investment approach; there may be no inefficiency and the returns that are achieved may be a compensation for taking an unconventional type of risk. It has been shown

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<sup>1</sup>The discussion of the carry trade comes and goes with the activity itself. It has often focused on specific countries such as Turkey, Iceland and the Czech Republic where interest rates are relatively high and on funding currencies like the US dollar, the Swiss Franc, Euro and Japanese Yen where interest rates are relatively low and where there is a developed banking system is ready to provide funding for investors searching for higher yields. However, there are no reliable figures on the size of the activity.

in Chapter 3 that speculation is unlikely to be completely uninformed. This chapter assesses the second explanation for the breakdown in UIP with an investigation of the nature of carry trade returns. These returns are found to be leptokurtic (or fat-tailed), negatively skewed, serially correlated in many cases, affected by the type of currency regime and sensitive to changes in international risk aversion. The evidence suggests that the returns to the carry trade are not abnormal but a return for taking *crash risk* that is characterised by unpredictable large losses that increase with the length of the period running up to the crash.

In this way, the carry trade can be seen as being a micro version of Minsky's FIH (see Section 1.2.2 for full discussion of the FIH). While Minsky presents a story where there is a gradual build up of speculative borrowing, increased fragility then a crash, carry trade positions are likely to be built while conditions are calm; the establishment of carry trade positions appear to generate abnormal returns as the purchase of the investment currency will tend to cause it to appreciate rather than depreciate; the carry trade itself will start to generate crash risk as the appreciation of the investment currency takes it further away from equilibrium which can increase the risk of crash and ensure that any crash that happens is deeper and more damaging than would otherwise be the case. In this way the carry trade receives a compensation for taking crash risk. However, the carry trade also causes an increase in the amount of crash risk.

This chapter assesses carry trades in Europe. There are a number of conditions that make Europe a very fertile ground for this activity: there have been periods when there have been relatively large interest rate differentials between some countries; there are a number of fixed exchange rate regimes; there is a divergence between very highly developed financial systems in the core and less developed systems to the periphery. These are all features that encourage the establishment of carry trade positions. However, it is very likely that the results established here would be applicable to other parts of the world.

Europe is also a good place to start with some analysis of speculative activity in the foreign exchange market because there is a rich history of speculative activity in European foreign exchanges. From the successive devaluations of sterling under the Bretton Woods system through to the crises of the Exchange Rate Mechanism (ERM), into some of the monetary problems that CEE countries have faced when they have tried to stabilise their exchange rates, European nations have sought to limit effects of speculation on their economies. Most recently a version of the carry trade has caused some problems in Europe as it has led to large capital flows into those countries with relatively high rates of return within the Euro area (like Greece and Spain).

## 4.2 Literature review

As discussed in Chapter 2, Section 2.2.2, a test of UIP can take the form,

$$E[\Delta s_{t+j}] = \beta_0 + \beta_1 f_{t+j} + \varepsilon \quad (4.1)$$

where  $E[\Delta s_{t+j}]$  is the expected change in the log of the exchange rate between periods  $t$  and  $j$ ,  $f_{t+j}$  is the forward premium expressed as the difference between the logs of the spot rate and the forward rate for period  $j$ ;  $\varepsilon$  is an error term that is assumed to be a independent and identically distributed random variable with a mean of zero, while  $\beta_0$  and  $\beta_1$  are the coefficients to be estimated. if UIP holds,  $\beta_0$  should be equal to zero and  $\beta_1$  should be equal to unity as the forward rate should be an unbiased estimate of the future exchange rate. There may be frequent errors in the estimate (represented by  $\varepsilon$ ) but these should on average be zero.

There is no carry trade if this holds as the gain from borrowing a lower interest rate currency and depositing in a higher yielding unit will be expected to be balanced by a capital loss on the depreciation of the investment currency against the funding unit. However, the evidence from Froot and Thaler (Froot, 1990) and others suggests that UIP does not hold on average. Estimating the  $\beta_1$  from Equation 4.1 finds that the value is usually much lower than the value of one that would be implied by UIP. Indeed, the fact that the carry trade exists shows that there are investors who believe that they can identify the times when UIP will not hold.

As UIP is a key component of international financial theory, there has been a tremendous effort to understand more about this apparent *puzzle*. Some suggest that it is the lack of stationarity in the series that causes estimation problems (Engel, 1996) and (Roll and Yan, 2000) ; others argue that this is really an issue for developed rather than developing nations (Bansal and Dahlquist, 1999); tests using 10 year bond yields indicate that the puzzle applies to the short-term but not long-term rates(Chinn and Meredith, 2004). There is also a wide ranging discussion over whether, once the assumption of risk-neutrality is abandoned, the apparent breakdown is the result of failing to correctly account for this risk.

### 4.2.1 Risk premium

If the assumption that investors are *risk neutral* or indifferent to risk is abandoned in favour of risk aversion there will be a risk premium to compensate investors for taking risk. The interest differential will be equal to the expected change in the exchange rate

plus an additional premium for taking the risk of an adverse outcome. In that case the negative estimate for  $\beta$  could mean that investors required additional return for holding foreign currency assets. As such, it is possible to augment Equation 4.1 with an additional term that would account for the risk premium.

$$E[\Delta s_{t+j}] = \beta_0 + \beta_1 f_{t+j} + \beta_2 rp_{t+j} + \varepsilon \quad (4.2)$$

where  $rp_{t,j}$  is the risk premium at time  $t$  for  $j$  periods ahead. Again,  $\beta_0$ ,  $\beta_1$  and  $\beta_2$  are the parameters of the model (to be estimated) and  $\beta_0$  should be equal to zero while  $\beta_1$  and  $\beta_2$  should sum to one so that, on average, any discrepancy between the forward rate and the expected change in the exchange rate is offset by the risk premium. This seems reasonable when domestic rates are below overseas rates and the risk premium is a compensation for holding foreign assets but if domestic rates are above those abroad, there is a risk premium on domestic assets.

Bilson addresses this and other factors that may drive a wedge between the forward rate and the expected rate by considering *speculative efficiency* which is efficiency once risk premia, transaction costs and information costs have been accounted for. He finds the optimal investment strategy and tests it under a variety of specifications, including out of sample, finding that there are no other factors that can add to the forecasting ability of the forward rate (Bilson, 1981).

However, as the risk premium and expectations about the exchange rate are not observed, the model is not identified unless some additional information is available.

$$rp_t = fd_t + \Delta s_{t+j}^e \quad (4.3)$$

By using surveys of expectations from the *Economist Financial Report* for the period June 1981 to August 1988, Froot is able to isolate the effect of the risk premium by using the survey to estimate  $\Delta s_{t+j}^e$ . The survey measures reveal that abnormal returns are expected on foreign currency deposits when US interest rates are low and these expectations do not usually include a risk premium. Where there does appear to be a premium it is very small. However, survey evidence is not particularly reliable or comprehensive, and the analysis of the risk premium as an explanation of the forward bias puzzle has continued.<sup>2</sup>

<sup>2</sup>There are a number of surveys of investor opinion that are regularly conducted by financial service information companies. However, these are disparate and, in many cases, unsystematic and it is not clear whether they measure speculative sentiment or investor opinion more generally. The Wall Street Journal runs an annual survey of investor opinion but this is focused mostly on US equities. The *Economist* magazine also solicits opinion, but in a relatively unstructured and *ad hoc* fashion. In the

Indeed, Froot also shows that short rates consistently predict excess returns on a variety of assets. For foreign exchange, stock, bond and commodity markets, a one percentage annualised increase in the short-term interest rate is associated with about a three percentage point reduction in annualised excess returns (Froot, 1990). There could also be a liquidity issue that is not formally addressed by Froot. If low interest rates are symptomatic of money creation in the banking system from lending that is being used to purchase assets, this can lead to short-run appreciation of assets values. This would be consistent with FIH-type behaviour where informed-speculators push asset prices beyond levels associated with intrinsic value, raising the risk of a violent reversal once the liquidity spigot is turned off.

### 4.2.2 Expectations

There are two related questions that need to be addressed: are expectations about future exchange rates formed in a fashion that can be considered *rational*; and what is the information set on which these expectations are formed. In the analysis conducted thus far, expectations are assumed to be rational in the sense of Muth (Muth, 1961), meaning that economic agents understand the model that describes the system and that therefore there are no systematic expectational mistakes. This means that, as described above, if UIP describes the relationship between interest rates and the exchange rate, economic agents form their expectations by this rule.

It is also possible that expectation could be formed on a wider information set than the sample of exchange rate returns that were available to researchers. If market participants fear a large, future depreciation of an exchange rate (say the Mexican peso, which is the example most initially used to explain the *Peso Problem*), the fact that this is a rare or even unique event means that these expectations may not be recovered from the historic sample of the Mexican peso. Rogoff looked at the Mexican peso futures from June 1974 to June 1976 and found evidence contrary to the implications of market efficiency which was explained by the market's persistent belief that the Mexican peso would be devalued. The peso was devalued in August 1976 and again in December 1994 (Rogoff, 1980), (Lewis, 2008). Therefore, expectations were proved right even though pre-devaluation research would find a problem.

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foreign exchange market, there is a broad set of market forecasts that was collected by the financial services company *MMS International* (formerly Money Market Services), which polled a broad range of financial market participants on key exchange rates for one and four week forecast horizons. Frankel and Froot found that the median forecast from the MMS survey exhibited trend-following behaviour at the one to three week horizon while there is mean-reversion beyond that point. Frankel and Froot also assess the 'Financial Report' that has been produced by *The Economist* magazine and *Currency Forecasters Digest* and find a wide dispersion of opinion and express some concern about the aggregation of such divergent forecasters (Froot and Frankel, 1989) and (Frankel and Froot, 1987) .

The Peso problem implies that when there are expectations about a future, discrete change in fundamental value, rational forecast errors may be consistently different from zero. For example, if there is considered to be a 5% chance of a 50% devaluation of a fixed exchange rate, the expected depreciation of 2.5% will never actually be seen. This raises a series of questions about how far economic agents can be expected to form subjective probability estimates of future events that match the objective probabilities as assumed by (Muth, 1961, p. 316). There is a lot of evidence to suggest that this is not possible. A large number of decision-making experiments that have been conducted by psychologists indicate that there is particular difficulty with the assessment or estimation of the probability of events that are extremely unlikely (Kahneman and Tversky, 1979).

This may lead back to the understanding of risk. An explanation that is partially explored by Froot and Thaler is that assessing risk by the first two moments of a distribution is inadequate in a situation where returns are not expected to be normally distributed. There are steady returns from a long Mexican peso position funded by US dollars, but there were also large and uncertain risks that are very difficult to quantify. A small risk of extreme inflation and large depreciation of the peso would not be balanced by any similar possibility of an appreciation of the Mexican unit and therefore the distribution of inflation expectations is very likely to show a large negative skew (Froot and Thaler, 1990, p. 186).

### 4.2.3 Crash risk

There are a number of recent studies that have assessed the skewed nature of the returns that are associated with the carry trade. For example, (Brunnermeier et al., 2008) develop a general model of what they call *crash risk*, which is due to the sudden unwinding of carry trade. The crash happens when risk-appetite and funding-liquidity decrease. They use exchange rates for the US dollar against eight major currencies for the period 1986 to 2006 and the three month interest rate to assess the returns for an investment in foreign currency financed by domestic (US) currency.

$$z_{t+1} \equiv (i^* - i) - \Delta s_{t+1} \quad (4.4)$$

where  $z_{t+1}$  is the return in excess of the prediction of UIP as  $i^*$  is the overseas three month interest rate and  $i$  is the domestic three month interest rate and  $\Delta s_{s+1}$  is the change in the log of the exchange rate measured as foreign currency per US dollar (Brunnermeier et al., 2008, pp. 8-9). They find that carry trades have large Sharpe Ratios, negative skewness and positive excess kurtosis. However, as the Sharpe Ratio



assumes a symmetric distribution of returns, there are some clear weaknesses in this method.

Brunnermeier and Pedersen show how this *crash risk* can be increased by the interaction of institutional features like illiquidity, margin calls and the evaporation of funding for speculator funding. When conditions deteriorate, investors seek to exit the carry position, liquidity declines, banks become more cautious about funding speculative positions and an increase in margin requirements, together with a reduction in funding lead to spirals of selling and exaggerated price movements (Brunnermeier and Pedersen, 2009).

Gabrisch and Orlowski carry out an investigation of equity markets, money market rates and exchange rates in some CEE countries using a mean version of the general auto-regressive conditional heteroscedasticity model with a generalised error distribution (GARCH-M-GED) to assess the nature of the disturbances in these time series. The inflation-targeting countries of Czech Republic, Poland, Hungary and Romania are assessed with a sample from January 3, 2000 to August 7, 2009. The study finds that there is evidence of leptokurtic disturbance for each of these financial variables with the GED parameter significantly below the level of two that would be associated with a normal distribution. They argue that this type of behaviour of financial assets makes the operation of a Taylor Rule for monetary policy inoperable. It is clear that fat-tailed, negative-skewed distributions are a common feature of CEE financial markets. Indeed, it appears from this study that foreign exchange shocks, such as the effects of the carry trade, translate across other financial markets (Gabrisch and Orlowski, 2011).

Spronk, Vershoor and Zeinkel use a heterogeneous agent model with carry traders in addition to fundamental and chartist traders. This is an augmentation of the model of fundamental and chartist traders that is presented by (Frankel and Froot, 1990a), where fundamental traders expect a return to fundamental value and chartists expect a continuation of the trend. Traders adjust their strategy towards those that are most successful. The model is able to replicate the heavy tails, excess volatility and volatility clustering that is evident in foreign exchange rates. Another interesting feature of this model that suggests a link with Minsky's FIH is the negative relationship between market volatility and carry trade activity (Spronk et al., 2013). The carry trade is built while conditions are calm.

Variants of the carry trade are a key component of capital flow in emerging economies with fixed exchange rates. Korinek assesses the welfare implications of capital flows from the stance of externalities. These externalities emerge due to the failure of agents to account for the systemic risk that is created by capital inflow. Korinek says that emerging markets may appear to be integrated into international markets but this integration is contingent upon financial constraints not being binding. Private agents fail to

internalise the endogenous nature of the access to international financial markets. This risk is a function of the build-up of foreign currency debt and the amplified potential for a feedback loop to exacerbate capital outflow, exchange rate depreciation and the reduction in the overseas value of domestic collateral and ability to service debt. In other words, there are carry trade participants that fail to fully appreciate the crash risk that they are taking.

Korinek proposes a tax to internalise these external risks and suggests different levels of tax for different types of capital inflow based on the probability of future capital outflow. This puts the largest tax on foreign currency debt and the smallest on foreign direct investment flow. Korinek argues that the risk of capital outflow changes over time with the greatest risk after a period of high capital inflow and the lowest risk after a period of re-balancing (Korinek, 2011)

In order to try to quantify the value of this crash risk, Jurek has tried to quantify the expectations of something like a catastrophic risk that may be apparent in UIP by looking at the price of options that could be used to hedge a potential crash in the exchange rate. He asserts that the common finding that carry trades generate excess returns is misleading because these returns are a compensation for risk. Though he finds that G10 carry trades for the 1990-2008 period generate Sharpe Ratios that are twice the level of the S&P 500 equity returns, Jurek estimates that these generally disappear once the cost of option hedging of crash risk is included (Jurek, 2007). This is consistent with the notion that any returns to the carry trade (see Equation 4.4) are a compensation for taking crash risk rather than abnormal or excess return.

#### **4.2.4 European financial markets**

There are two main types of speculative activity associated with the carry trade that have been found in the European foreign exchange markets. The first is that conducted by professional carry trade investors, taking advantage of the break-down in UIP and apparently well aware of the risk that they are taking; the second are ordinary households that are attracted to the trade by the incentive of a low level for foreign currency interest rates. Domestic households are a significant, less well informed component, and, in most cases, less able to absorb the sort of losses that can occur in extreme periods. The European Bank for Reconstruction and Development (EBRD) Transition Report for 2010 called *Recovery and Reform* puts an emphasis on the need to develop local currency capital markets as a critical part of the post-crisis reform agenda, designed to reduce macroeconomic, financial and personal risk (Berglof, 2010). Developing a theme from the 2009 report, the EBRD highlight the credit boom that developed in many

CCE and CIS states from the early part of the current century and the cost involved in minimising the disturbance caused by the outflow of capital and the downward pressure on the exchange rate. The report showcases the fact that foreign-currency loans account for more than 50% of the total advances in many CEE and CIS countries. The exceptions from the group of countries considered in this paper are the Czech Republic, Poland and Russia. When loans are broken down by maturity, it is clear that, possibly due to uncertainty over the long-term value of units, the share of foreign currency increases with the length of the loan.

The main reason for domestic institutions' use of foreign currency debt is that it appears to be cheaper than the domestic alternative (*Focus on European Economic Integration: Foreign Currency Loans*, 2011, pp. 32-33). However, the EBRD report also discusses the disconnect that seems to exist between the private benefit of borrowing in foreign currency and the social cost that is created by the increased risk of financial dislocation. If this excessive borrowing of foreign currency debt is the result of a mis-pricing of risk, there is a role for government regulation to facilitate improvement. It is clear that there are some reasons why this speculative activity is rational individually, but in total it creates costs in terms of crash risk that are born by society.

A study of foreign currency borrowing and bank balance sheet by Brown and De Haas was used by the European Bank for Reconstruction and Development (EBRD) to show that higher foreign currency deposits, higher interest rate differentials and lower foreign exchange volatility were associated with higher levels of foreign currency borrowing. This is consistent with the idea that the opportunity for foreign currency borrowing, perceived opportunity cost and short-term risk profile are amongst key factors that entice domestic agents to borrow in overseas units (Brown and De Haas, 2010). These factors will form the starting point for the carry trade model that is developed here.

## 4.3 Methods

### 4.3.1 The carry sample

A full assessment of the carry trade in CEE and CIS countries is impossible without information about the positions that have been taken and the returns that have been achieved by international speculators and domestic households and firms. This private information is not available. It appears that no database or private source of this type of data has been made public. However, a sample of possible carry trades can be constructed from information about exchange rates and interest rates that was available

over the period under consideration. This is the method that was adopted in (Brunnermeier et al., 2008) and presented in Equation 4.4. The aim is to get a sample that is representative of the potential for the carry trade and to use this to establish how the profits from this speculative activity evolve over time. Finally, a model of carry trade profits will be used to understand the factors that encourage the establishment of carry trade positions and the risks that are being taken.

The spot exchange rate and deposit rates for 1 month and 3 months were collected from the Thomson-Reuters 3000 Xtra system for the major CEE and CIS countries and for some other important European countries that have been prominent in the carry trade. The Icelandic Krona (ISK), the Norwegian Krone (NOK) and Turkish Lira (TUK) are generally regarded as being carry trade candidates and will be used as one benchmark against which to test the other countries. The selection was based on the availability of data. Slovakia and Slovenia were excluded because they have already joined the euro. Lithuania and Serbia were not included because there is a lack of deposit data. The data are end of month rates (the closing rate on the last day of the month).

The US dollar, the euro, the Swiss franc and the Japanese yen were used as funding currencies. Habib and Stracca have tried to assess the fundamentals of low yield, safe haven or funding currencies and have concluded that the net external asset position, the size of the stock market and, in some cases, the interest rate spread are the key feature indicating external stability, financial development and the presence of the carry trade for developed countries respectively (Habib and Stracca, 2012). The funding currencies chosen for this study fulfil these basic criteria.

One issue that arises with the use of monthly data is whether this creates a bias in the results. However, an examination of daily exchange rate and interest rate data does not suggest any seasonal pattern that would cause end of month rates to be systematically different from the average. One way to deal with this would be to use daily data in the calculation. However, the higher the frequency, the more likely that measurement error or the bid-ask spread will affect the findings.

### **4.3.2 A carry-trade model**

There are a number of factors that can be assumed to influence carry-trade activity and the performance of the trade itself. Section 4.2.4 has an overview of the findings of (Brown and De Haas, 2010), which identify the exchange rate regime and the interest rate spread as being the key factors behind the participation of households in the carry trade. In Section 4.2.3 (Brunnermeier et al., 2008), (Spronk et al., 2013) and others have found that international risk aversion is an important feature in reducing the prevalence

of the carry trade. This study seeks to build a model that has three main components: the exchange rate regime, the interest rate spread and a measure of international risk. These factors will then be used to understand more about carry trade risk and return.

### 4.3.3 Exchange rate regime

The nature of the exchange rate regimes is an important factor that can affect the performance of the carry trade. A fixed exchange rate can be an invitation to conduct the carry trade if there are interest rate differentials, particularly if the monetary authorities make a pledge to maintain the exchange rate. A flexible exchange rate means that there is much greater risk for the participant in the carry trade and therefore less carry activity is likely to be seen in these circumstances. The IMF classifies exchange rate regimes according to a range of rigidity running from a currency board through a fixed peg or crawling peg to a fully floating exchange rate (IMF, 2009). This classification can be simplified into three broad groups within the countries under study: those that have a permanently fixed exchange rate through the whole of the period (denoted group one), those that are fixed initially but gradually loosen the ties as the period progresses, or *vice-versa* (denoted group two) and those that largely allow the exchange rate to fluctuate (denoted group three). The group categorisation is next to the country name. This categorisation will be used throughout the study.

### 4.3.4 Risk and uncertainty

Risk and uncertainty are a central theme and were discussed in detail in Section 1.2.4. The carry trade is closer to that part of risk that is quantifiable, and these calculations will be presented here. However, there is also a very important element that is uncertain: when will the crash happen? As has been seen from the analysis of the informational content of speculation in Chapter 3, this is not very easy to discern. In order to increase the amount of information that is used to detect the times when the risk of a crash has increased, carry trade participants are likely to be very aware of the actions of other market participants. They will use this observation to assess what information the others have: if they are involved in the trade, they are likely to be acting on information that encourages them to believe that conditions will remain calm and the carry will remain successful; if they exit carry positions, they probably have information that suggests that the calm conditions are coming to an end and the risk to the carry trade has increased.

As a result, one of the chief characteristics of the carry trade is that it tends to provide a self-fulfilling affirmation and negation of UIP. This is all very dependent on expectations. If financial markets are expected to be calm, the benefits of the interest rate differential

TABLE 4.1: IMF Exchange Rate Arrangements and Monetary Policy Frameworks 1994 - 2010

Country	Currency	Regime (1994)	Regime (2008)	Reference
<b>CEE/CIS</b>				
Bulgaria (1)	BGN	Currency board	currency board	EUR
Czech Republic (3)	CZK	Managed float	Float	EUR
Croatia (2)	HRK	Managed float	Fixed peg	EUR
Estonia (1)	EEK	Currency board	Currency board	EUR
Hungary (2)	HUF	Fixed peg	Float	EUR
Latvia (1)	LVL	Fixed peg	Fixed peg	Basket
Poland (3)	PLN	Float	Float	
Romania (2)	RON	Crawling peg	Managed float	EUR
Russia (2)	RUB	Managed float	Fixed peg	Basket
Ukraine (2)	UAH	Fixed peg	Managed float	US dollar
<b>Other</b>				
Iceland	ISK	Float	Float	
Norway	NOK	Float	Float	
Turkey	TRY	Float	Float	

The categories come from the (IMF, 2009). The data are used as the basis for dividing the countries into three broad categories of exchange rate: those that have a permanently fixed exchange rate through the whole of the period under study; those that are fixed initially but gradually loosen the ties as the period progresses; those that substantially allow the exchange rate to fluctuate. Countries are allocated to one of three categories according to whether they have a main fixed exchange rate (1), a mixed regime or crawling peg (2) and a free float (3).

will appear to be most attractive; if uncertainty increases, doubts about the carry trade can become more prominent as the probability that a sharp movement in exchange rates could outweigh the benefits of the interest rate differential will increase. The more intense the fear that the investment currency is likely to start appreciating against the funding unit, the greater the risk that the build-up of speculative positions will be unwound in a cascade that provides a self-fulfilling crash.

There are a number of ways that expectations about the future may be affected: a change in the exchange rate regime; a market-induced change in the value of the exchange rate; an adjustment in economic fundamentals that makes it more or less likely that there will be a large change in the exchange rate. The first means that political events are important, particularly those that could represent a change in government or policy. This is most acute when there is a fixed rate or a crawling peg as any change is likely to result in a significant discrete adjustment such as that associated with the peso problem (see Section 1.2.3 for a more complete discussion). The other cases mean that the broad range of influences on the exchange rate have to be continually monitored when the currency is allowed to float.

A second strand of uncertainty that is likely to affect the carry trade flows from the

level of risk aversion or risk appetite in the international financial system. Increased uncertainty about the future, meaning that there is a perception that knowledge is less precise, is likely to lead to caution of the type identified by Keynes in his assessment of uncertainty and the liquidity premium (Keynes, 1936, p. 148, p. 240). This caution is likely to affect not only those in the specific exchange rate market but also those in the periphery and related markets. For example, as risk aversion rises generally, the cost of funding speculative positions is likely to increase (in terms of interest payment and margin requirement), funding currencies are likely to appreciate due to safe-haven effects and more risky, high-yield and emerging currencies may suffer a tendency to weaken, even before carry trades are unwound. The unwinding of the carry trade accelerates the process.

This chapter will concentrate primarily on the international disturbances to expectations and the rise in international risk aversion. This is likely to have a two-fold effect: it will cause some unwinding of carry positions and it may also cause some flight-to-quality for funding currencies. As an extension of this work, measures of domestic disturbance could be included. These could try to capture changes in domestic political conditions or changes in domestic risk aversion. For example, the yield spread between domestic and core bonds, the price of credit default swaps or opinion polls of support for governing parties could be used.

#### 4.3.5 Measuring international risk aversion

The measure of international risk aversion that will be used in this study is the VIX index. VIX is the ticker symbol for the Chicago Board Options Market Volatility Index. This is an index of one-month implied volatility on the S&P 500 stocks. See (Chicago Board of Trade, 2009) for full details on the method of calculation.<sup>3</sup> The VIX is the square root of the S&P 500 variance over the next 30 days. The VIX is quoted in annualised standard deviation. This translates into the annualised expected movement in the S&P 500 in the next 30 days. When the index increases, implied volatility has increased, presumably because demand for options has risen relative to supply. It is believed that the increase in the demand for options, given that this is most likely to happen when fund managers want to protect against the risk of a sharp movement in equity prices, is a sign of increased uncertainty, concern about the future or risk aversion.

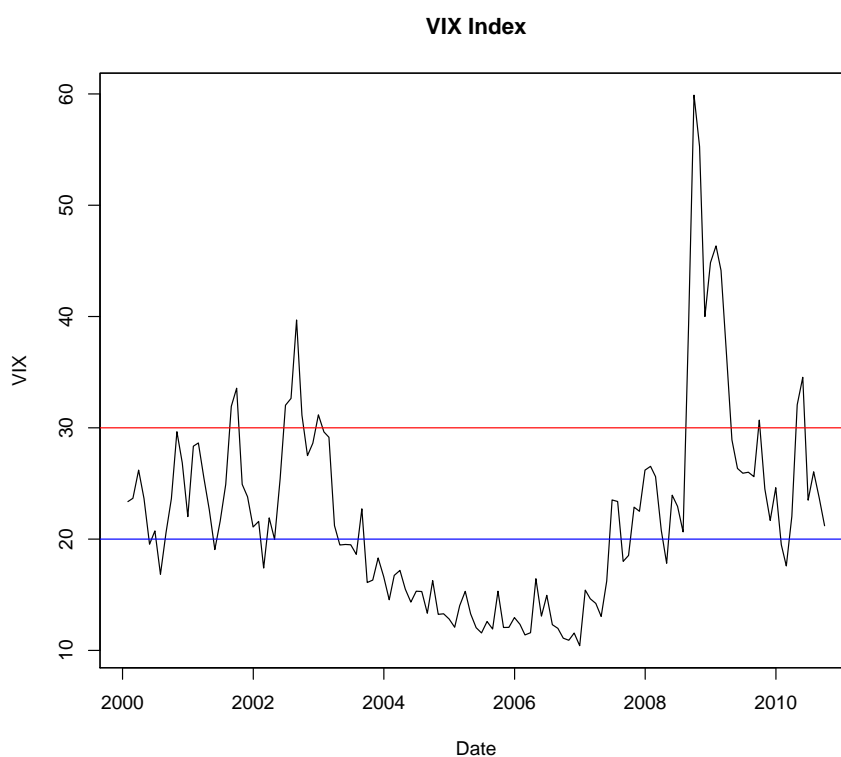
Figure 4.1 shows the performance of the VIX index through the period under study. It also shows the 90th and 60th percentiles which are used to determine periods of Crisis

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<sup>3</sup>See (Brenner and Galai, 1989) for initial thoughts on the construction of volatility index. (Diamond, 2012) shows that the VIX index is the volatility of a variance swap. (Demeterfi et al., 1999) gives additional details of the pricing and use of volatility swaps.

and Moderation respectively. These levels are chosen because intuitively they seem to be reasonable levels to associate with the terms *Crisis* and *Moderation* and by using Figure 4.1 to ensure that they are not dominated by specific periods. The 90th percentile of VIX reading for the period January 2000 to September 2010 is just above 32 while the sixtieth percentile is just over 23. The first means that market expectations, drawn from options prices of the constituents of the S&P 500 index, are that the volatility of the S&P 500 will be above an annualised 32% or  $32\%/\sqrt{12} = 9.2$  percentage points over the coming month, meaning that, if the distribution of returns are normal, the returns could be up to plus or minus 9.2% in 68% of the time. For the period of moderation the same calculation is for an expected monthly range of less than 6.6% on the same basis.

FIGURE 4.1: The VIX index and critical thresholds used in the study



In this study, during periods of moderation, it is expected that carry trade positions will be built up, while during the crisis it is more likely that they will be unwound. More broadly, this is also the pattern that would be expected to be seen in the whole economy. Minsky's FIH asserts that it is the periods of calm that encourage speculative lending to increase and the crisis that initiates a sharp, skewed reversal. In this way the carry is a micro-version of the FIH, and the drivers and consequences of this speculative



activity are likely to provide very good pointers to the drivers and consequences of the speculative activity at the macro level.

There are a number of other indicators that could be used in place of the VIX index. These would include the spread between the top rated AAA bonds and the non-investment grade BBB bonds, one of the emerging market bond indices, implied volatility on some other financial instruments or even the level of speculative positions in some US futures contracts (where there is data availability from the CFTC). The aim in all these cases would be to establish an objective or quantifiable measure of international risk aversion.

## 4.4 Results

### 4.4.1 UIP test

As a starting point of the investigation, a standard test of whether the forward rate provides an unbiased prediction of the future exchange rate is made. The forward rate is constructed from exchange rate and deposit data for 1-month and 3-month rates against all the funding currencies. This is based on the assumption that CIP holds. For example the 1-month forward rate of the Hungarian Forint against the EUR would be calculated as

$$EURHUF_t^{f1m} = \frac{(1 + HUF1M_t)^{\frac{1}{12}} \times EURHUF_t}{(1 + EUR1M_t)^{\frac{1}{12}}} \quad (4.5)$$

where  $EURHUF_t^{f1m}$  is the 1 month forward rate for euro in terms of Hungarian Forint at time t,  $HUF1M_t$  is 1 month Hungarian Forint deposit rate,  $EUR1M_t$  is the 1 month Euro deposit rate and  $EURHUF_t$  is the current rate of Euro in terms of Hungarian currency.

There is confirmation of the deviation from UIP through the period that is being studied. The test of the unbiased forward rate (Equation 4.1) records an estimate for  $\beta_2$  that is below one in six of the ten CEE equations against the US dollar and for eight of the ten CEE and CIS against the Euro. The second column of Tables 4.2 and 4.3 identify those cases where the t-test of the restriction on unity for the coefficient is rejected at conventional statistical levels.

#### 4.4.2 Carry trade tests

In addition, a profit series is calculated based on conducting the carry trade using each of the CEE and CIS sample currencies. The calculation is based on an investment that borrows in the funding currency, exchanges these units for the higher-yield currency and then converts back to repay the funding at the end of the month or the end of three months respectively. Therefore, it is assumed that there is an open position that maintains the risk that exchange rate movements will enhance or offset the interest rate pick up. For the calculation of a normalised one month carry trade involving the Hungarian Forint using the Euro as the funding currency, the calculation is

$$P1MEURHUF_t = \frac{(1 + HUF1M_t)^{\frac{1}{12}} \times EURHUF_t}{(1 + EUR1M_t)^{\frac{1}{12}} \times EURHUF_{t+1M}} \quad (4.6)$$

where  $HUF1M_t$  is the 1 month Hungarian Forint deposit rate at time  $t$ ,  $EUR1M_t$  is the 1-month euro denominated deposit rate at time  $t$ ,  $EURHUF_t$  is the exchange rate in terms of Hungarian Forint required for one euro at time  $t$  and  $EURHUF_{t+1M}$  is the spot rate in 1 month's time. This is fundamentally the same as Brunnermeier's, which is Equation 4.4 (Brunnermeier et al., 2008). The value of P1MEURHUF is one when uncovered interest parity holds and the relatively higher interest rate in Hungary is exactly offset by a depreciation of the Hungarian currency against the euro over the course of the month. Carry trade positions speculate that the depreciation in the exchange rate will be less than the interest rate differential or positive carry: values of P1MEURHUF above 1 show a gain on the month, values less than 1 show a loss. A reading of 1.01 is a 1% gain for the month and a reading of .99 is a 1% loss for the month.

#### 4.4.3 Risk-adjusted return

Though the nature of the carry trade suggests that the assumption of normal, symmetric returns should be questioned, a Modified Sharpe Ratio (MSR) can be computed to make some initial and rather cautious comparison of the return to the carry trade compared to the return that is available on other assets. The MSR is calculated as a simple comparison of return per unit of risk, assuming that the risk free rate is zero so that returns are calculated from the break-even point.

TABLE 4.2: Descriptive Statistics of Sample One Month Carry Trade against the US dollar

Country	Coefficient	Mean	Standard Deviation	Modified Sharpe Ratio	Skew	Kurtosis	Maximum	Minimum
Bulgaria (1)	0.9854	1.0024	0.0318	0.0755	-0.0182	4.2100*	1.1018	0.8956
Estonia (1)	0.9684*	1.0049	0.0319	0.1536	0.0429	4.2328*	1.1054	0.9036
Latvia (1)	0.9522*	1.0033	0.0274	0.1204	0.0580	6.7653*	1.1137	0.9009
Croatia (2)	0.9750*	1.0058	0.0315	0.1841	-0.1471	3.9846*	1.0863	0.8973
Romania (2)	0.9173***	1.0080	0.0342	0.2339	-0.3948*	6.0664*	1.1193	0.8682
Russia (2)	0.9303***	1.0023	0.0232	0.0991	-1.5591*	14.6058	1.0840	0.8648
Ukraine (2)	0.9808	1.0021	0.0302	0.0695	-3.3897*	23.5276*	1.0981	0.7971
Czech (3)	0.9818	1.0071	0.0377	0.1883	-0.1857	3.5011*	1.1076	0.8826
Hungary (3)	0.9636	1.0077	0.0426	0.1808	-0.8653*	6.2039*	1.1209	0.8183
Poland (3)	0.9577**	1.0074	0.0408	0.1814	-0.6905*	4.8083	1.1046	0.8554
Norway (3)	0.9751	1.0043	0.0333	0.1291	-0.3425*	4.2913*	1.0801	0.8756
Iceland (3)	0.9715	1.0050	0.0473	0.1057	-0.7531*	7.6745*	1.1908	0.7940
Turkey (3)	0.7960*	1.0122	0.0542	0.2066	-1.0979*	7.4436*	1.1473	0.7576
S&P 500		0.9977	0.0474	-0.0485	-0.5081*	3.5923*	1.0935	0.8289

Countries are classified according to (1) generally fixed exchange rate or currency board; (2) Crawling peg or liberalisation of the exchange rate regime during the period of study; (3) largely floating. The classification is based on the IMF *IMF Classification of Exchange Rate Arrangements and Monetary Policy Frameworks 2004 to 2009* see Table 4.1 for fuller details. The "Coefficient" column is the ordinary least squares (OLS) estimate of the  $\beta_1$  coefficient from the evaluation of equation  $\Delta s_{t+j} = \beta_0 + \beta_1 f_{t+j} + \varepsilon_t$ , where  $\Delta s_{t+j}$  is the change in the spot exchange rate over j periods ahead,  $f_{t+j}$  is j-period forward rate,  $\varepsilon_t$  is an error term and  $\beta_0$  and  $\beta_1$  are coefficients to be estimated. The statistical significance of  $\beta_1$  is assessed with conventional t-statistics where \*, \*\* and \*\*\* indicate 10%, 5% and 1% levels of statistical significance respectively. The other columns show the descriptive statistics for the profits from a carry trade calculated as  $P1MEURHUF_t = \frac{(1+HUF1M_t)^{\frac{1}{12}} \times EURHUF_t}{(1+EUR1M_t)^{\frac{1}{12}} \times EURHUF_{t+1M}}$ . The Modified Sharpe Ratio is calculated as the mean return per unit of risk assuming that there is a constant risk-free rate and that the breakeven point is the reference against which returns are judged. Skewness and kurtosis are measured in the conventional way with significance calculated as cases where the test statistic is greater than two standard error of skew (ses) or two standard errors of kurtosis (sek) respectively and identified by an asterisk when beyond this point.

From Tables 4.2 and 4.3, the MSR reveals that for positions funded against the US dollar, a carry investment in Romania has the highest return for unit of conventionally measured risk at 0.2339 per month compared to 0.2066 for Turkey and 0.1883, 0.1841, 0.1808 and 0.1814 for the Czech Republic, Croatia, Hungary and Poland respectively. When funding against the Euro, the Czech Republic and Hungary have ratios of 0.1751 and 0.1780 respectively while Iceland is at 0.1639. Croatia, Poland, Romania and Estonia are not far behind.

Evidence from the sample one month carry trade show that in all currency cases there is an expected positive return when funded against the US dollar (see Table 4.2). Against the Euro the outcome is more mixed. On average a loss is made when depositing funds in Bulgaria, Russia, Ukraine and Latvia. An analysis of the results shows a range of returns on carry trade funded by the US dollar from 1.0080 for Romania to 1.0021 for the Ukraine, or 0.8% per month (around 10% annualised) and 0.2% per month (around 2.5% annualised). These returns compare quite favourably with the better known carry countries like Norway, Iceland and Turkey where the sample returns over this period are 1.0043, 1.005 and 1.0112 (0.43%, 0.5% and 1.1% respectively). The 1% average return on a US dollar funded investment in Turkish deposits is the most favourable in this sample. This would give just a little more than 14% annualised return. The others are 5% and 6% respectively. These returns also compare favourably with the sample return available on the S&P 500 index which made an average loss through the same period calculated on the same funding process.

For the positions funded by the Euro, Polish and Hungarian positions achieve a mean return of 0.42% (just over 5% annualised). This is just a little less than the 0.77% (nearly 10% annualised) achieved for a Turkish carry position but more than the 0.11% and 0.07% for Iceland and Norway respectively. There are average losses for deposits made in Bulgaria, Russia, Ukraine and Latvia. See Table 4.3. The positions for carry trades funded by Swiss francs (not reported but available on request) show average carry profits for Czech, Croatia, Hungary, Poland, Romania and Estonia (as well as Norway, Iceland and Turkey). For carry trades funded by the Japanese yen, all the carry positions are profitable on average.

In conclusion, the preliminary investigation shows that UIP generally does not hold for the main CEE and CIS exchange rates during the period under study and it appears that there are returns from investing in the carry trade. The question of whether these returns are sufficient to compensate for the risk that is being taken will be investigated in the next section by building a carry trade model and using that to understand more about the nature of the risk and return.

TABLE 4.3: Descriptive Statistics of Sample One Month Carry Trade against the Euro

Country	Coefficient	Mean	Standard Deviation	Modified Sharpe Ratio	Skew	Kurtosis	Maximum	Minimum
Bulgaria (1)	0.5425***	0.9999	0.0024	-0.0417	-0.1397	4.1821*	1.0061	0.9917
Estonia (1)	-0.34798***	1.0004	0.0023	0.1739	0.2811	3.0352	1.0064	0.9952
Latvia (1)	0.9677***	0.9989	0.0121	-0.0909	-0.8626*	7.8075*	1.0413	0.9411
Croatia (2)	0.8153***	1.0016	0.0109	0.1468	-1.0107*	6.2748*	1.0260	0.9523
Romania (2)	0.9733*	1.0039	0.0253	0.1541	-0.0625	3.5665	1.0761	0.9284
Russia (2)	0.9687*	0.9987	0.0282	-0.0461	-1.8364*	11.3095*	1.0522	0.8367
Ukraine (2)	0.9872	0.9985	0.0396	-0.0379	-1.0945*	8.0828*	1.1096	0.7969
Hungary (3)	0.8866***	1.0042	0.0236	0.1780	-0.8433*	7.3652*	1.0734	0.8908
Poland (3)	0.9433***	1.0042	0.0292	0.1438	-0.5596*	0.4968	1.0770	0.9124
Czech (3)	0.9812	1.0031	0.0177	0.1751	-0.4826*	4.2841*	1.0465	0.9460
Norway (3)	0.8966***	1.0011	0.0202	0.0545	0.0266	7.6811*	1.0975	0.9210
Iceland (3)	0.9819***	1.0007	0.0427	0.1639	-0.8212*	8.3528*	1.1727	0.8273
Turkey (3)	0.9291	1.0077	0.0556	0.1384	-0.7185*	6.2073*	1.1890	0.8273
S&P 500		0.9977	0.0474	-0.0485	-0.5081*	3.5923*	1.0935	0.8289

Countries are classified according to (1) generally fixed exchange rate or currency board; (2) Crawling peg or liberalisation of the exchange rate regime during the period of study; (3) largely floating. The classification is based on the IMF *IMF Classification of Exchange Rate Arrangements and Monetary Policy Frameworks 2004 to 2009* see Table 4.1 for fuller details. The "Coefficient" column is the ordinary least squares (OLS) estimate of the  $\beta_1$  coefficient from the evaluation of equation  $\Delta s_{t+j} = \beta_0 + \beta_1 f_{t+j} + \varepsilon_t$ , where  $\Delta s_{t+j}$  is the change in the spot exchange rate over j periods ahead,  $f_{t+j}$  is j-period forward rate,  $\varepsilon_t$  is an error term and  $\beta_0$  and  $\beta_1$  are coefficients to be estimated. The statistical significance of  $\beta_1$  is assessed with conventional t-statistics where \*, \*\* and \*\*\* indicate 10%, 5% and 1% levels of statistical significance respectively. The other columns show the descriptive statistics for the profits from a carry trade calculated as  $P1MEURHUF_t = \frac{(1+HUF1M_t)^{\frac{1}{12}} \times EURHUF_t}{(1+EUR1M_t)^{\frac{1}{12}} \times EURHUF_{t+1M}}$ . The Modified Sharpe Ratio is calculated as the mean return per unit of risk assuming that there is a constant risk-free rate and that the breakeven point is the reference against which returns are judged. Skewness and kurtosis are measured in the conventional way with significance calculated as cases where the test statistic is greater than two standard error of skew (ses) or two standard errors of kurtosis (sek) respectively and identified by an asterisk when beyond this point.

#### 4.4.4 A carry-trade model

The aim of this section is to build a model to explain the carry trade and to use this to learn more about the profits and risk associated with the activity. As was identified in Section 4.3.2, the main components of the carry model should be the exchange rate regime, the level of international risk aversion and the interest rate differential. Given the assumption that calm conditions will encourage carry trade positions to be established and that this will tend to mean that the carry trade is successful by the encouraging appreciation of the investment currency at the expense of the funding currency, it may be suspected that there will be some momentum behind the carry trade and that an increase in profits for the carry trade will encourage other participants to enter the market.

The initial assessment of the carry trade is carried out with simple ordinary least squares (OLS)<sup>4</sup> using the profits from the carry trade as the dependent variable and using the lag of the dependent variable, the VIX index and the spread between the interest rates in the investment and funding currencies. The carry trade should benefit from calm conditions and, when these are in place, carry positions are likely to be gradually built up. This would suggest serial correlation in the profit series would be seen in periods of calm. Changes in the VIX index are designed to capture adjustments in international risk preference that should make the carry trade less attractive. Therefore, lower levels of the VIX are associated with calm and the building of profitable positions; higher levels of the VIX should be associated with reversals, as carry trade positions are unwound, negative profits, increased liquidity constraints and a rise in risk aversion amongst investors and funders of the position, and an increased probability of crash risk. The interest rate differential makes the carry trade attractive in the first place and provides a greater buffer against a depreciation of the investment currency against the funding unit. Therefore, the greater the interest rate differential the greater the expected profit and the greater the crash risk that should be expected. The equation to be estimated is

$$y_{it} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon \quad (4.7)$$

<sup>4</sup>There is likely to be some bias to the estimates of the coefficient on the lagged dependent variables as a result of using this method and therefore the results should be treated with some caution. In an estimation of  $y_t = a + b_1 y_{t-1} + e_t$ ,  $E(y_{t-1}, e_t) \neq 0$ . The bias will disappear asymptotically so long as there is no serial correlation in the residuals. Therefore, the inspection of the residuals is most important in this case (White, 1961). So long as there is no serial correlation in the residuals, the bias will be positive for the lagged dependent variable and negative for the coefficient on the other explanatory variables. There is no evidence of serial correlation in the regressions estimated here. Q-statistics, estimating serial correlation in the residuals to 12 lags are not statistically significant for any of these equations. *Monte Carlo* estimates indicate that the bias on the lagged dependent variable with a sample size of over 100 (as is the case here) would only be in the region of 1.0% and 1.5%, while the bias in the coefficient on the other explanatory variables would be in the region of 1.5% to 2.5% (Keele and Kelly, 2006)

where  $y_t$  is the return to the carry trade for country  $i$  at time  $t$ ,  $x_1$  is the lag of the dependent variable,  $x_2$  is the VIX index and  $x_3$  is the interest rate differential;  $\beta_0$ ,  $\beta_1$ ,  $\beta_2$  and  $\beta_3$  are the coefficients to be estimated. The results of the investigation are presented in Tables 4.4 and 4.5. The VIX index is statistically significant and negative in each case. There is mixed evidence on serial correlation. Russia, Ukraine and Iceland show signs of momentum behind the carry trade that could indicate a build up of risky positions. In Croatia, Latvia and Estonia, there is evidence of negative feedback. This may be a function of the natural fluctuation within an exchange rate band. There may be mean-reversion to the centre of the band when the exchange rate is fixed. Interest rate differentials have a positive effect in all cases, but it is not always statistically significant. As would be expected, the more fixed the exchange rate, the more important the interest rate differential appears to be for the carry trade. An interest rate differential will encourage the building of carry trade positions when the exchange rate is fixed.

TABLE 4.4: Influences on the carry trade funded by US dollars

Country	Exchange Rate Regime	Auto-regression	VIX	Rate Spread
Bulgaria	(1)	0.0243	-0.0005	0.0027*
Estonia	(1)	-0.0134	-0.0009**	0.0044**
Latvia	(1)	-0.1618	-0.0008***	0.0034***
Croatia	(2)	-0.0477	-0.0007*	0.0021**
Romania	(2)	0.0033	-0.0011***	0.0004*
Russia	(2)	0.3420***	-0.0007***	0.0011**
Ukraine	(2)	0.2504***	-0.0016***	0.0018***
Hungary	(2)	0.0058	-0.0012***	0.0028**
Czech Republic	(3)	0.0138	-0.0009**	0.0030
Poland	(3)	0.08043	-0.0013***	0.0010
Turkey	(3)	0.0947	-0.0013***	0.0003
Iceland	(3)	0.1838**	-0.0009*	0.0000
Norway	(3)	0.0792	-0.0010**	0.0032*

These are the coefficients on the equation  $y_{it} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon_t$ , where  $y_{it}$  is the profit from the carry trade at time  $t$ ,  $X_1$  is the lag of the dependent variable,  $X_2$  is the VIX index of implied volatilities on the S&P 500 index,  $X_3$  is the 1-month interest rate differential between the currency and the funding unit (US dollars).  $\beta_0$ ,  $\beta_1$  and  $\beta_2$  are coefficients to be estimated. \*, \*\* and \*\*\* signify that the estimated coefficients are significantly different from zero using t-statistics at the 10%, 5% and 1% level of significance respectively.

There are surprisingly few differences in the results of funding with the US dollar compared to funding with the Euro. Russia and the Ukraine, where the exchange rate is more referenced against the US dollar, show quite a strong influence from the interest rate differential on the profitability of the carry trade when funded against the US unit, but this disappears when assessing the interest rate differential with the Euro; the more

fixed the exchange rate, the more interest rate differentials are important, the more variable, the more international crisis affects the profitability of the carry trade.

TABLE 4.5: Influences on the carry trade funded by the Euro

Country	Exchange Rate Regime	Auto-regression	VIX	Rate Spread
Bulgaria	(1)	-0.2603***	0.0000	0.0010***
Estonia	(1)	-0.4639***	0.0000	0.0010***
Latvia	(1)	0.0571	0.0000	0.0014***
Croatia	(2)	-0.1684*	-0.0010	0.0009*
Romania	(2)	0.0645	-0.0007***	0.0004*
Russia	(2)	0.1715*	-0.0002	0.0000
Ukraine	(2)	0.1074	-0.0010**	0.0007
Hungary	(2)	0.0746	-0.0006***	0.0021**
Czech Republic	(3)	0.0294	-0.0004**	0.0038*
Poland	(3)	0.1966**	-0.0008***	0.0011*
Turkey	(3)	0.0358	-0.0010**	0.0000
Iceland	(3)	0.1087	-0.0008	0.0002
Norway	(3)	-0.0256	-0.0003	0.0004

These are the coefficients on the equation  $y_{it} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon_t$ , where  $y_{it}$  is the profit from the carry trade at time  $t$ ,  $X_1$  is the lag of the dependent variable,  $X_2$  is the VIX index of implied volatilities on the S&P 500 index,  $X_3$  is the 1-month interest rate differential between the currency and the funding unit (Euro).  $\beta_0$ ,  $\beta_1$  and  $\beta_2$  are coefficients to be estimated. \*, \*\* and \*\*\* signify that the estimated coefficients are significantly different from zero using t-statistics at the 10%, 5% and 1% level of significance respectively.

#### 4.4.5 Moderation and Crisis

The FIH postulates that there are periods of calm, during which speculative positions are built as shocks become increasingly difficult to imagine. However, these calm conditions and the build up of speculative positions that accompany them create the conditions under which the potential for a large crash is increased. The carry trade appears to have a very similar pattern. Therefore, this study will assess whether the carry trade can be characterised by two distinct periods: the calm or moderation when speculative positions are build; the crisis of panic when positions are unwound. This part of the paper seeks to understand the nature of returns to the carry trade in these two regimes.

Indeed, underlying this hypothesis, the distribution of returns to the carry trade can be postulated as having two phases: a relatively tight distribution about the mean during periods of calm and broad or fat-tailed distribution with a negative mean during times of crisis. To make a comparison of the two regimes, the sample carry trades are broken into two categories. The first is the period calm or moderation and labeled M and the second of crisis and is labeled C. Using the VIX index as a signal of international crisis



the sample is divided into those crisis periods when the VIX is above the 90th percentile of the whole period under investigation and those calm periods when it is less than the 60th percentile. The levels are chosen with reference to the data (see Figure 4.1) to ensure that there are a sufficient number of observations in each category and to try to prevent the 2007 - 2008 financial crisis dominating the period of crisis. On inspection, it is clear that the recent crisis is important, but there are some representatives from earlier. It would have been interesting to have used a rolling quantile but the relative sparsity of data made this unfeasible.

There are a number of themes that emerge from the result of this exercise (Table 4.6 for US dollar funding and Table 4.7 for Euro funding). For US dollar funding, carry returns in the crisis period are below those in the period of calm for all cases and in all cases, apart from Bulgaria, where results may be affected by one large discrete devaluation at the beginning of the sample, the mean return switches from being a profit to being a loss. For Euro funding, crisis returns are lower in all cases but Bulgaria, Latvia, Estonia and Iceland, and the mean return again switches from profit to loss. These findings are consistent with the hypothesis that carry trades are successfully built in times of calm and unprofitably unwound in the crisis.

The decline in profitability is statistically significant for Poland, Romania and Norway when funding with US dollars and Poland, Hungary and Estonia when funding with Euro. The test used is an F-test analysis of variance that compares the variability between the mean of the two groups with the variability of the samples within the two groups modified along the lines of Welch to compensate for differences in the variance of the two groups (Welch, 1951). It is not surprising that a floating exchange rate regime is more likely to encounter significant variation in carry returns.

The second finding is that the increase in international uncertainty and risk aversion is associated with an increase in in the risk attached to carry trade profits, whether measured in conventional or unconventional ways. The standard deviation of carry returns funded against the US dollar is larger in the crisis period relative to that recorded in the period of calm for all CEE and CIS countries in this sample. An F-test of the ratio of the standard deviation of the two return periods (crisis and moderation) is significant in all cases. It is very likely that this is at least partially a function of the US dollar leg of the trade becoming more volatile due to international issues. However, though US-dollar-funded carry-trade with Iceland shows the same pattern of increased volatility, the increase in the standard deviation of Norwegian and Turkish crisis returns may be a little larger for the crisis, they are not statistically significant using the same F-test standard. For Euro funding of the carry trade, all cases bar Latvia and Estonia show greater risk in the crisis period. These results should not be surprising given the currency

board arrangements that are designed to minimise the fluctuations in the exchange rate. The increased volatility for Bulgaria, which also has a currency board, is associated with the pre-board period. However, only in the case of the Czech Republic, Ukraine and Russia are differences in variance statistically significant under the test constructed.

The F-test of standard deviation equality assumes a normal distribution. As noted in the literature and the initial investigation, this is not likely to be an accurate description of returns to the carry trade. Therefore, a non-parametric test of the return distributions in crisis and calm can be carried out. The test conducted is the Mann-Whitney-Wilcoxon (MWW) rank sum test. The test will compare the ranks of the two series and the U statistic

$$U_1 = R_1 - \frac{n_1(n_2 + 1)}{2} \quad (4.8)$$

where  $R_1$  is the rank of series 1,  $n_1$  is the number of observations in series 1 and  $n_2$  is the number of observations in series 2. The smallest U statistic for the two series is chosen.  $U - 1$  is normally distributed in larger samples with tables for less than 30 observations. A large value for the test statistic is a general indication that the means, medians or general characteristics of the two distributions are different in the two samples.

There is consistent and persistent evidence that profitability of the carry trades is affected by the international crisis and changes in risk aversion. This is most evident in the countries that allow their exchange rates to float. It seems that linking to a funding currency will reduce the possibility of extremely negative exchange rate outcomes, though there may be other monetary costs associated with the implementation of the stabilisation policy.

Using the robust MWW method to test whether the distribution of the carry trade profits in the two regimes are different (identified as an asterisk in the *standard deviation* column of Tables 4.6 and 4.7), reveals significant results for Poland, Romania, Russia and Turkey with US dollar funding and Hungary, Poland, Estonia, Norway and Turkey for EUR funding. The conclusion is that the distribution of returns in periods of calm and moderation in these cases are not the same, providing support for the hypothesis that carry trades can be characterised by two regimes, moderation and crisis, and that the distribution of carry trade profits for the period of moderation has a high mean, and a compact and symmetric distribution while the mean for the crisis is lower (probably negative) and the distribution is wide and skewed. The profits are lower and the risk is higher.

TABLE 4.6: Carry trade vs US dollar: A comparison of Crisis (C) and Moderation (M) modes

Country	Crisis	Moderation	Crisis	Moderation	Crisis	Moderation	Crisis	Moderation
	Mean		Standard Deviation	Standard Deviation	Skew		Kurtosis	Kurtosis
Bulgaria (1)	0.9869	0.9998	0.0542*	0.0245	0.2119	0.0993	3.0996	2.2825
Estonia (1)	0.9894	1.0019	0.0539***	0.0237	0.2980	0.1177	3.0854	2.8024
Latvia (1)	0.9893	1.0011	0.0548***	0.0192	0.5186	-0.2981	3.4178	3.5784
Croatia (2)	0.9911	1.0033	0.0492***	0.0239	-0.5192	0.1090	2.5149	3.2016
Romania (2)	0.9780*	0.0118	0.0585**	0.0290	-0.3242**	0.6032	2.2246	4.9414
Russia (2)	0.9799	1.0040	0.0519***	0.0125	-0.5190**	-0.7216	3.3035	5.8705
Ukraine (2)	0.9722	1.0049	0.0787***	0.0124	-0.8091	1.1037	3.2066	6.5962
Czech (3)	0.9823	1.0046	0.0522**	0.0306	-0.2056	-0.2102	2.5504	2.7822
Hungary (3)	0.9752	1.0079	0.0773***	0.0342	-0.6404	-0.5227	2.6642	2.6364
Poland (3)	0.9693*	1.0080	0.0669**	0.0330	-0.3928*	-0.3027	1.9318	2.8995
Norway (3)	0.9812*	1.0044	0.0593	0.0297	-0.9127	0.2421	2.7733	3.0321
Iceland (3)	0.9937	1.0094	0.1265***	0.0329	0.4620	0.0329	1.9136	3.0460
Turkey (3)	0.9696	1.0212	0.0725	0.0440	-1.1087*	-0.3614	2.9842	6.3445
S&P 500	0.9849	0.9966	0.0899**	0.0367	0.2461	-0.4854	1.3363	3.4212

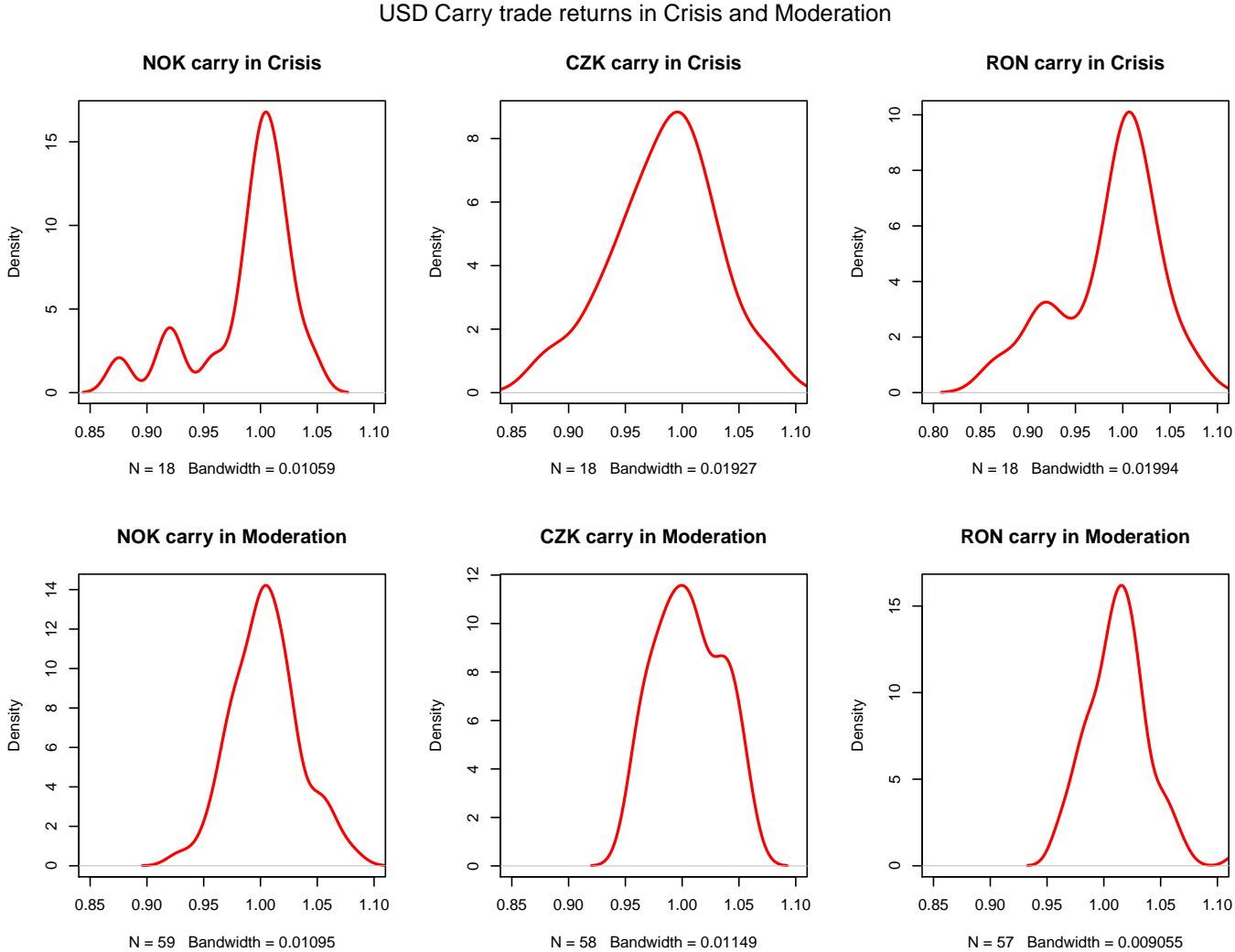
Countries are classified according to (1) generally fixed exchange rate or currency board; (2) Crawling pego or liberalisation of the exchange rate regime during the period of study; (3) largely floating. The classification is based on the IMF *IMF Classification of Exchange Rate Arrangements and Monetary Policy Frameworks 2004 to 2009* see table 4.1 for fuller details. The crisis mode is identified by the VIX index being above the 90th percentile while the moderation is below the 60th percentile. The test of the difference in means is an analysis of variance F-test that compares the variability of the means of the two groups with the variation of the samples within groups, modified along the lines of the (Welch, 1951) for possible differences in the standard deviation of the samples. The comparison of the standard deviations is based on an F-test of the two variances, the distribution of the profits during the crisis and moderation periods is compared using the rank test proposed by Mann-Whitney-Wilcoxon to produce a U statistic (noted in the skew column). In all cases the statistical significance of the difference between the two periods at the 1%, 5% and 10% levels is identified by \*\*\*, \*\* and \* respectively.

TABLE 4.7: Carry trade vs the Euro: A comparison of Crisis (C) and Moderation (M) modes

Country	Crisis Mean	Moderation	Crisis Standard	Moderation Deviation	Crisis Skew	Moderation	Crisis Kurtosis	Moderation
Bulgaria (1)	0.9979	0.9989	0.0037	0.0019	-0.6208	0.0177	2.3408	5.0171
Estonia (1)	1.0023	0.9999	0.0022	0.0020	0.5329***	0.3551	1.9143	3.9310
Latvia (1)	1.0036	0.9990	0.0106	0.0111	0.1292	0.1126	2.1531	5.5973
Croatia (2)	0.9981	1.0020	0.0143	0.0091	-1.1246	-0.3460	2.9392	4.0375
Romania (2)	0.9886	1.0076	0.0379	0.0227	-0.1564	0.5149	1.3058	3.3333
Russia (2)	0.9755	1.0018	0.0781***	0.0198	-0.9529	-0.1711	2.6817	3.3539
Ukraine (2)	0.9530	1.0031	0.1130***	0.0286	0.0877	-0.0538	1.9163	3.0344
Czech (3)	0.9823	1.0026	0.0350**	0.0133	0.1880	-0.1890	1.3283	3.0750
Hungary (3)	0.9656*	1.0070	0.0405	0.0212	-1.1734***	-0.5259	2.9761	5.4320
Poland (3)	0.9520 ***	1.0068	0.0321	0.0263	0.4844***	-0.5970	2.3183	3.3204
Norway (3)	0.9974	1.0032	0.0597***	0.0169	0.8849*	-0.07930	2.9493	3.8786
Iceland (3)	1.0022	1.0072	0.1179***	0.0284	0.1495	-0.7455	1.8228	4.8749
Turkey (3)	0.9770	1.0193	0.0407	0.0483	-0.1328**	-0.2182	1.7780	6.0263
S&P 500	0.9849	0.9966	0.0899**	0.0367	0.2461	-0.4854	1.3363	3.4212

Countries are classified according to (1) generally fixed exchange rate or currency board; (2) Crawling peg or liberalisation of the exchange rate regime during the period of study; (3) largely floating. The classification is based on the IMF *IMF Classification of Exchange Rate Arrangements and Monetary Policy Frameworks 2004 to 2009* see table 4.1 for fuller details. The crisis mode is identified by the VIX index being above the 90th percentile while the moderation is below the 60th percentile. The test of the difference in means is an analysis of variance F-test that compares the variability of the means of the two groups with the variation of the samples within groups, modified along the lines of the (Welch, 1951) for possible differences in the standard deviation of the samples. The comparison of the standard deviations is based on an F-test of the two variances, the distribution of the profits during the crisis and moderation periods is compared using the rank test proposed by Mann-Whitney-Wilcoxon to produce a U statistic (noted in the skew column). In all cases the statistical significance of the difference between the two periods at the 1%, 5% and 10% levels is identified by \*\*\*, \*\* and \* respectively.

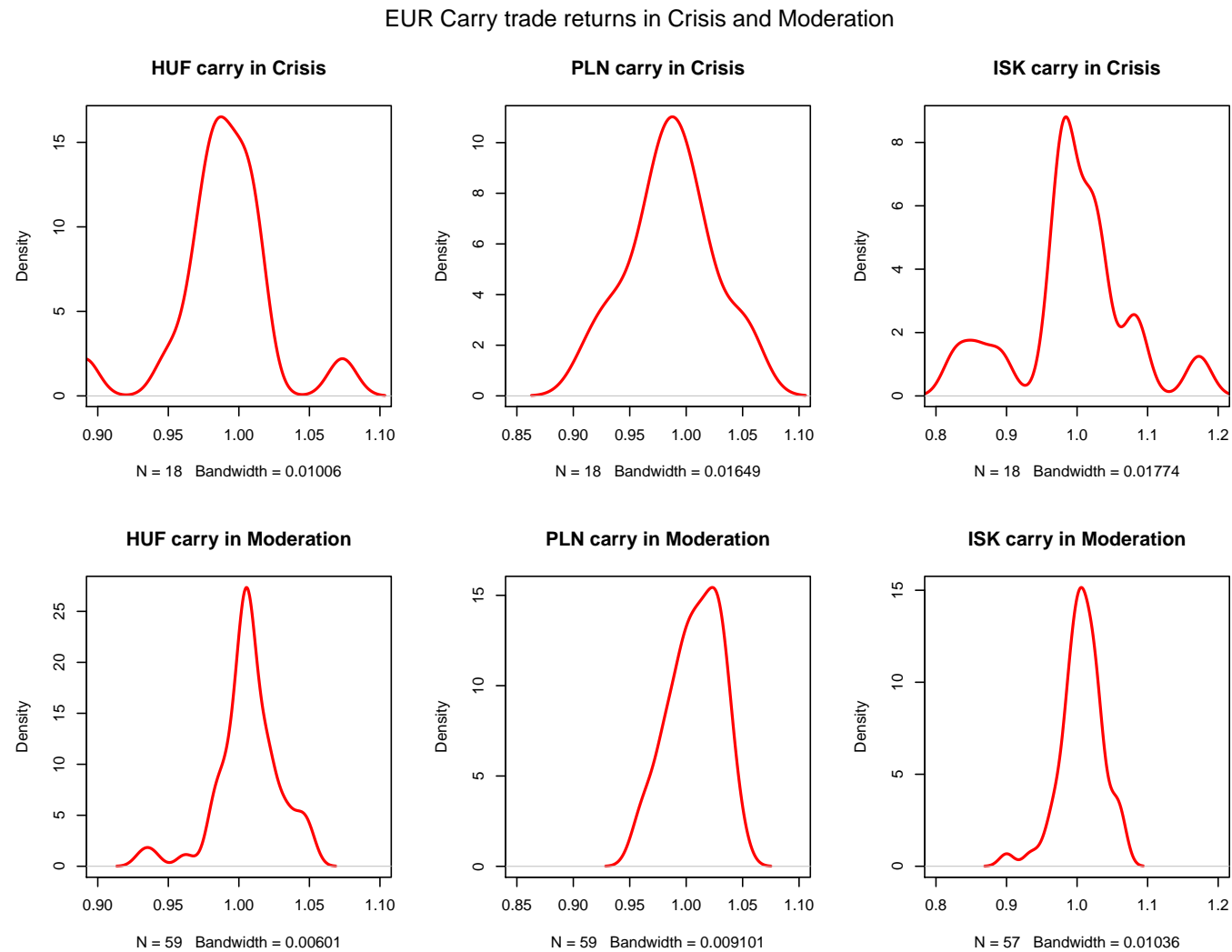
FIGURE 4.2: The Distribution of USD Carry Trade Returns in Moderation and Crisis



The difference in the carry trade profit during periods of moderation and crisis is very clear when presented graphically with *kernel density estimates*. A kernel density estimate is a smoothed histogram. Rather than putting the data points into a *bin*, a normal distribution with a mean on each point is established and these kernels are added together to get a smoothed line. The size of the standard deviation that is applied to the normal distribution about the data point is called the *bandwidth*. There is a trade-off between the establishment of a smooth line with a large bandwidth and the dissipation of the information that this implies. The default *Silverman's rule of thumb* is used in this case and reported at the bottom of the graph (Silverman, 1986, p. 48). This analysis is carried out with the *density* function in base package in R (R Core Team, 2013) see (Venables and Ripley, 2002) for more details of the smoothing process and Appendix C, Section C.5 for code used to construct Figures 4.2 and 4.3.

Figure 4.2 shows the distribution of carry trade returns for Norway (NOK), Czech Republic (CZK) and Romania (RON) when funded against the US dollar during the period of Crisis (C) and period of Moderation (M) respectively; Figure 4.3 shows the distribution of carry trade returns for Hungary (HUF), Poland (PLN) and Iceland (ISK) against the Euro during the period Crisis (C) and Moderation (M). The x axis is fixed to ensure clear comparison. It is evident that during the times of increased international risk aversion, the returns to the carry trade are not only lower on average but they are more dispersed, more negatively skewed and more likely to be losses.

FIGURE 4.3: The Distribution of EUR Carry Trade Returns in Moderation and Crisis



## 4.5 The carry trade and speculation

This chapter has sought to understand more about speculation by looking closely at one particular speculative activity in the foreign exchange market. A sample of potential carry trade was created, the profits were analysed and a model of carry trade profits was created. The model confirms previous work that has identified the nature of the exchange rate regime, the interest rate differential and the level of international risk aversion as being the main contributors to carry trade profits. It is clear that there are at least two regimes under which the carry trade operates: when the carry trades are broken down into those that happen when international risk aversion is elevated and contrasted to those where it is moderate, the returns during the period of crisis are found to be much lower, most likely negative, and the risk, whether measured by standard deviation or the higher moments, is much higher.

Many of the characteristics of speculation that have already been identified are evident in the carry trade: there are real effects; there is some information that speculators take advantage of; there are feedback effects and momentum; and, the relationships that are evident are not simple or precise. The speculative activity of the carry trade is a consequence of the belief amongst a wide range of economic agents, ranging from international speculators through to regular firms and individuals, that UIP does not hold. However, while the carry trade is on average successful, there are spectacular collapses that are very difficult for these agents to forecast with accuracy. Awareness of these potential shocks tends to be pushed into the background when conditions have been calm for some time and the evidence of carry trade success is apparent. However, it can swiftly return when there is a rise in international risk aversion.

The level of uncertainty over the future exchange rate movements is very high. However, this is inevitably reduced in currency peg, particularly if the monetary and political authorities are pledging to fight the sort of depreciation that is to be feared. For regular households, there is a feeling of safety in numbers and it would be foolish to miss out. For more sophisticated investors, as has been seen in Chapter 3, the greatest returns are for those at the start of the trend. Price momentum helps to further reduce any doubts by ensuring initial success: the carry trade causes the investment currency to appreciate rather than depreciate and the central bank may initially be fighting to keep the exchange rate down. Therefore, carry trade activity is particularly attractive if others are participating.

The analysis of the carry trade that has been conducted here suggests that there are large, unconventional risks associated with the strategy. Much depends on expectations and these expectations become self-fulfilling. If expectations about the future depend



so much upon what others think, any equilibrium will be fragile. Small doubts can turn complacency into panic. As has been seen in Chapter 3, for institutional investors there is a need to get into the trade at the earliest opportunity so that the momentum of others can be utilised. However, for all participants, when the reverse happens, it will be essential to exit before everyone else.

It has been argued here that the carry trade is a micro version of a Minsky-Kalecki-Levy speculative accelerator model where speculative activity and subsequent reversal are self-reinforcing. Hedge financing that errs towards speculative financing can mean that increased investment will raise profits sufficiently to ensure that they are enough to cover all debt payments. These are good investments. However, there is a limit to how far this can be pushed. Diminishing returns from investment will set in, ensuring that the financing scheme becomes more speculative and gradually raising the prospect of a crash. With the carry trade, the trades themselves tend to negate the tendency of the funding currency to appreciate against the investment currency, increasing the attraction of the trade and drawing others into the activity. However, this will increase the risk, if there is a reversal, as traders will be wary of such a turn-around and will be ready to exit, adding to the pressure for a crash, when it occurs.

As discussed briefly in Section 4.1, European monetary authorities have faced a number of struggles with exchange rate speculation. This has taken different forms: the guardians of investment currencies have struggled to contain exchange rates and inflationary forces when carry trade positions have been established. If the exchange rate is fixed, there is a need to purchase overseas assets, expanding the central bank balance sheet and the monetary base at a time when domestic banks are full of the deposits of carry trade investors. If the exchange rate is allowed to float, there is a loss of competitiveness or pressure to reduce domestic interest rates. In either case, the short-run impact on domestic demand is likely to be positive through lower import or funding costs; the long-run consequences are likely to be a *hollowing out* of domestic industry or asset price inflation. The negative consequences of the imbalances that have developed are likely to be exposed as a result of the crash that happens when capital reverses: the exchange rate, interest rates and asset prices fall; import prices increase, reserves and the monetary base shrink. The crash or *sudden stop* to the inflow of capital and its reversal cause exchange rate depreciation, inflationary pressure to add to an overall sense of economic panic and curtailment of available funds.

The evidence of this chapter leaves political and monetary authorities with an exchange rate problem. The results from Tables 4.4 and 4.5 indicate that the more fixed the exchange rate the more carry trade profits will be determined by relative interest rates. As is known, this will limit the independent use of monetary policy; the more the exchange

rate is allowed to fluctuate, the greater the exposure to changes in international risk aversion and the more international shocks will be translated to the domestic economy through exchange rate depreciation. Curtailing speculative activity would be one way to ease this monetary dilemma. This is an issue that is discussed in the concluding chapter.

## Chapter 5

# Conclusion

### 5.1 Speculation and exchange rates

This investigation of exchange rates began with the proposition that fundamental value is provided by PPP. There are a number of caveats: the appreciation of the real exchange rate is likely to accompany economic development, exchange rates often diverge from *fundamental value* and, when they do, it takes some time to return to *equilibrium*. The use of international capital flows to understand adjustments in the real exchange has ensured that the number of explanatory variables has been reduced to a manageable size while the VAR method allowed for estimation when there is feedback from the exchange rate to capital flows.

It is clear from the model's IRFs that speculation is a significant contributor to deviations in the exchange rate from PPP, that it can affect the real exchange rate even outside the short-run and that models that try to understand the exchange rate without speculation may be mis-specified. Moreover, event studies of extreme speculative positions indicate that speculation is part of the process of price discovery and that speculation is not mere noise.

While speculation drives the exchange rate, information about the strength of speculative sentiment and the weight of speculative traders contributes little to knowledge about future foreign exchange returns. Nonetheless, when one specific speculative activity is investigated in more detail, it becomes more apparent that speculation is only partially informed about the risk that is being taken with the carry trade. The failure of UIP to hold is the information that attracts speculators to the carry trade. However, while conventional measures suggest that this trade can generate excess returns, a Sharpe Ratio for example may be relatively attractive, the fat-tailed and negatively skewed

distribution of these returns means that while there are a lot of small gains to be made, these are likely to be accompanied by catastrophic losses. The complexity of the process surrounding this particular speculative activity is a consequence of feedback effects, risk of overshooting and the establishment of positions that will be swiftly reversed if sentiment shifts. There are also institutional features that mean that the creation and unwinding of leverage is likely to be asymmetric in nature. It is clear that speculation increases fragility.

Understanding more about speculation in this one market can also provide some information about the economic role of speculation more generally. The FIH that was proposed by Minsky operates in a very similar way to the carry trade: there are more profitable opportunities for lending and investment when the economy is doing well and the additional lending will encourage boom conditions that will feedback into the expectations of firms, households and governments; while the virtuous circle of profits and lending or asset price appreciation and lending mean that positive expectations are rewarded, reinforced and confirmed in the short-run, this activity is increasing economic fragility because firm and household debt-to-equity and debt-to-income ratios are rising and the repayment of debt is becoming more dependent on the continuation of the extraordinary debt-fuelled profits or asset price appreciation. Government and regulatory attitudes are also affected by this process: the calls for caution are undermined by the apparent success of those who have borrowed most; doubters are dismissed or capitulate; rules are relaxed. It is important to be vigilant when it appears to be least necessary.

### 5.1.1 Enterprise and speculation

At this point, it may be useful to try to define the difference between speculation and entrepreneurship and the actions of speculation and innovation. Keynes made a clear and precise distinction in *The General Theory*. In chapter 12 he made the unfavourable comparison between speculation as “the activity of forecasting the psychology of the market” and enterprise as “forecasting the prospective yield of assets” (Keynes, 1936, p. 139). The investment horizon is also important. Speculation tends to be of the short-term while enterprise is more about long-term. This leaves an uncomfortable fuzziness around the boundary. It is clear that the sort of high frequency trading that depends on nanoseconds and accumulation of basis point crumbs is speculation at one extreme and the *value investment* of Warren Buffett or entrepreneurial creation of new corporations lies at the other, but this leaves great doubts about the position of *alternative investments* like *hedge funds* or *private equity* or even *venture capital* and *business angels*. It also means that institutional features that affect investors’ ability to take the long-term view are important. The De Long noise-trader model depends on there being a

myopic view. Without that, arbitrage is trivial. Institutional constants on markets are important in emphasising short-term activity, which may be destabilising, rather than long-term action that is more likely to be beneficial.

It can also be asserted that entrepreneurship is about goods and services while speculation is about distribution and financial assets. This seems fruitful and the debate can then perhaps resolve around the role of financial markets in the economy. If the smooth and efficient operation of financial markets is important for intermediation and risk-sharing, speculation may be valued; if financial markets are part of the process of financialisation, contributing to de-industrialisation, increased inequality, instability and volatility, speculation is not appreciated and its benefits are illusory.<sup>1</sup>

### 5.1.2 Uncertainty and noise

Knight identifies three key elements of risk and uncertainty: insurance, speculation and enterprise (Knight, 1921, p. 200). He argues that there is little coverage of entrepreneurship in English-speaking economics because there is too much focus on the long-term and the adjustment from one equilibrium to another. This is the sort of fixation with Marshallian statics that Shackle discussed in *A Scheme of Economic Theory* (Shackle, 1965). Rational expectations explicitly assumed that there are speculators to take advantage of disequilibrium. As Muth notes, it is this speculation that provides the means by which the world moves from one theoretical point of balance to another. However, the activity of speculators and the process that facilitates this shift is less well analysed. This research has sought to analyse risk, uncertainty and speculation and to use this to understand more about the adjustment.

Before looking in more depth at what this means for economic modelling and policy-making, it is important first to summarise what has been uncovered about noise, uncertainty and speculation. It appears that speculation is not pure noise as it is at least partially informed. However, noise is a vital ingredient behind innovation and the working of financial markets. Noise is the *uncertainty* that Knight argued was essential to profits and a contrast to risks that could be calculated and insured; noise is the *uncertainty* that caused Keynes's speculators to focus more on outguessing each other over the short-term rather than seeking long-run, fundamental value; noise is also what lies beyond Simon's *Bounded Rationality* and is the basis for Shackle's assertion that quantifying probable outcomes was impossible for many tasks. Noise is also the encouragement to seize the opportunity and to trade and therefore is a vital contributor to the

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<sup>1</sup>Financialisation here means the expansion and encroachment of the activity of finance into areas that were previously part of other sectors such as manufacturing or agriculture. See (Gabor, 2011) for an analysis of the financialisation of CEE, including the role of the carry trade in Romania.

creation of new products and processes and to innovations as well as being a provider of liquidity and the very existence of effective financial markets.

In some places, uncertainty can be seen as an even more fundamental part of economic growth and development. For example, *Evolutionary Economics* looks at the importance of uncertainty as a force in economic evolution. This is a distinction between the mainstream discussion of the adjustments to changes in technology or preference and the behavioural origins of these changes. Finding a link with anthropology, evolutionary economics looks at the economic process as a whole and argues that “transformation occurs because not one, but a range of behavioral rules are adopted and applied by economic decision-makers when faced by uncertainty.” (Foster and Metcalf, 2012, p. 421). The economic agents deal with uncertainty by applying a *bundle of rules* with the formation of new bundles of rules representing something like an innovation. There is experimentation with new ways of doing things. Like Shackle, these writers discuss the interplay between opportunity and threat that results from uncertainty. They are interested in a competitive process rather than a competitive equilibrium.

Uncertainty and decision-making was discussed in Chapter 1 Section 1.2.4. On one level it means that the sample that is being used to assess the probability of the event is not sufficiently large to include all the possible outcomes. This is an example of the *peso problem*. It suggests that the information about the problem will become available given sufficient time or effort. Given resources, cognitive, time or other, uncertainty can be overcome. (Davidson, 2010) makes the case that there is a major distinction between this sort of uncertainty, which, Davidson argues, encompasses Nassim Taleb’s *Black Swan* (Taleb, 2007) as well as theories of *behavioural finance*, with definitions of uncertainty that assert that there are some things that are fundamentally *unknowable*. In Davidson’s words, it is a system that is *non-ergodic*, with the non-ergodic in this sense meaning that the system is unique and that it is impossible to group events into sets that have uniform characteristics to make more general inferences. It is not a matter of insufficient information or inadequate cognitive capacity. Davidson asks why economic agents do not learn the underlying laws of the economy and overcome their behavioural biases (Davidson, 2010, p. 570). This is particularly relevant when considering speculation in financial markets, especially when it is being done increasingly by machines that have been programmed to be Bayesian. There is some tension between the early Keynes of *The Treatise on Probability* (Keynes, 1921) where uncertainty appears to be quantifiable, and the later Keynes of the *General Theory* (Keynes, 1936) where it is presented as something that is much more elusive. It is an area of controversy for scholars of Keynes. However, it is not controversial to say that Shackle and the Austrians and others were of the belief that there was an uncertainty that could not be quantified no matter how much time or effort were applied and that Keynes edged towards this view (though he

clearly did not come to Hayek's conclusions). This particular type of uncertainty is often called *ambiguity* (Daniel, 1961) and (Camerer and Weber, 1992). Therefore, three categories of uncertainty can be identified: risk, which can be fully understood and quantified; uncertainty, which can be quantified eventually; and, ambiguity that cannot be understood or quantified in the same way.

Modern financial markets have become swifter, more precise and more dominated by machines. As behavioural science has taken over economics, machines have taken over trading and investment. The imperfections that have been found by psychologists do not exist in the robots that make markets and trading decisions based largely on the Bayesian rules that were identified in Section 1.2.3. While this will ensure that there is no emotion and no divergence from Bayesian decision-making (unless the programmer wants there to be), not only are there mistakes made in the programming of trading machines,<sup>2</sup> but the machines will not have the ability to act when there is ambiguity and will not be able to identify those cases that require intuition or behavioural rules that allow decision-making when there is limited information or high levels of noise. In the case of the *Flash Crash* it was the human speculators who started to buy bargains at very low prices to break the vicious cycle of decline. The humans can see no news to justify the 80% decline in value, the machines work on rules that can never be sufficiently complex to cover all eventualities.

### 5.1.3 Confidence

Confidence is a recurrent theme. When information is scarce and the type of uncertainty is toward that of ambiguity, it will be difficult for most economic agents to make decisions. Behavioural economics generally finds that in these cases most people stay with what they already have. Overwhelmed by choice and unable to decide, they hold back. However, confidence may mean the ability to act when there is insufficient information to make a decision. In a world with limited information the confident will be decisive. This is the explanation for the link between confidence and innovation. In addition, in the short-run, confidence is likely to be magnified by success. As such, there is a feedback effect that tends to foster confidence and may encourage overconfidence. Seizing the opportunity, taking some risk but ignoring the large, infrequent threat could mean that in the short-run overconfidence speculators succeed at the expense of more cautious risk-averse or risk aware investors. Many of the over-confident entrepreneurs and speculators are likely to experience the extreme negative tail and will fail or *blow*

---

<sup>2</sup>The so-called *Flash Crash* of May 2010 saw prices of some stocks fall by up to 80% in a matter of minutes as machines sold relatively large orders in illiquid markets (*Findings regarding the market events of May 6, 2010*, 2010), while the demise of Knight Capital, the investment bank sunk by its own machines when automated trading lost \$460 million (Rooney and Yousef, 2012), are two recent examples.

*up*. However, not much is heard from them. The minority that are sufficiently fortunate to avoid this, are successful, their stories are told and, as a consequence, decisive action is valued.

## 5.2 Macroeconomic models

As has already been discussed, since the onset of the financial crisis work that seeks to ensure that economic models are able to deal with the effect of the financial crisis on the broader economy has become attractive again. The BIS, IMF and numerous governmental, policy and academic institutions have held conferences and written papers to address a range of issues such as *heterogeneous expectations*, *financial accelerators*, *economic stability*, alternatives to the rational expectations model are proposed and it is demanded that finance be put back at the heart of economics. There is a new emphasis on the broader evolution of economic ideas. Economic history is back in fashion. As the first item on his *10 Step Recovery Plan* Alan Blinder includes *Remember That People Forget* (Blinder, 2013). Gorton argues that the 70 year quiet period after the Great Depression was a result of the regulation that constrained the financial system. However, as the shock was forgotten and regulation relaxed, the opening up of offshore centres, together with the rise in international capital flows has increased the risk. Gorton argues for a historical perspective to economics that will help to prevent complacency in the future (Gorton, 2012).

Speaking at an LSE conference on *What Economics and policy makers should learn from the financial crisis*, Blanchard and Weber made the case for bringing microeconomic details about banking and finance into the macroeconomic models. Blanchard in particular argued for an augmented IS-LM with wedge between the central bank policy rate and the rate that would apply to household and corporate borrowing. The spread between the two rates would be a function of the state of the financial system. The gap would be at its lowest during the period of calm, confident expansion; the gap would increase after panic, shock and de-leveraging. On a more sophisticated level, Blanchard also suggested that leverage and liquidity be added to the DSGE models (Blanchard and Weber, 2013). Speculation could also be added to that list.

### 5.2.1 Modelling speculation

If economic models are to be improved, this study suggests that speculation has to play a part. The key components of speculation that have been identified here are: a limited



horizon, in looking forward to the opportunities and looking back at the evidence; positive feedback in expectations formation, speculative activity and confidence; stochastic and explosive reversals that are proportional to the time that it has taken the bubble to develop.

The first step in improving the models is to consider the expectations that drive speculative activity. While *rational expectations* may be a good way to think about expectations in the long-run, as has been seen, it is not very useful when trying to assess short-term adjustments. The first step towards a more substantial understanding of macroeconomic evolution would be to replace rational expectations with something that is more adaptive so that aggregate risk aversion will adjust to memory of the recent past and will have a process that feeds back onto itself. If the market is efficient and expectations are based on the rational principles of (Muth, 1961), there are no opportunities for abnormal returns unless there are already inefficiencies. Speculators are either investing on the basis that the current outcome is inefficient and removing that inefficiency or they are acting irrationally. This research suggests that it is more likely to be the former. Changes to the modelling of expectations would be particularly appropriate in the aftermath of a financial crisis that was at least partially caused by models that relied on a data span that did not go back sufficiently far into the past to capture the whole range of possible outcomes<sup>3</sup>.

There is already a broad literature on adaptive learning; and this looks to be an excellent starting point for new models. Adaptive expectations models have grown from the initial ideas of Cagan (Cagan, 1956) and Friedman (Friedman, 1957). This literature has been built by two encouraging steps: a rejection of full rational expectations as being implausible in favour of a model of *bounded rationality* where expectations can be formed with the use of models that are less than full econometric specifications and which can be changed or updated over time; and a recognition that agents do not all rely on the same view or model of the world and that some models may be mis-specified. There are two areas that have received particular attention: the discounting of older data and the switching between different forecasting models over time. Each of these can be useful in trying to model non-linear elements that have been characteristic of economic process in the period surrounding the financial crisis. These are also consistent with the analysis of speculation that was carried out in Chapter 4.

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<sup>3</sup>It appears that the data used to model the credit quality of *Collateralised Debt Obligations* (CDO) and mortgage bonds was of a finite span that included limited correlation between house prices in different parts of the US and did not include the period of the 1930's *Great Depression* where prices across the whole country fell simultaneously. Given a mortgage bond that is diversified nationally, the assumption about the correlation between house markets can change the probability of default substantially. See (*CDO rating methodology: Some thoughts on model risk and its implications*, 2004) and (Committee on the Global Financial System Study Group, 2008) for more details.

In addition to a short historical perspective, a new model of expectation should have positive feedback. As discussed above, an important component of speculation is the ability to make decisions when things are uncertain. Self-belief, it appears, is the key to this. Therefore, the sort of positive feedback that comes from successful speculative activity such as the carry trade will make speculators more confident, encouraging them to assume more crash risk and, in the process, increase the amount of crash risk in the economy. Feedback will encourage others to join the game. Therefore, an action that starts by taking advantage of an inefficiency, which could be new information that requires a new price, runs the risk of being pushed beyond the point where prices are in equilibrium. As has been seen, this is not likely to be a simple issue of over-shooting. Fundamental intrinsic value is, after all, not easy to pin down in many cases and therefore, though there is a risk that the late-comers to the party will suffer the *the winner's curse* by paying too much, it is the nature of the risk that is developed that is the real threat.

### 5.2.2 Modelling bank lending

One key sector that can benefit from updated modelling is that of the banking sector. It is apparent that this is the area where speculation and the macro economy are in contact. It is the place where speculators and entrepreneurs are financed. Developing what has been said before, there are four elements to a good model of bank lending: positive feedback, short memory, stochastic bursting of credit bubbles; and the intensity of the crash being proportional to the time that credit has been expanding.

Macroeconomic behaviour of the banking system should be based on confidence and expectations about the probability of default. Credit availability will be a function of the expected likelihood of default. The relationship between the expected likelihood of default and actual likelihood is related to recent performance by an adaptive expectations model that takes a rolling sum of recent defaults. The parameters of the expectations model are conditional on the state and nature of the business cycle: whether expansion or contraction and whether the cycle is short or long. When the economy is expanding or contracting, there is positive feedback to the expansion and contraction of credit respectively; the switch from credit expansion to credit contraction in a short cycle is relatively smooth, it becomes more violent the longer the cycle has progressed.

In an *Adaptive Minsky Credit Model* (AMCM) expectations that form the basis for lending and borrowing decisions are formed from two models. The first is a limited, rolling history that forgets disasters and shocks. The second is a full rational expectations model (RE) with a full probability distribution, including the skewness and fat tails.

The former will allow crash risk to build as economic conditions remain calm and for speculation to build on itself. Under the latter, market participants would remain cautious despite the recent past. The model also requires a stochastic crash element that will first reverse the direction of the AMCM parameters, causing banks to cut back on credit and households and firms to seek to repay debt, and then return to the RE model.

The mechanics of this reversal could be something similar to the way that price stickiness is introduced into DSGE models. The two main types are *Calvo price stickiness* where firms change prices in a random fashion (Calvo, 1983) or *Taylor* where random firms take a set amount of time to change prices (Taylor, 1980). In addition, a sort of *survival function* can be introduced that randomly reverses with an intensity that is proportional to the length of time since the last shock.<sup>4</sup> It is the probability that an event will occur at a specified time. Rearranging the function and providing a probability distribution would allow the banking system to *blow up* with a given probability at specific dates in the future. The intensity of the initial banking reversal can be a function of the time elapsed since the last event. This model can then be calibrated and tested against evidence on banking expansion and collapse.

This modelling of financial instability could also be extended to the financial system by allowing asset prices to diverge from intrinsic value during a period of calm when the credit for investment purposes becomes more plentiful. It should also be possible to add a similar random adjustment to asset prices to account for the random bursting of asset bubbles. Without explicit modelling of the network interactions of the financial system, it is clear that the longer a credit expansion has been in progress, the greater the threat from the deflation of the credit bubble. This means that stochastic survival function that will become more intense the greater the gap between this and the last credit deflation. Once again, this would depend on the economic actors not understanding the model that is driving the intensity of the credit contraction otherwise this would be included in their lending and borrowing decisions. In fact, this confidence should increase with the length of the credit expansion. Therefore, expectations would again be of the adaptive nature.

### 5.3 Policy

Policy makers are already hard at work trying to ensure that the sort of financial shock that was experienced in 2007 and 2008 does not happen again. This is not likely to be successful. Not only will the nature of the financial fragility that emerges in the future

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<sup>4</sup>The survival function is one that has been used to model lifespan in biological organisms. However, it has also been used to model the time to a particular event.

be different from that which has been recently experienced but, despite current efforts, vigilance will be relaxed. There have been a number of recent attempts to find precise measures that will identify the build-up of systematic financial risk<sup>5</sup>. This is extremely difficult as the financial system evolves and, as was seen in the prelude to the recent crisis, new avenues of financing allow new methods and types of risk to develop. In addition, it is clear that the estimation of extreme risk is very difficult and a lack of data is likely to exacerbate problems of estimation. Therefore, it may be more prudent to consider the main themes of the FIH and to use these as guides to identifying where and when risks are developing.

Looking at interest rates for evidence of expansionary policy is insufficient as it is the availability and demand for credit rather than its price that is of greatest importance. The relationship between the quantity of money and the nominal economy is notoriously volatile. However, bank lending has a good record in providing a coincident indicator of financial health. For example, it is clear that in the US and the Euro area there was a build-up of credit in the run up to the financial crisis. US money stock (measured as M2) was rising at a year-on-year rate of over 10% by the end of 2008 and the M3 measure of money in the Euro area was rising at a year-on-year rate of just less than 10% at the start of 2007. More importantly, loans by US depository institutions to commercial and industrial companies were running at an average of 37.0% in the first half of 2006 compared to the previous year and in the Euro area M3 loans were increasing at over 10% year-on-year in the same period (Federal Reserve Statistical Release, 2013) and (European Central Bank Statistics, 2013). It is also possible to look for general evidence of over-valuation in asset prices as evidence of carry-like uses of the available credit: divergence from PPP in exchange rates, high levels of PE ratio and low yields, compacted spreads in credit and other yields. In the build up to the 2007 to 2008 financial crisis, all asset prices were inflated, from bonds to equities and fine wine and real estate, yields across the board were at record lows.

However, assuming that future shocks cannot always be prevented, it is also important to try to minimise the adverse consequences of any shock that happens. Minsky spoke about *compartmentalisation* and *transparency* and put the emphasis on adapting these principles to the specific institutions of the time. He was aware that the system that had been set up by *Glass Steagall*, after the Wall Street Crash and the depression of the 1930s had been eroded. He cites the creation of financial holding companies that incorporate commercial banks, investment banks and mutual funds as well as the development of securitisation as contributing to this breakdown in compartmentalisation

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<sup>5</sup>There is more about global risk measures in (Brunnermeier and Oehmke, 2012, p. 66). There is also a study on early warning indicators from Drehmann and Juselius at the BIS (Drenham and Juselius, 2013).

(Minsky, 1994). This seems prescient. However, the financial areas that seemed by many to be too risky, such as alternative investment vehicles like hedge funds, turned out to be relatively unimportant in the financial crash, while the investment banks that had been assumed to be safe were very vulnerable. There appear to be two reasons for this: hedge funds tend to be numerous and small and they could be allowed to collapse without many side effects or externalities; investment banks were *too big to fail*, connected to other investment banks and very vulnerable to a tightening of funding conditions. Hedge funds were like the entrepreneurs who tried and failed, while the investment banks were the larger, more established units that should have been more cautious and stable. Regulations are now being put into place to enforce this behaviour on investment banks. It remains to be seen whether this will be maintained beyond the memory of the current crisis.

The carry trade is a specific problem for many countries. There have been calls for the activity to be legally constrained and, for households, this seems to be a sensible plan. For financial institutions, the currency market is just one version of the process of carry. This involves keeping funding costs below that of the investment income. It describes the industry of banking, a yield curve investment as well as the financing of CDO holdings in the repo market that was one part of the financial crisis.<sup>6</sup> However, financial theory suggests that the increase return that is achieved in this way will only be a compensation for taking increased risk. That is what was found here with the foreign exchange carry trade. It suggests that all types of carry, including banking itself, are risky in unconventional ways. It also highlights the inherent instability of the financial system.

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<sup>6</sup>See (Gorton, 2010) for a detailed view of the way that bank repo funding became the equivalent of a bank run for investment banks in 2007.



# Appendix A

## R Code for Chapter 2

### A.1 Introduction

This appendix presents links to the data and the R code ‘that will allow replication of the analysis that is conducted in Chapter 2. The raw data comprises real and nominal exchange rates, together with the the capital flow series, proxies for speculative activity and nominal GDP. A summary of the data are presented in Table 2.2. It is available from Github in file VARdata.csv. The code to create Tables, Figures and Analysis in Chapter 2 is presented below.

### A.2 Data preparation

The main preparation is conducted with the file Prepare.R available from Github. <https://github.com/RobHayward/SVARdoc/blob/master/Prepare.R>. All the other files are in the same repository. This file can be pasted into a new R file and will load and prepare the data so long as the csv file is saved to the R working directory. Alternatively, use code below.

```
da <- read.csv("./VARdata.csv", header=TRUE, sep=",")
```

The next code will deflate the capital flow by nominal GDP and present the data in percentage points.

```
da$CCA<-(d$CCA/d$NGDP2)/10  
da$DCCA<-(d$DCCA/d$NGDP2)/10  
da$CNB<-(d$CNB/d$NGDP2)/10
```

```

da$CNBa <- (d$CNB - d$COT)/d$NGDP2/10
da$CNE<-(d$CNE/d$NGDP2)/10
da$CNFDI<-(d$CNFDI/d$NGDP2)/10
da$COT<-(d$COT/d$NGDP2)/10

```

The next step is to tidy file so that variables have the same length. This involves deleting rows that are not complete. This requires the first 52 rows with missing values to be deleted. In addition variables that are not used in the final analysis (such as nominal GDP and current account) are also removed at this stage.

```

da<-da[-c(1:52),]
da<-da[,-c(1:2,9,10,12,13)]

```

The sentiment data are adjusted so that the long positions in foreign currency become long US dollar positions to make the IRFs more logical and size of series is increased ten fold for compatibility with the other series.

```

da$S1 <- da$S1*(-10)
da$S2 <- da$S2*(-10)

```

### A.3 Dummy variables

This section covers the creation of the dummy variables: (D1) is the Mexican interest rate shock; (D2) is the 1994 US interest rate increase that caused a large movement in international bonds; (D3) is the effect of the financial crisis. The rows corresponding to the years that the dummy will be positive are identified in the comment.

```

# D1 Q386 to Q188 (3 to 9 in da)
d[120:121,]
da$D1=0
da$D1[c(3:9)]=1
# D2 2Q94 to 2Q95 (34 to 38 in da).
da$D2=0
da$D2[c(34:38)]=1
# D3 3Q2007 to 4Q2008 (139 to 144 in da).
da$D3=0
da$D3[c(87:92)]=1

```



The dummies must be amalgamated into a matrix called 'dum' and columns are named so that they can be use with VAR.

```
dum<-cbind(da$D1,da$D2, da$D3)
colnames(dum) <- c("D1", "D2", "D3")
```

## A.4 Time Series Plot of Variables

This code will create a time series object and the plot that is presented in Figure 2.1. The time series begins in the first period of 1986 and the time period is quarterly.

```
dt<-ts(da,start=c(1986.1),frequency=4)
```

The figure ts.pdf is used in the text and the size of the object is determined.

```
pdf("ts.pdf", paper= "a4", width = 10, height = 10, title = "ts")
par(mfcol=c(3,2), oma = c(0,0,0,0))
plot(dt[,c(2:7, 9, 11)], main = "Cumulative capital flow and exchange rate")
```

## A.5 VAR lag selection

This code will use the function VARselect from the vars package (Pfaff, 2008*b*) and (Pfaff, 2008*a*) to determine the optimal lag length. Inputs to the function are the maximum length to use (lag.max) and the type of VAR to consider (which can contain a trend, constant or neither).

```
info<-VARselect(da,lag.max=8,type='t')
```

This will estimate the following model

$$\mathbf{y}_t = A_1 \mathbf{y}_{t-1} + \dots + A_p \mathbf{y}_{t-p} + C D_t + \mathbf{u}_t \quad (\text{A.1})$$

and uses the

$$AIC(n) = \ln \det(\tilde{\zeta}_u(n)) + \frac{2}{T} n K^2 \quad , \quad (\text{A.2})$$

$$HQ(n) = \ln \det(\tilde{\zeta}_u(n)) + \frac{2 \ln(\ln(T))}{T} n K^2 \quad , \quad (\text{A.3})$$

$$SC(n) = \ln \det(\tilde{\zeta}_u(n)) + \frac{\ln(T)}{T} n K^2 \quad , \quad (\text{A.4})$$

$$FPE(n) = ft \left( \frac{T + n^*}{T - n^*} \right)^K \det(\tilde{u}(n)) \quad , \quad (\text{A.5})$$

with  $\tilde{u}(n) = T^{-1} \sum_{t=1}^T \hat{\mathbf{u}}_t \hat{\mathbf{u}}_t'$  and  $n^*$  as the total number of the parameters in each equation and  $n$  assigns the lag order.

## A.6 VAR model

The VAR is estimated with the VAR function. The VAR object that is created is called Var1 and will be used in the rest of the analysis. The elements to select are the underlying data frame that is going to be used (da in this case - see output of Section A.2); the lag length ( $p = 4$ ), as determined by output of Section A.5; type is a VAR with trend and constant as determined by the Log likelihood and other criteria (discussed in Section 2.4.1 and presented in Table 2.4; there are no seasonal dummies so this is left as Null; the exogenous variables (other than the trend and the constant are the dummy variables that are in the matrix 'dum' (as discussed in Section A.3).

```
Var1<-VAR(da,p=4, type='both',season=NULL, exog=dum)
```

## A.7 Diagnostic Tests

The main diagnostic tests of model assumptions are computed with the the following functions. The tests are those detailed in the main text Section 2.4.2. The (Edgerton and Shukur, 1999) small-sample adjustment to the LM serial correlation test is applied; univariate and multivariate hetroscedasticity and normality tests are applied. Each model is tested separately. Here the tests are done on 'Var1'. Different versions with alternative series, lag lengths and other adjustments can be made.

The log likelihood, stability of the roots, AIC and BIC are extracted with the following code.

```
logLik(Var1)
roots(Var1)
AIC(Var1)
BIC(Var1)
```

The tests for serial correlation, arch and normality are test with this code.

```

Var1.ser<-serial.test(Var1,lags.pt=8,type="EG")
Var1.arch<-arch.test(Var1,lags.multi=4, multivariate.only=FALSE)
Var1.norm<-normality.test(Var1,multivariate.only=FALSE)

```

## A.8 SVAR

This is the code to create the restricted matrix B (here it must be called A) that is used in the SVAR. The restrictions are the same as the Table 2.3 and briefly in the code comments below. The restrictions are described in Section 2.3.9. To impose alternative restrictions change the A matrix and run code below as before.

```

#Setting up the A matrix.
#change the restrictions according to the theory to be tested.
Amat=diag(7)
Amat[1,1]<-1
Amat[2,2]<-1
Amat[3,3]<-1
Amat[4,4]<-1
Amat[5,5]<-1
Amat[6,6]<-1
Amat[7,7]<-1
Amat[1,2]<-NA #bond vs equity
Amat[1,3]<-0 #bond vs fdi
Amat[1,4]<-0 #bond vs no
Amat[1,5]<-0 #bond vs fx
Amat[1,6]<-NA #bond vs spread
Amat[1,7]<-0 #bond vs sentiment
Amat[2,1]<-NA #equity bonds
Amat[2,3]<-NA #equity fdi (estimated cos similar influences)
Amat[2,4]<-0 #equity cot (dubious if inflow has an effect)
Amat[2,5]<-NA #equity fx
Amat[2,6]<-0 #equity spread (can be justified)?
Amat[2,7]<-NA #equity sentiment
Amat[3,1]<-0 #fdi bond
Amat[3,2]<-NA #fdi equity
Amat[3,4]<-0 #fdi cot
Amat[3,5]<-NA #fdi fx
Amat[3,6]<-0 #fdi spread

```

```
Amat[3,7]<-0 #fdi sentiment
Amat[4,1]<-NA #cot bond
Amat[4,2]<-0 #cot equity
Amat[4,3]<-0 #cot fdi
Amat[4,5]<-NA #cot vs fx
Amat[4,6]<-0 #cot vs spread
Amat[4,7]<-NA #cot vs s1
Amat[5,1]<-0 #fx and bond
Amat[5,2]<-NA #fx vs equity
Amat[5,3]<-NA #fx and FDI
Amat[5,4]<-NA #fx and no
Amat[5,6]<-NA #fx vs spread
Amat[5,7]<-NA #fx vs s1
Amat[6,1]<-NA #spread and bonds
Amat[6,2]<-0 #spread and equities
Amat[6,3]<-0 # spread and fdi
Amat[6,4]<-0 # spread and cot
Amat[6,5]<-NA #spread and fx
Amat[6,7]<-0 #spread and sentiment
Amat[7,1]<-0 #S1 vs bond
Amat[7,2]<-NA #S1 vs equity
Amat[7,3]<-0 #S1 vs fdi
Amat[7,4]<-NA #sentiment vs no
Amat[7,5]<-NA # sentiment vs fx
Amat[7,6]<-0 #sentiment vs spread
Amat
```

To estimate the Structural VAR, the function SVAR is used. The inputs are the base VAR (here Var1), whether the A matrix or B matrix is to be restricted (A in this case) and the nature of the optimisation. The default is a scoring algorithm but minimisation of the log likelihood can also be used if the `estmethod` is set to `direct`. The `Svar1` object is returned with a number of components of the SVAR including coefficients, the variance-covariance matrix and the estimation to the A matrix. These can be used in additional analysis if necessary.

```
# Estimate the SVAR
Svar1<-SVAR(Var1,estmethod='direct',Amat=Amat,hessian=TRUE)
```

## A.9 Plotting IRF

The following R code will create the IRF graphs Figures 2.4, 2.9 and 2.10 for IRFs created with Models 1, 2 and 3 respectively. These are based on Var1, Var2 and Svar1 R objects that have been created above. The first step is to create Var2 which makes a random change to the order of the variables in the VAR.

```
sample <- sample(c(1:7), size = 7, replace = FALSE)
head(sample)
Var2<-VAR(da[,sample],p=4, type='both',season=NULL, exog=dum)
```

Now the IRF are created. There is a seed for the random variables that will be used in the bootstrapping of the confidence intervals. The function pdf will create an object that will be used in the final file and a4r will make it a4 size with a rotation to landscape aspect. The page is broken into 2 rows of 3 figures with the par function while oma sets the frame of the figure. The function irf will create irfs with from the input varest object (Var1, Var2 and Svar1 for models 1, 2 and 3 respectively), n.ahead sets the irf window, the response will be the real trade weighted index in each case (RTWI) while the impulse will be one of the other variables, if 'ortho' is TRUE the simple, lower diagonal parameterisation of the A matrix is used to identify the structural shocks, the response can be cumulative, 'boot' will bootstrap the confidence intervals rather than assume a normal distribution and runs sets the number of runs to be used. The rest of the code extracts the data and creates the graph.

## A.10 System Two

The code below is an example for System Two (Var2). Change this to Var1 or Svar1 to create the other IRFs.

```
set.seed(123)
pdf("IRF2.pdf", paper= "a4r", width = 9, title = "IRF2")
par(mfcol=c(2,3), oma = c(0,0,1,0))
# System 2 CNB-----
irf.rtwicnb <- irf(Var2, n.ahead=8,impulse='CNB', response='RTWI',ortho=TRUE,
                  cumulative=TRUE,boot=TRUE, runs=1000)
a<-irf.rtwicnb$irf
b<-irf.rtwicnb$Upper
c<-irf.rtwicnb$Lower
```

```
aa<-data.frame(c(a,b,c))
plot(aa[,1], xlim=c(1,8), ylim=c(-6, 6), type='l',
      main='CNB shock: System 2',
      ylab='RTWI', xlab='Quarters')
lines(aa[,2], type='l', col='red', lty=2)
lines(aa[,3],type='l', col='red',lty=2)
abline(h=0, col='red',lty=6)
# System 2 CNE-----
irf.rtwicne <- irf(Var2, n.ahead=8,impulse='CNE', response='RTWI',ortho=TRUE,
                  cumulative=TRUE,boot=TRUE, runs=100)
a<-irf.rtwicne$irf
b<-irf.rtwicne$Upper
c<-irf.rtwicne$Lower
aa<-data.frame(c(a,b,c))
plot(aa[,1], xlim=c(1,8), ylim=c(-4, 8), type='l',
      main='CNE shock: System 2',
      ylab='RTWI', xlab='Quarters')
lines(aa[,2], type='l', col='red', lty=2)
lines(aa[,3],type='l', col='red',lty=2)
abline(h=0, col='red',lty=6)
# System 2 CNFDI -----
irf.rtwicnfdi <- irf(Var2, n.ahead=8,impulse='CNFDI', response='RTWI',ortho=TRUE,
                   cumulative=TRUE,boot=TRUE, runs=100)
a<-irf.rtwicnfdi$irf
b<-irf.rtwicnfdi$Upper
c<-irf.rtwicnfdi$Lower
aa<-data.frame(c(a,b,c))
plot(aa[,1], xlim=c(1,8), ylim=c(-4, 6), type='l',
      main='CNFDI shock: System 1',
      ylab='RTWI', xlab='Quarters')
lines(aa[,2], type='l', col='red', lty=2)
lines(aa[,3],type='l', col='red',lty=2)
abline(h=0, col='red',lty=6)
# System 2 COT-----
irf.rtwicot <- irf(Var2, n.ahead=8,impulse='COT', response='RTWI',ortho=TRUE,
                  cumulative=TRUE,boot=TRUE, runs=100)
a<-irf.rtwicot$irf
b<-irf.rtwicot$Upper
c<-irf.rtwicot$Lower
```

```
aa<-data.frame(c(a,b,c))
plot(aa[,1], xlim=c(1,8), ylim=c(-4, 4), type='l',
      main='Cot shock: System 2',
      ylab='RTWI', xlab='Quarters')
lines(aa[,2], type='l', col='red', lty=2)
lines(aa[,3],type='l', col='red',lty=2)
abline(h=0, col='red',lty=6)
# System 2 Spread-----
irf.rtwispread <- irf(Var2, n.ahead=8,impulse='SPREAD2', response='RTWI',ortho=TRUE,
                    cumulative=TRUE,boot=TRUE, runs=100)
a<-irf.rtwispread$irf
b<-irf.rtwispread$Upper
c<-irf.rtwispread$Lower
aa<-data.frame(c(a,b,c))
plot(aa[,1], xlim=c(1,8), ylim=c(-2, 6), type='l',
      main='Spread shock System 2',
      ylab='RTWI', xlab='Quarters')
lines(aa[,2], type='l', col='red', lty=2)
lines(aa[,3],type='l', col='red',lty=2)
abline(h=0, col='red',lty=6)
# system 2 Sentiment -----
irf.rtwisent <- irf(Var2, n.ahead=8,impulse='S1', response='RTWI',ortho=TRUE,
                  cumulative=TRUE,boot=TRUE, runs=100)
a<-irf.rtwisent$irf
b<-irf.rtwisent$Upper
c<-irf.rtwisent$Lower
aa<-data.frame(c(a,b,c))
plot(aa[,1], xlim=c(1,8), ylim=c(-2, 6), type='l',
      main='Speculative shock: System 2',
      ylab='RTWI', xlab='Quarters')
lines(aa[,2], type='l', col='red', lty=2)
lines(aa[,3],type='l', col='red',lty=2)
abline(h=0, col='red',lty=6)
dev.off()
```





## Appendix B

# R Code Chapter 3

The basic data for Chapter 3 are in the files `RR.csv` and `Futures.csv`. `RR.csv` contains the risk reversal skew and the exchange rate data that accompanies the option prices; `Futures.csv` has the Commodities and Futures Trade Commission (CFTC) *Commitment of Traders* (COT) data and exchange rate data. The files are available from Github `RR.csv` and `Futures.csv`

### B.1 My stats function

The following function is used extensively in this chapter to calculate descriptive statistics. The code is adapted from (Kabacoff, 2011). When applied to a data frame or a matrix it will calculate the mean, standard deviation, maximum, minimum, skew, kurtosis standard error of skew and standard error of kurtosis.

```
mystats <- function(x, na.omit=FALSE){
  if (na.omit)
  x <- x[!is.na(x)]
  m <- mean(x)
  s <- sd(x)
  t <- m/s
  n <- length(x)
  skew <- sum((x-m)^3/s^3)/n
  ps <- ((6*n*(n-1))/((n-1)*(n+1)*(n+3)))^0.5
  kurt <- sum((x-m)^4/s^4)/n - 3
  pk <- ((n^2-1)/((n-3)*(n + 5)))^0.5
  max <- max(x)
```

```

min <- min(x)
return(c(n=n, mean=m, t= t, stdev=s, skew=skew, ps = ps,
        kurtosis=kurt, pk = pk, max = max, min = min))
}

```

## B.2 Code for Monte Carlo Simulation of the Noise Trader Model

This is the code to create the simulation of the final price Equation 3.12. The details are reported in Table 3.1. The code will generate time series MPM and RWM with the random misperception and random weight of noise traders respectively.

The package `eventstudies` is used extensively in this chapter to manage the data and align the event windows so it should be loaded using the function `require` to ensure that all of its functions are available (Shah et al., 2011).

```
require(eventstudies)
```

The first act is to build a function called "DeLong" that has the following inputs:  $\rho$  as the actual misperception,  $\rho_{\text{omu}}$  as the average misperception,  $r$  as the risk free rate,  $\mu$  is the weight of speculators in the total market participants,  $\rho_a$  as the parameter for risk aversion,  $\rho_{\text{osd}}$  is the standard deviation of the misperception. This is Equation 3.12. The price is returned.

```

DeLong <- function(rho, rhomu, r, mu, ra, rhosd){
p = 100 + (mu * (rho - rhomu))/(1 + r) + (mu * rhomu)/r -
        ((2 * ra * mu^2 * rhosd^2)/(r * (1 + r)^2))
return(p)
}

```

In the first model the misperception as a random variable with a mean of 1 and a standard deviation of 1.

```

rho <- rnorm(1000, 1, 1)
p <- DeLong(rho = rho, rhomu = 1, r = 0.1, mu = 0.5,
            ra = 0.3, rhosd = 1)

```

The price series can be plotted.

```
plot(p, type = 'l')
```

Now create a data frame with the price and the misperception and turn this into a "zoo" object called pz so that it can be used with the eventstudies package. Calculate returns.

```
da <- cbind(p, rho)
pz = as.zoo(da)
pz$r <- 100*diff(log(pz$p))
```

Now identify the points when the misperception is extreme (here defined as being above the 95th percentile) and create a data frame called "eventslist.ex" for these extremes. The function "phys2eventtime" will align the event dates in a new data frame (called "a" here). The data frame is reduced to a window that is just the event date and the following period with the "window" function and this is in a new data frame called "P.ex".

```
pz$e = as.numeric(pz$rho >= quantile(pz$rho, 0.95, na.rm = TRUE))
eventslist.ex <- data.frame(index(pz$e[pz$e == 1]))
eventslist.ex$unit <- as.character("r")
colnames(eventslist.ex) <- c("when", "unit")
a <- phys2eventtime(pz, eventslist.ex, width = 2)
P.ex <- window(a$z.e, start = 0, end = 1)
```

Calculate the descriptive statistics by taking the transpose of the matrix P.ex with "t" and applying the function "mystats" (see Section B.1 above). Results will be displayed in the data frame "P.d".

```
P.ext <- t(P.ex)
P.ext
P.d <- apply(P.ext, 2, FUN = mystats, na.omit = TRUE)
P.d
```

Now repeat this process with mu as the random variable with smoothed changed that is an equally weighted two period moving average.

```
mu1 <- as.zoo(rnorm(1000, 0.5, 0.2))
mu2 <- lag(mu1, 1)
mu <- 0.5 * mu1 + 0.5 * mu2
```

The extreme analysis is repeated for the weight of noise traders.

```
p <- DeLong(rho = 1, rhomu = 1, r = 0.1, mu = mu,
            ra = 0.3, rhosd = 1)
pz$e = as.numeric(pz$mu >= quantile(pz$mu, 0.95, na.rm = TRUE))
eventslist.ex <- data.frame(index(pz$e[pz$e == 1]))
eventslist.ex$unit <- as.character("r")
colnames(eventslist.ex) <- c("when", "unit")
a <- phys2eventtime(pz, eventslist.ex, width = 2)
P.ex <- window(a$z.e, start = 0, end = 1)
P.ext <- t(P.ex)
P.d <- apply(P.ext, 2, FUN = mystats, na.omit = TRUE)
P.d
```

### B.3 Data preparation

So long as the file RR.csv is in the working directory, the following code will install into a the data into a zoo object called "FX.z", extract the exchange rate series and calculate the foreign exchange returns. The date is set with 'format'.

```
daz <- read.zoo("./RR.csv", header = TRUE,
               format = "%d-%b-%y", sep = ",")
FX.z <- daz[,c("AUD", "EURGBP", "EURSEK", "GBP", "CHF", "EURCHF", "EURJPY", "EUR",
              "CAD", "JPY")]
str(FX.z)
FX.z$AUDr <- 100*diff(log(FX.z$AUD))
FX.z$EURGBPPr <- 100*diff(log(FX.z$EURGBP))
FX.z$EURSEKPr <- 100*diff(log(FX.z$EURSEK))
FX.z$GBPPr <- 100*diff(log(FX.z$GBP))
FX.z$CHFPr <- 100*diff(log(FX.z$CHF))
FX.z$EURCHFPr <- 100*diff(log(FX.z$EURCHF))
FX.z$EURJPYr <- 100*diff(log(FX.z$EURJPY))
FX.z$EURr <- 100*diff(log(FX.z$EUR))
FX.z$CADr <- 100*diff(log(FX.z$CAD))
FX.z$JPYr <- 100*diff(log(FX.z$JPY))
```

## B.4 Descriptive Statistics

Apply the descriptive statistics function to the foreign exchange returns. See Section B.1.

```
FX.m <- apply(FX.z, 2, FUN = mystats, na.omit = TRUE)
```

The following code will repeat this process for the risk-reversal data and will create Table 3.3.

```
daz <- read.zoo("./RR.csv", header = TRUE,
  format = "%d-%b-%y", sep = ",")
FX.z <- daz[,c("AUDRR", "EURGBPRR", "EURSEKRR", "GBPRR", "CHFRR", "EURCHFRR",
  "EURJPYRR", "EURRRR", "CADRR", "JPYRR")]
FX.d <- apply(FX.z, 2, FUN = mystats, na.omit = TRUE)
```

The following code draws and prepares the data from the file (Futures.csv) and calculates the descriptive statistics of exchange rates and the three measures of sentiment that are presented in Table 3.4.

```
da <- read.csv("./Futures.csv", header = TRUE)
da$S1 <- (da$NCL-da$NCS)/(da$NCL+da$NCS+da$NCSP)
da$S2 <- (da$NCL-da$NCS)/da$OI
da$S3 <- (da$NCL+da$NCS+da$NCSP)/da$OI
da <- da[,c(2, 3, 5, 19, 20, 21)]
da.CAD <- subset(da[,2:6], subset = da$Exchange == "CAD")
da.CHF <- subset(da[,2:6], subset = da$Exchange == "CHF")
da.EUR <- subset(da[,2:6], subset = da$Exchange == "EUR")
da.GBP <- subset(da[,2:6], subset = da$Exchange == "GBP")
da.JPY <- subset(da[,2:6], subset = da$Exchange == "JPY")
FX.d <- apply(da.CAD, 2, FUN = mystats, na.omit = TRUE)
```

## B.5 Code for Tables 3.6 and 3.7 Figures 3.1 and 3.2

This code uses the eventstudies package in the same fashion as the simulated noise trader model to set up the extreme for the risk-reversal skew to establish the *event* of the extreme and then align returns data with the event so that average exchange rate returns for the event window can be established. The currency, quantile that is being

tested, whether it is the whole event window CARW or just the window after the event CARA have to be specified. The average return as well as bootstrap the confidence intervals to assess whether the returns are statistically different from zero are returned. The calculations are reported in Table 3.6.

```

currency = "EURGBP"
extreme = "high"
hi = as.numeric(0.95)
lo = as.numeric(0.05)
# select window either "whole lot" or "after".
cum = "whole lot"
# select the size of the event window
wind = as.numeric(1)
#####
if(extreme == "high"){
FX.z$ex <- as.numeric(FX.z[,2] >= quantile(FX.z[,2],
      hi, na.rm = TRUE))
} else if(extreme == "low") {
FX.z$ex <- as.numeric(FX.z[,2] <= quantile(FX.z[,2],
      lo, na.rm = TRUE))
} else(print("No Extreme"))
#####
eventslist.FXex <- data.frame(index(FX.z$ex[FX.z$ex ==1]))
eventslist.FXex$unit <- as.character("r")
colnames(eventslist.FXex) <- c("when", "unit")
eventslist.FXex$when <-as.Date(eventslist.FXex$when)
a <- phys2eventtime(FX.z, eventslist.FXex, width = wind)
#####
FX.exw <- window(a$z.e, start = wind * -1, end = wind)
FX.exa <- window(a$z.e, start = 0, end = wind)
FX.exwc <- remap.cumsum(FX.exw, is.pc = FALSE, base = 0)
FX.exac <- remap.cumsum(FX.exa, is.pc = FALSE, base = 0)
#####
FX.exwcm <- as.matrix(FX.exwc)
FX.exacm <- as.matrix(FX.exac)
MRW <- mean(FX.exwcm[(wind*2 + 1),])
MRA <- mean(FX.exacm[(wind + 1),])
#####
# the bootstrap

```

```

FX.exwc.b <- inference.Ecar(FX.exwc)
FX.exwc.b
FX.exac.b <- inference.Ecar(FX.exac)
FX.exac.b
#####

```

The second set of codes will carry out the same exercise for the futures position data. The calculations are reported in Table 3.7.

```

# Set conditions
# currency is CAD, GBP, JPY, EUR or CHF
currency = "CHF"
# window is number of weeks
wind = as.numeric(2)
# extreme is high or low
extreme = "high"
hi = as.numeric(0.95)
lo = as.numeric(0.05)
# cumulative is either whole or after
cum = "whole lot"
# Sentiment index is S1 or S2 or S3
S = "S1"
#####
if(currency == "CAD"){
FX = da.CAD
} else if(currency == "CHF"){
FX = da.CHF
} else if(currency == "EUR"){
FX = da.EUR
} else if(currency == "GBP"){
FX = da.GBP
} else if(currency == "JPY"){
FX = da.JPY
} else("Error with exchange rate")
#####
if(S == "S1") {
FX$$ <- FX$$S1
} else if(S == "S2"){
FX$$ <- FX$$S2

```

```

} else if(S == "S3"){
FX$$S <- FX$$S3
} else("Error with sentiment index")
#####
if(extreme == "high"){
FX$ex <- as.numeric(FX$$S >= quantile(FX$$S,
      hi, na.rm = TRUE))
} else if(extreme == "low") {
FX$ex <- as.numeric(FX$$S <= quantile(FX$$S,
      lo, na.rm = TRUE))
} else(print("No Extreme"))
#####
# Create zoo object
FX.z <- as.zoo(FX, order.by = FX$Date)
#####
eventslist.FXex <- data.frame(index(FX.z$ex[FX.z$ex ==1]))
eventslist.FXex$unit <- as.character("r")
colnames(eventslist.FXex) <- c("when", "unit")
a <- phys2eventtime(FX.z, eventslist.FXex, width = wind)
#####
FX.exw <- window(a$z.e, start = wind * -1, end = wind)
FX.exa <- window(a$z.e, start = 0, end = wind)
FX.exwc <- remap.cumsum(FX.exw, is.pc = FALSE, base = 0)
FX.exac <- remap.cumsum(FX.exa, is.pc = FALSE, base = 0)
#####
FX.exwcm <- as.matrix(FX.exwc)
FX.exacm <- as.matrix(FX.exac)
MRW <- mean(FX.exwcm[(wind*2 + 1),])
MRA <- mean(FX.exacm[(wind + 1),])
#####
# the bootstrap
FX.exwc.b <- inference.Ecar(FX.exwc)
FX.exwc.b
FX.exac.b <- inference.Ecar(FX.exac)
FX.exac.b
#####

```



## B.6 Event windows

The following R code will create Figures 3.1 and 3.2. First set the parameters. Change "AUD" to other currencies and "low" to high as well as the quantile, whether calculating the whole window ("whole lot") or just the post-event ("after") and the size of the window ("wind"). The par function divides the figure into 3 rows and 2 columns.

```
par(mfrow = c(3,2))
currency = "AUD"
extreme = "low"
# select percentile
hi = as.numeric(0.95)
lo = as.numeric(0.05)
# select window either "whole lot" or "after".
cum = "whole lot"
wind = as.numeric(16)
```

The file FX.exc.b must have been created already (see Section B.5 above).

```
dim = seq(-wind, wind, 1)
FX.exc.b <- inference.Ecar(FX.exc)
FX.exc.b
FX.exc.bm <- matrix(FX.exc.b, ncol = 3, dimnames = list(dim,
  c("2.5%", "Mean", "97.5%")))
title3 = title = paste("Cumulative ", currency, " returns", sep = "")
matplot(x = dim, FX.exc.bm[,1:3], type = 'l', lty = c(2, 1, 2),
  main = title3, ylab = "Returns", xlab = "Event Days",
  xlim = c(min(dim), max(dim)), ylim = c(min(FX.exc.bm[,1]),
  max(FX.exc.bm[,3])))
abline(v = 0)
```



## Appendix C

# R and Eviews Code Chapter 4

The analysis carried out in this chapter has been conducted with a combination of Eviews and R.

### C.1 Data Preparation

The data file for this chapter is UIP.csv. It is available from Git Hub repository. UIP.csv The file was created from raw foreign exchange, interest rate and VIX data that was downloaded from the Thomson-Reuters system. The forward rate and the profits from the carry trade were calculated from this raw data in Eview using the following code.

```
'create a group of the time series exchange rate
group xs
for %i bgn czk hrk huf pln ron rub uah lvl eek try isk nok
genr {%i}eur={%i}*eurusd
'add the exchange rates to the group so that we can count them
xs.add {%i}eur
'calculate the 1-month forward rate from the deposit rate
series f{%i}eur=(((({%i}1m/100)+1)^(1/12))*{%i}eur)/(((eur1m/100)+1)^(1/12))
'calculate the profit as a ratio from the uncovered carry trade.
series p{%i}eur=(((({%i}1m/100)+1)^(1/12))*{%i}eur*(1/{%i}eur(1)))/(((eur1m/100)+1)^(1/12))
```

### C.2 VIX

The following R code will extract the VIX data from the file calculate the 90th and 60th percentiles and plot a chart with borders used for Crisis (C) and Moderation (M).

```

da <- read.csv("./UIP.csv", header=TRUE, na.strings = NA)
quantile(da$VIX, 0.9)
quantile(da$VIX, 0.6)
min(da$DATE)
max(da$DATE)

```

For the plot, create a zoo object

```

require(zoo)
da$DATE <- as.Date(da$DATE, format = "%d/%m/%Y")
daz <- as.zoo(da[28], order.by = da$DATE)
pdf("VIX.pdf", paper= "a4", width = 8, title = "VIX")
par(omi = c(0,0,0,0))
plot(daz$VIX, type = 'l', main = "VIX Index", ylab = "VIX",
      xlab = "Date")
abline(h = 30, col = 'red')
dev.off()

```

### C.3 Carry trade model

The following Eviews code will estimate the simple carry trade model for each of the currency pairs. The following code is used for the estimation of individual carry trade regressions presented in Tables 4.4 and 4.5.

```

table (11, 7) results2
group xs
!linecounter=2

for %k SC SD T-stat Vix SD T-stat Rate SD T-tate
results2(1,!linecounter)=%k

!linecounter=!linecounter+1
next

!linecount=2
for %i huf pln bgn czk ron rub uah hrk lvl eek try isk nok

equation eq{%i}p.ls p{%i}usd c p{%i}usd(-1) vix ({%i}1m-usd1m)

```

```

results2(!linecount+1, 1)=%i
results2(!linecount+1, 2)=eq{%i}p.@coefs(2)
results2(!linecount+1, 3)=eq{%i}p.@stderrs(2)
results2(!linecount+1, 4)=eq{%i}p.@tstats(2)
results2(!linecount+1, 5)=eq{%i}p.@coefs(3)
results2(!linecount+1, 6)=eq{%i}p.@stderrs(3)
results2(!linecount+1, 7)=eq{%i}p.@tstats(3)
results2(!linecount+1, 8)=eq{%i}p.@coefs(4)
results2(!linecount+1, 9)=eq{%i}p.@stderrs(4)
results2(!linecount+1, 10)=eq{%i}p.@tstats(4)
-----

```

## C.4 Eviews analysis of carry returns in crisis and moderation

The data are subset into the two periods and the descriptive statistics for the two periods are compared. The crisis data are in the file 'resultsover' and the moderation data are in 'resultsunder'. The results are presented in Tables 4.6 and 4.7.

```

for %i huf pln bgn czk ron rub uah hrk lvl eek
equation eq{%i}.ls p{%i}usd c p{%i}usd(-1) vix
next

```

-----  
This creates a table for the results of the descriptive statistics  
-----

```

group xs
'create a table for results
table (11,7) resultsover
!linecounter=2
for %k mean sd skew kur max min
resultsover (1, !linecounter)=%k
!linecounter=!linecounter+1
next

for %i huf pln bgn czk ron rub uah hrk lvl eek
group xs
xs.add {%i}

```

```
next

smpl @all if vix>30

for !i =1 to xs.@count
%iname=xs.@seriesname(!i)

resultsover(!i+1,1)=%iname
resultsover(!i+1,2)=@mean(p{%iname}usd)
resultsover(!i+1,3)=@stdev(p{%iname}usd)
resultsover(!i+1,4)=@skew(p{%iname}usd)
resultsover(!i+1,5)=@kurt(p{%iname}usd)
resultsover(!i+1,6)=@max(p{%iname}usd)
resultsover(!i+1,7)=@min(p{%iname}usd)

next

smpl @all if vix<20

table (11,7) resultsunder
!linecounter=2

for %k mean sd skew kur max min
resultsunder (1, !linecounter)=%k

!linecounter=!linecounter+1

next

for !i =1 to xs.@count
%iname=xs.@seriesname(!i)

resultsunder(!i+1,1)=%iname
resultsunder(!i+1,2)=@mean(p{%iname}usd)
resultsunder(!i+1,3)=@stdev(p{%iname}usd)
resultsunder(!i+1,4)=@skew(p{%iname}usd)
resultsunder(!i+1,5)=@kurt(p{%iname}usd)
resultsunder(!i+1,6)=@max(p{%iname}usd)
```

```
resultsunder(!i+1,7)=@min(p{%iname}usd)
```

```
next
```

## C.5 Crisis and Moderation Plots

This is the main plot of the distribution of the returns when there is Crisis (C) and Moderation (M). This will create the Figures 4.2 and 4.2.

```
pdf("hist3.pdf", paper= "a4r", width = 9, title = "Carry trade")
par(mfcol=c(2,3), oma = c(0,0,2,0))
plot(density(dah$PNOKUSD, na.rm = TRUE), main = "NOK carry in Crisis",
      col = 'red', lwd= 2, xlim = c(0.85, 1.10))
plot(density(dal$PNOKUSD, na.rm = TRUE), main = "NOK carry in Moderation",
      col = 'red', lwd = 2, xlim = c(0.85, 1.10))
plot(density(dah$PCZKUSD, na.rm = TRUE), main = "CZK carry in Crisis",
      col = 'red', lwd= 2, xlim = c(0.85, 1.10))
plot(density(dal$PCZKUSD, na.rm = TRUE), main = "CZK carry in Moderation",
      col = 'red', lwd = 2, xlim = c(0.85, 1.10))
plot(density(dah$PRONUSD, na.rm = TRUE), main = "RON carry in Crisis",
      col = 'red', lwd= 2, xlim = c(0.80, 1.10))
plot(density(dal$PRONUSD, na.rm = TRUE), main = "RON carry in Moderation",
      col = 'red', lwd = 2, xlim = c(0.85, 1.10))
mtext("USD Carry trade returns in Crisis and Moderation", outer = TRUE)
dev.off()

# second hist graph-----
pdf("hist4.pdf", paper= "a4r", width = 9, title = "Carry trade")
par(mfcol=c(2,3), oma = c(0,0,2,0))
plot(density(dah$PHUFEUR), main = "HUF carry in Crisis",
      col = 'red', lwd= 2, xlim = c(0.90, 1.10))
plot(density(dal$PHUFEUR), main = "HUF carry in Moderation",
      col = 'red', lwd = 2, xlim = c(0.90, 1.10))
plot(density(dah$PPLNEUR), main = "PLN carry in Crisis",
      col = 'red', lwd= 2, xlim = c(0.85, 1.10))
plot(density(dal$PPLNEUR, na.rm = TRUE), main = "PLN carry in Moderation",
      col = 'red', lwd = 2, xlim = c(0.85, 1.10))
plot(density(dah$PISKEUR), main = "ISK carry in Crisis",
```

```
col = 'red', lwd= 2, xlim = c(0.80, 1.20))
plot(density(dal$PISKEUR, na.rm = TRUE), main = "ISK carry in Moderation",
col = 'red',lwd = 2, xlim = c(0.80, 1.20))
mtext("EUR Carry trade returns in Crisis and Moderation", outer = TRUE)
dev.off()
# overlay Crisis and Moderation chart-----
pdf("hist5.pdf", paper= "a4r", width = 9, title = "Carry trade")
par(mfcol=c(2,3), oma = c(0,0,2,0))
plot(density(dah$PHUFEUR), main = "HUF carry in Crisis",
col = 'red', lwd= 2, xlim = c(0.90, 1.10))
lines(density(dal$PHUFEUR), main = "HUF carry in Moderation",
col = 'blue',lwd = 2)
plot(density(dah$PPLNEUR), main = "PLN carry in Crisis",
col = 'red', lwd= 2, xlim = c(0.85, 1.10))
lines(density(dal$PPLNEUR, na.rm = TRUE), main = "PLN carry in Moderation",
col = 'blue',lwd = 2)
plot(density(dah$PISKEUR), main = "ISK carry in Crisis",
col = 'red', lwd= 2, xlim = c(0.80, 1.20))
lines(density(dal$PISKEUR, na.rm = TRUE), main = "ISK carry in Moderation",
col = 'blue',lwd = 2)
mtext("EUR Carry trade returns in Crisis and Moderation", outer = TRUE)
dev.off()
```



# Bibliography

- Akaike, H. (1981), 'Likelihood of a model and information criteria', *Journal of Econometrics* **16**(1), 3–14.
- Akerlof, G. (1970), 'The market for lemons: Quality uncertainty and the market mechanism', *Journal of Political Economy* **84**(3), 488–500.
- Allen, F., Morris, S. and Postlewaite, A. (1993), 'Finite bubbles with short sale constraints and asymmetric information', *Journal of economic theory* **61**(2), 206–229.
- Andersen, L. C. and Jordan, J. L. (1968), 'Monetary and fiscal actions: A test of their relative importance in economic stabilizations', *Federal Reserve Bank of St. Louis Review* pp. 11–24.
- Arrow, K. J. (1965), The theory of risk aversion, in Y. Jahnssonin, ed., 'Essays in the Theory of Risk Bearing', Markham, Chicago.
- Bachelier, L. (1900), Theorie de la speculation, in P. Cootner, ed., 'The Random Character of Stock Prices', pp. 17 – 78.
- Balassa, B. (1964), 'The purchasing power parity doctrine: A reappraisal', *Journal of Political Economy* **72**, 584–596.
- Ball, R. and Brown, P. (1968), 'An empirical evaluation of accounting income numbers', *Journal of Accounting Research* **Autumn**, 159–178.
- Bansal, R. and Dahlquist, M. (1999), 'The forward premium puzzle: different tales from developed and emerging economies', *Journal of International Economics* **51**(1), 115 – 144.
- Basu, S. (1977), 'Investment performance of common stocks in relation to their price-earnings ratios: a test of the efficient market hypothesis', *Journal of Finance* **32**(3), 663–682.
- Baumol, W. J. and Bowen, W. G. (1966), *Performing Arts: the Economic Dilemma*, Twentieth Century Fund.

- Benabou, R. and Tirole, J. (2002), 'Self-confidence and personal motivation', *Quarterly Journal of Economics* **117**(3), 871–913.
- Benabou, R. and Tirole, J. (2004), 'Willpower and personal rules', *Journal of Political Economy* **112**(4), 848–886.
- Berglof, E. (2010), Recovery and reform, Transition report, EBRD.
- Bernanke, B. (1986), 'Alternative explanation of the money-income correlation', *NBER Working Papers* **1842**.
- Bernard, V. (1993), Stock price reactions to earnings announcements, in R. Thaler, ed., 'Advances in Behavioural Finance', Russell Sage Foundation, New York.
- Bilson, J. (1981), 'The 'speculative efficiency' hypothesis', *The Journal of Business* **54**(3), 435–451.
- Bilson, J. F. (1978), 'The monetary approach to the exchange rate: Some empirical evidence', *IMF Staff Papers* .
- BIS (2010), 'Triennial central bank survey of foreign exchange and derivatives market activity in 2010'.  
**URL:** <http://www.bis.org/publ/rpfx10t.htm>
- BIS Location Banking Statistics* (2012).  
**URL:** <http://www.bis.org/statistics/bankstats.htm>
- BIS Statistics* (2012).  
**URL:** <http://www.bis.org/statistics/index.htm>
- Black, F. (1986), 'Noise', *The Journal of Finance* **41**(3), 529–543.
- Black, F. and Scholes, M. (1973), 'The pricing of options and corporate liabilities', *Journal of Political Economy* **81**(3), 637–654.
- Blanchard, O. and Quah, D. (1987), 'The dynamic effects of aggregate demand and supply disturbances', *American Economic Review* **79**(4), 655–673.
- Blanchard, O. and Watson, M. (1982), Bubbles, rational expectations and financial markets, in P. Watchel, ed., 'Crises in the Economic and Financial Structure: Bubbles, Bursts, and Shocks', D.C. Heath and Co.
- Blanchard, O. and Weber, A. (2013), 'What should policy makers and economists learn from the financial crisis?'

- Blinder, A. (2013), 'Financial collapse: A 10-step recovery plan', *New York Times* .  
**URL:** <http://www.nytimes.com/2013/01/20/opinion/sunday/financial-collapse-a-10-step-recovery-plan.htm>
- Bollerslev, T. (1986), 'Generalized conditional autoregressive conditional heteroscedasticity', *Econometrica* **31**(3), 307 – 327.
- Box, G. E. P. and Cox, D. R. (1964), 'An analysis of transformations', *Journal of the Royal Statistical Society* **26**(2), 211–252.
- Brady, M. E. (1993), 'J.M. Keynes's theoretical approach to decision-making under conditions of risk and uncertainty', *The British Journal of the Philosophy of Science* **44**(2), 357–376.
- Brancaccio, E. and Fontana, G., eds (2011), *The Global Economic Crisis: New Perspectives on the Critique of Theory and Policy*, Routledge.
- Brandon, K. and Fernandez, F. (2005), 'Financial innovation and risk management: An introduction to credit derivatives', *Journal of Applied Finance* pp. 52–63.
- Branson, W. H. (1968), *Financial Capital Flows in the US Balance of Payments*, Amsterdam.
- Branson, W. H. and Henderson, D. (1985), The specification and influence of asset markets, in R. Jones and P. Kenen, eds, 'Handbook of International Economics', Vol. 2, North Holland.
- Branson, W. H. and Hill, R. (1971), 'Capital movements in the OECD area', *OECD Economic Outlook* (Occasional Studies).
- Brenner, M. and Galai, D. (1989), 'New financial instruments for hedging changes in volatility', *Financial Analysts Journal* **45**(4), 61–65.
- Breusch, T. S. (1979), 'Testing for autocorrelation in dynamic linear models', *Australian economic papers* **17**(31), 334 – 355.
- Brown, M. and De Haas, R. (2010), 'Foreign currency lending in emerging Europe: Bank-level evidence', *EBRD Working Paper* (122).
- Brown, R. L., Durbin, J. and Evans, J. (1975), 'Techniques for testing the constancy of regression techniques over time', *Journal of the Royal Statistical Society: Series B (Methodological)* **37**(2), 149 – 192.
- Brunnermeier, M., Nagel, S. and Pedersen, L. (2008), 'Carry trades and currency crashes', *NBER Working Papers* (14473).

- Brunnermeier, M. and Oehmke, M. (2012), ‘Bubbles, financial crises and systemic risk’, *NBER Working Papers* (18398).
- Brunnermeier, M. and Pedersen, L. (2009), ‘Market liquidity and funding liquidity’, *Review of Financial Studies* **22**(6), 2201 – 2238.
- Bruno, M. and Sachs, J. (1982), ‘Energy and resource allocation: A dynamic model of the ‘Dutch disease’’, *Review of Economic Studies* **49**, 845–859.
- Cagan, P. (1956), *The Monetary Dynamics of Inflation*, University of Chicago Press, Chicago.
- Calvo, G. A. (1983), ‘Staggered prices in a utility maximizing framework’, *Journal of Monetary Economics* **12**(3), 383 – 398.
- Camerer, C. and Weber, M. (1992), ‘Recent developments in modeling preferences: uncertainty and ambiguity’, *Journal of Risk and Uncertainty* **5**, 325 – 370.
- Campbell, J., Grossman, S. and Wang, J. (1993), ‘Trading volume and serial correlation in stock returns’, *Quarterly Journal of Economics* **108**(4), 905 – 939.
- Cassel, G. (1916), ‘The present situation of the foreign exchanges’, *Economic Journal* **26**(23), 319–323.
- CDO rating methodology: Some thoughts on model risk and its implications* (2004), *BIS Working Papers* (163).
- CFTC (2012), ‘Us commodity futures trading commission: Cot’.  
**URL:** <http://www.cftc.gov/marketreports/commitmentsoftraders/index.htm>
- Chan, L., Hamao, H. and Lakonishok, J. (1991), ‘Fundamentals and stock returns in Japan’, *The Journal of Finance* **46**(5).
- Chelley-Steeley, P. L. and Tsorakidis, N. (2013), ‘Bid-ask spread dynamics in foreign exchange markets’, *International Review of Financial Analysis* **29**, 119 – 131.
- Chicago Board of Trade (2009), ‘The vix white paper’.  
**URL:** <http://www.cboe.com/micro/vix/vixwhite.pdf>
- Chick, V. (1997), ‘Some reflections on financial fragility in banking and finance’, *Journal of Economic Issues* **31**(2), 535 – 541.
- Chinn, M. and Meredith, G. (2004), ‘Monetary policy and long-horizon uncovered interest parity’, *IMF Staff Papers* **51**, 409 – 430.
- Chopra, N., Lakonishok, J. and Ritter, J. R. (1992), ‘Measuring abnormal performance: Do stocks overreact?’, *Journal of Financial Economics* **31**, 245 – 268.

- Chris Kubelec, F. S. (2010), 'The geographical composition of national external balance sheets: 1980-2005', *Bank of England Working Paper* (384).
- Christiano, L., Motto, R. and Rostagno, M. (2013), 'Risk shocks', *NBER Working Paper* (18682).
- Committee on the Global Financial System Study Group (2008), 'Rating in structured finance: what went wrong and what can be done to address shortcomings?'.  
*Coordinated Portfolio Investment Survey* (2012).  
**URL:** <http://cpis.imf.org/>
- Cootner, P. (1960), 'Returns to speculators: Telsner vs keynes', *Journal of Political Economy* **68**(4), 396 – 404.
- Cootner, P. (1962), 'Stock prices: Random vs systematic changes', *Industrial Management Review* **3**(2).
- Corden, W. M. and Neary, J. (1982), 'Booming sector and de-industrialisation in a small open economy', *The Economic Journal* **92**(Dec), 825–848.
- Corio, C. (2012), 'The financial cycle and macroeconomics: What have we learnt?', *BIS Working Paper* (39).
- Cowen, T. (2010), *The Great Stagnation: How America Ate All the Low Hanging Fruit of Modern History, Got Sick, and Will (Eventually) Feel Better*, Penguin, New York.
- Cutler, D. M., Porterba, J. M. and Summers, L. R. (1986), 'What moves stock prices: Moves in stock prices reflect something other than news about fundamental values', *The Journal of Portfolio Management* **15**(3), 4–12.
- Dahl, D. B. (2012), *xtable: Export tables to LaTeX or HTML*. R package version 1.7-0.  
**URL:** <http://CRAN.R-project.org/package=xtable>
- Daniel (1961), 'Risk, ambiguity, and the Savage axioms', *Quarterly Journal of Economics* **75**, 643–669.
- Davidson, P. (2010), 'Black swans and Knight's epistemological uncertainty: are these concepts also underlying behavioural and post-walrasian theory?', *Journal of Post Keynesian Economics* **32**(4), 567 – 571.
- De Bondt, W. F. M. and Thaler, R. H. (1985), 'Does the stock market overreact?', *The Journal of Finance* **40**(3), 793–805.
- De Bondt, W. F. M. and Thaler, R. H. (1990), 'Do security analysts overreact?', *American Economic Review* **80**(2), 52 – 57.

- De Gregorio, J., Giovannini, A. and Wolf, H. C. (1994), 'International evidence on tradables and nontradables inflation', *European Economic Review* **38**, 1325–44.
- De Long, B. J., Shleifer, A., Summers, L. H. and Waldmann, R. J. (1990), 'Noise trader risk in financial markets', *The Journal of Political Economy* **98**(4), 703–738.
- Del Negro, M. and Otrok, C. (2008), 'Dynamic factor models with time varying parameters: measuring changes in international business cycles', *Federal Reserve Bank of New York Staff Report* (326).
- Demeterfi, K., Derman, E., Kamal, M. and Zou, J. (1999), 'More than you ever wanted to know about volatility swaps', *Goldman Sachs Quantitative Strategies Research Notes* .
- Devereux, M. B. and Sutherland, A. (2011), 'Country portfolios in open economy macro models', *Journal of the European Economic Association* **9**(2), 337–369.
- Diamond, R. V. (2012), 'Vix as a variance swap'.  
**URL:** <http://ssrn.com/abstract=2030292>
- Dolly, J. (1933), 'Characteristics and procedures of common stock split-ups', *Harvard Business Review* **11**(3), 316 – 327.
- Dornbusch, R. (1976), 'Expectations and exchange rate dynamics', *Journal of Political Economy* **84**(6), 1161–1176.
- Drenham, M. and Juselius, M. (2013), 'Evaluating early warning indicators of banking crisis: Satisfying policy requirements', *BIS Working Papers* (421).
- Edgerton, D. and Shukur, G. (1999), 'Testing autocorrelation in a system perspective', *Econometric Reviews* **18**(4), 343–386.
- Edwards, W. (1982), Conservatism in human information processing, in 'Judgment Under Uncertainty: Heuristics and Biases', Cambridge University Press, Cambridge.
- Efron, B. (1979), 'Bootstrap methods: another look at the jackknife', *The Annals of Statistics* **7**(1), 1 – 25.
- Eichengreen, B. and Park, Y. C. (2006), Global imbalances: Implications for Emerging Asia, in 'presented to the IADB Annual Meetings Seminar'.
- Enders, W. (2010), *Applied Econometric Time Series*, 3 edn, Wiley.
- Engel, C. (1996), 'The forward discount anomaly and the risk premium: A survey of recent evidence', *Journal of Empirical Finance* **3**(2), 123 – 192.

- Engle, R. F. (1982), 'Autoregressive conditional heteroscedasticity with estimates of the variance of united kingdom inflation', *Econometrica* **50**(4), 987 – 1007.
- Engle, R. F., Lilien, D. M. and Robins, R. P. (1987), 'Estimating time varying risk premia in the term structure: the ARCH-M model', *Econometrica* **55**(2), 391 – 407.
- European Central Bank Statistics (2013), 'ECB monetary aggregates'.  
**URL:** <http://www.ecb.int/stats/money/aggregates/aggr/html/index.en.html>
- Evans, M. D. and Lyons, R. (2002), 'Order flow and exchange rate dynamics', *The Journal of Political Economy* **10**(1), 170–180.
- Fair, R. C. (1970), 'The estimation of simultaneous equation models with lagged endogenous variables and first order serially correlated errors', *Econometrica* **38**(3), 507–516.
- Fama, E. (1965), 'The behaviour of stock market prices', *The Journal of Business* **38**, 34–105.
- Fama, E., Fisher, L., Jensen, M. and Roll, R. (1969), 'The adjustment of stock prices to new information', *International Economic Review* **10**(1), 1–21.
- Fama, E. and French, K. (1988), 'Permanent and temporary components of stock prices', *Journal of Political Economy* **96**(2), 246 – 273.
- Federal Reserve Statistical Release (2013), 'Money stock measures (h6) release'.  
**URL:** <http://www.federalreserve.gov/releases/h6/current/h6.htm>
- Findings regarding the market events of May 6, 2010* (2010).  
**URL:** <http://www.lbl.gov/cs/html/CIFT-LBL-report.pdf>
- Fischer, S. (1980), *Rational expectations and economic policy*, University of Chicago Press, Chicago.
- Fisher, I. (1932), *Booms and Depressions: Some First Principles*, Adelphi, New York.
- Fisher, I. (1933), 'The debt-deflation theory of great depressions', *Econometrica* **1**(4), 337.
- Focus on European Economic Integration: Foreign Currency Loans* (2011), Quarterly Focus Q1, Oesterreichische National Bank.
- Forbes, W. (2009), *Behavioural Finance*, John Wiley, Chichester.
- Foster, J. and Metcalf, J. S. (2012), 'Economic emergence: An evolutionary economic perspective', *Journal of Economic Behavior and Organization* **82**, 420 – 432.

- Frankel, J. A. (1984), *Tests of Monetary and Portfolio Balance models of Exchange Rate Determination*, University of Chicago Press.
- Frankel, J. A. (1986), International capital mobility and crowding out in the us economy: Imperfect integration of financial markets or goods markets, in R. Hafer, ed., 'How open is the US economy', Lexington Books.
- Frankel, J. A. and Froot, K. (1987), 'Using survey data to test standard propositions regarding exchange rate expectations', *American Economic Review* **77**, 133 – 153.
- Frankel, J. A. and Froot, K. (1990a), 'Chartists, fundamentalists and trading in the foreign exchange market', *The American Economic Review* **80**(2), 181 – 185.
- Frankel, J. A. and Froot, K. (1990b), 'Exchange rate forecasting techniques, survey data, and implications for the foreign exchange market', *NBER Working Paper* (3470).
- Frenkel, J. A. (1976), 'A monetary approach to exchange rates: Doctrinal aspects and empirical evidence', *Scandinavian Journal of Economics* **78**, 200–224.
- Friedman, M. (1953), The case for flexible exchange rates, in 'Essays in Positive Economics', University of Chicago Press, pp. 157–203.
- Friedman, M. (1957), *Theory of the Consumption Function*, Princeton University Press, Princeton.
- Froot, K. (1990), 'Short rates and expected asset returns', *NBER Working Paper* (3247).
- Froot, K. and Frankel, J. A. (1989), 'Forward discount bias: Is it an exchange rate risk premium?', *Quarterly Journal of Economics* **6**, 139 – 161.
- Froot, K. and Rogoff, K. (1995), Perspectives on PPP and long-run real exchange rate, in 'Handbook of International Economics', Vol. 3, pp. 1647 – 1688.
- Froot, K. and Thaler, R. (1990), 'Anomalies: Foreign exchange', *The Journal of Economic Perspectives* **4**(3), 179 – 192.
- Fung, H.-G., Leung, W. L. and Zhu, J. (2004), 'Nondeliverable forward market for Chinese RMB: a first look', *China Economic Review* **15**(3), 348 – 352.
- Gabor, D. (2011), *Central Banking and Financialization: A Romanian account of how Eastern Europe became subprime*, Studies in Economic transition, Palgrave, New York.
- Gabrisch, H. and Orlowski, L. (2011), 'The extreme risk problem for monetary policies of the euro-candidates', *Comparative Economic Studies* **53**, 511 – 534.
- Garman, M. and Kohlhagan, S. (1983), 'Foreign currency option values', *Journal of International Money and Finance* **2**(3), 231 – 237.



- Geanakoplos, J. (2010), 'The leverage cycle', *Cowles Foundation Working Paper* (1304).
- Gilovich, T., Vallone, R. and Tversky, A. (1985), 'The hot hands in basketball: on the misperception of random sequences', *Cognitive Psychology* **17**.
- Godfrey, L. (1978), 'Testing against general autoregressive and moving average error models when the regressors include lagged dependent variables', *Econometrica* **46**(6), 1293 – 1302.
- Goodhart, C. (1975), 'Monetary relationships: a view from Threadneedle street', *Papers in Monetary Economics* .
- Gordon, R. (2012), 'Is US economic growth over? faltering innovation confronts six headwinds', *Centre for Economic Policy Research Policy Insight* (63).
- Gorton, G. B. (2010), *Slapped in the face by the invisible hand: banking and the panic of 2007*, OUP, Oxford.
- Gorton, G. B. (2012), *Misunderstanding Financial Crises: Why we don't see them coming*, OUP, Oxford.
- Granger, C. (1969), 'Investigating causal relationships by econometric models and cross-spectral methods', *Econometrica* **37**(3), 424–438.
- Gray, R. W. (1963), 'Onions revisited', *Journal of Farm Economics* **45**(2), 273 – 276.
- Green, W. H. (2003), *Econometric Analysis*, Prentice Hall.
- Grossman, S. J. and Stiglitz, J. E. (1980), 'On the impossibility of informationally efficient markets', *The American Economic Review* **70**(3), 393–408.
- Haavelmo, T. (1943), 'The statistical implications of a system of simultaneous equations', *Econometrica* **11**(1), 1 – 12.
- Habib, M. and Stracca, L. (2012), 'Getting beyond carry trade: What makes a safe haven currency?', *Journal of International Economics* **87**(1), 50 – 64.
- Hamilton, J. D. (1994), *Time Series Analysis*, Princeton University Press.
- Harrod, R. (1933), *International Economics*, Palgrave Macmillan, London.
- Harvey, A. C. (1993), *Time Series Models*, Pearson.
- Hau, H. and Rey, H. (2006), 'Exchange rates, equity prices and capital flows', *Review of Financial Studies* **19**(1), 273 – 317.
- Hayek, F. (1945), 'The use of knowledge in society', *The American Economic Review* **35**(4), 518 – 530.

- Heering, W. (1996), 'A suggestion for generalizing the subjectivistic theory of probability', *APT Papers* .
- Heyde, F. and Neyer, U. (2010), 'Credit default swaps and the stability of the banking sector', *International Review of Finance* **10**(1), 27 – 61.
- Hicks, J. R. (1946), *Value and Capital*, Clarendon Press, Oxford.
- Hicks, J. R. (1962), 'Liquidity', *Economic Journal* **72**(288), 787–802.
- Hodrick, R. (1988), *The empirical evidence on the efficiency of forward and futures foreign exchange markets*, Harwood Academic Publishers, Switzerland.
- Hölscher, J. and Jarmuek, M. (2005), 'Overvalued or undervalued euroland entry?', *Post-Communist economies* **17**(2), 235 – 250.
- IMF (2001), *Balance of Payments and International Investment Position Manual*, sixth edn, International Monetary Fund.  
**URL:** <http://www.imf.org/external/pubs/ft/bop/2007/bopman6.htm>
- IMF (2009), 'Classification of exchange rate arrangements and monetary policy frameworks'.  
**URL:** <http://www.imf.org/external/NP/mfd/er/index.aspx>
- Instefjord, N. (2005), 'Risk and hedging: Do credit derivatives increase bank risk?', *Journal of Banking and Finance* **29**(2), 333 – 345.
- Jegadeesh, N. and Titman, S. (1993), 'Returns to buying winners and selling losers: Implications for stock market efficiency', *The Journal of Finance* **48**(1), 65 – 91.
- Jarque, C. and Bera, A. (1980), 'Efficient tests for normality, homoscedasticity and serial independence of regression residuals', *Economic Letters* **6**(3), 255 – 259.
- Jarque, C. and Bera, A. (1981), 'Efficient tests for normality, homoscedasticity and serial independence of regression residuals: Monte carlo evidence', *Economic Letters* **7**(4), 313 – 318.
- Jarque, C. and Bera, A. (1987), 'Tests for normality of observations and regression residuals', *International Statistical Review* **55**(22), 164 – 172.
- Jensen, M. (1978), 'Some anomalous evidence regarding market efficiency', *Journal of Financial Economics* **6**, 95 – 101.
- Jurek, J. (2007), 'Crash-neutral currency carry trades', *AFA Atlanta Meetings Paper* .
- Juselius, K. (2007), *The Cointegrated VAR Model: Methodology and Applications (Advanced Texts in Econometrics)*, 2 edn, Oxford University Press, USA.

- Kabacoff, R. I. (2011), *R in Action*, Manning.
- Kahneman, D. (2012), *Thinking fast and slow*, Penguin, London.
- Kahneman, D. and Tversky, A. (1979), 'Prospect theory: An analysis of decision under risk', *Econometrica* **47**(2), 263–291.
- Kahneman, D. and Tversky, A. (1980), Causal schema in judgements under uncertainty, in M. Fishbein, ed., 'Progress in Social Psychology', Hillsdale, NJ.
- Kalecki, M. (1965), *Theory of Economic Dynamics*, Allen and Urwin, London.
- Kapner, K. (2006), 'Risk reversals', *Global Financial Markets Institute* .
- Keele, L. and Kelly, N. J. (2006), 'Dynamic models for dynamic theories: the ins and outs of lagged dependent variables', *Political Analysis* **14**(2), 186–205.
- Kendall, M. G. (1953), 'The analysis of economic time series 1', *Journal of the Royal Statistical Society* **116**(1), 11 – 25.
- Keynes, J. M. (1921), *Treaties on Probability*, McMillan, Cambridge.
- Keynes, J. M. (1923), 'A tract on monetary reform'.
- Keynes, J. M. (1925), *The Economic Consequences of Mr. Churchill*, L. and V. Woolf.
- Keynes, J. M. (1930), *A Treaties on Money*, Macmillan, London.
- Keynes, J. M. (1936), *The General Theory of Employment, Money and Interest*, Macmillan.
- Knight, F. (1921), *Risk, Uncertainty and Profit*, Houghton Mifflin, Boston.
- Koop, G. (2003), *Bayesian Econometrics*, Wiley, New York.
- Koop, G. and Korobilis, D. (2009), 'Bayesian multivariate time series', *Foundations and Trends in Econometrics* **3**(4), 267 – 358.
- Korinek, A. (2011), 'Hot money and serial financial crises', *IMF Economic Review* **59**, 306 – 339.
- Kouri, P. J. K. (1977), International investment and interest rate linkages under flexible exchange rates, in R. Z. Aliber, ed., 'The political economy of monetary reform', Macmillan, London.
- Kouri, P. J. and Porter, M. (1974), 'International capital flows and portfolio equilibrium', *Journal of Political Economy* **82**, 443–467.

- Krugman, P. (1978), 'Purchasing power parity and exchange rates: another look at the evidence', *Journal of International Economics* **8**, 397–407.
- Kydland, F. and Prescott, E. (1982), 'Time to build and aggregate fluctuations', *Econometrica* **50**(6), 1345–1370.
- Lakonishok, J., Shleifer, A. and Vishny, R. W. (1994), 'Contrarian investment, extrapolation and risk', *The Journal of Finance* **49**(5), 1541 – 1578.
- Lane, P. R. (2001), 'The new open economy macroeconomics: A survey', *Journal of International Economics* **54**(2), 235–266.
- Lane, P. R. and Milesi-Ferretti, G. M. (2007), 'The external wealth of nations part 2: Revised and extended estimates of foreign assets and liabilities 1970-2004', *Journal of International Economics* **73**(2), 223–250.
- LeRoy, S. F. (1989), 'Efficient capital markets and martingales', *Journal of Economic Literature* **27**, 1583 – 1621.
- Levy, S. and Levy, D. (1983), *Profits and the Future of American Society*, Basic Books, New York.
- Lewis, K. K. (2008), Peso problem, in S. N. Durlauf and L. E. Blume, eds, 'The New Palgrave Dictionary of Economics', Palgrave Macmillan, Basingstoke.
- Liu, T. (1960), 'Underidentification, structural estimation and forecasting', *Econometrica* **28**(4), 855–865.
- Lo, A. W. and MacKinlay, A. C. (1988), 'Stock market prices do not follow random walks: Evidence from specification tests', *Review of Financial Studies* **1**(1), 41 – 66.
- Lo, A. W. and MacKinlay, A. C. (1990), 'An econometric analysis of nonsynchronous trading', *Journal of Econometrics* **45**(1-2), 181 – 211.
- Lopez, J. A. (2001), 'Financial instruments for mitigating credit risk', *FRBSF Economic Letter* (34).
- Lorentan, M. (2005), 'Indexes of the foreign exchange value of the dollar', *Federal Reserve Bulletin* (Winter).
- Lucas, R. E. (1976), *Econometric Policy Evaluation: A Critique*, Vol. 1, Carnegie-Rochester Conference Series on Public Policy.
- Lucas, R. E. (1987), *Models of the business cycle*, Basil Blackwell, Oxford.
- Lyons, R. K. (1995), 'Tests of the microstructure hypothesis in the foreign exchange market', *Journal of Financial Economics* **39**(2-3), 321–351.

- Lyons, R. K. (2006), *The Microstructure Approach to Exchange Rates*, The MIT Press.
- Malmedier, U. and Tate, G. (2005), ‘CEO overconfidence and corporate investment’, *The Journal of Finance* **60**(6), 2661 – 2700.
- Mandelbrot, B. (1963), ‘The variation of certain speculative prices’, *The Journal of Business* **36**(4), 394 – 419.
- Mandelbrot, B. (1971), ‘When can price be arbitrated efficiently? a limit to the validity of random walk and martingale models’, *The Review of Economics and Statistics* **53**(3), 225 – 236.
- Marx, K. (1867), *Das Capital: A Critique of Political Economy*, Meissner, Hamburg.
- Masciandaro, D. and Passarelli, F. (2013), ‘Financial systemic risk: taxation or regulation’, *Journal of Banking and Finance* **37**(2), 587 – 596.
- McCulley, P. (2009), ‘The shadow banking system and Hyman Minsky’s economic journey’, *Global Central Bank Focus* .
- Meese, R. and Rogoff, K. (1983), ‘Empirical exchange rate models of the seventies do they fit out of sample?’, *Journal of International Economics* **14**(1-2), 3–24.
- Mengle, D. (2007), ‘Credit derivatives: An overview’, *Federal Reserve Bank of Atlanta Economic Review* **Q4**.
- Minsky, H. P. (1975), *John Maynard Keynes*, Columbia University Press, NY.
- Minsky, H. P. (1986), *Stabilizing an Unstable Economy*, Yale University Press.
- Minsky, H. P. (1992), The financial instability hypothesis, in M. S. P. Arestis, ed., ‘Handbook of Radical Political Economy’, Edward Elgar, Aldershot.
- Minsky, H. P. (1994), ‘Financial instability and the decline of banking: public policy implications’, *Levy Institute Working Paper* (127).
- Minsky, H. P. (1995), ‘Longer waves in financial relations: Financial factors in the more severe depressions II’, *Journal of Economic Issues* **29**(1).
- 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.
- Muth, J. F. (1961), ‘Rational expectations and the theory of price movements’, *Econometrica* **29**, 315 – 335.

- Myers, J. and Bakay, A. (1948), 'Influence of stock split-ups on market price', *Harvard Business Review* **26**(2), 251 – 255.
- Myrdal, G. (1939), *Monetary Equilibrium*, W. Hodge, London.
- Neely, C. J. and Weller, P. A. (2011), 'Technical analysis in the foreign exchange market', *Federal Reserve Bank of St. Louis Working Paper* (001B).
- Obstfeld, M. and Rogoff, K. (1995), 'Exchange rate dynamics redux', *The Journal of Political Economy* **103**(3), 624–660.
- Obstfeld, M. and Rogoff, K. (1996), *Foundations of International Macroeconomics*, The MIT Press.
- Obstfeld, M. and Rogoff, K. (2009), 'Global imbalances and the financial crisis: Products of common causes', *CEPR Discussion Paper* .
- O'Hara, M. (1998), *Market Microstructure Theory*, Blackwell Business.
- Osborne, M. F. M. (1959), 'Brownian motion in the stock market', *Operations Research* **7**(2), 145 – 173.
- Patinkin, D. (1982), *Anticipations of the General Theory and other essays*, Blackwell, Oxford.
- Pfaff, B. (2008a), *Analysis of Integrated and Cointegrated Time Series with R*, second edn, Springer, New York. ISBN 0-387-27960-1.  
**URL:** <http://www.pfaffikus.de>
- Pfaff, B. (2008b), 'VAR, SVAR and SVEC models: Implementation within R package vars', *Journal of Statistical Software* **27**(4).  
**URL:** <http://www.jstatsoft.org/v27/i04/>
- Pomeranets, A. (2012), 'Financial transaction taxes: International experiences, issues and feasibility', *Bank of Canada Review* (Autumn).
- Portes, R. (2009), Global imbalances, in M. Dewaripont, X. Freixas and M. Portes, eds, 'Macroeconomic Stability and Financial Regulation'.
- Pratt, J. W. (1964), 'Risk aversion in the small and in the large', *Econometrica* **32**, 122 – 136.
- Primiceri, G. E. (2005), 'Time varying vector structural regressions and monetary policy', *Review of Economic Studies* **75**, 821 – 852.

- R Core Team (2013), *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, Austria.  
**URL:** <http://www.R-project.org>
- RAND (1953), *A Million Random Digits with 100,000 Normal Deviations*, Free Press, Glencoe.
- Reinhart, C. and Rogoff, K. (2009), *This Time is Different: Eight Centuries of Financial Folly*, Princeton University Press, Princeton.
- Roberts, H. (1959), 'Stock market 'patterns' and financial analysis', *Journal of Finance* **14**(1), 1 – 10.
- Rogoff, K. (1980), 'Tests of the martingale model for foreign exchange futures markets', *Massachusetts Institute of Technology* (Ph.D Dissertation).
- Rogoff, K. (1996), 'The purchasing power parity puzzle', *The Journal of Economic Literature* **34**, 647–648.
- Roll, R. (1984), 'Orange juice and weather', *American Economic Review* **74**(5), 541 – 566.
- Roll, R. and Yan, S. (2000), 'An explanation of the forward premium puzzle', *European Financial Management* **6**(2), 121 – 148.
- Rooney, B. and Yousef, H. (2012), 'Knight's bizarre trades rattle markets'.
- Sachs, J. (1982), 'The current account in the macroeconomic adjustment process', *The Scandinavian Journal of Economics* **84**(2), 147–159.
- Samuelson, P. A. (1958), 'An exact consumption-loan model of interest with or without the social contrivance of money', *Journal of Political Economy* **66**(6), 467 – 482.
- Samuelson, P. A. (1964), 'Theoretical notes on trade problems', *Review of Economics and Statistics* **46**, 145–154.
- Samuelson, P. A. (1965), 'Proof that properly anticipated stock prices fluctuate randomly', *Industrial Management Review* **6**, 41–49.
- Sanders, D., Boris, K. and Manfredo, M. (2004), 'Hedgers, funds and small speculators in the energy futures market: An analysis of the CFTC's commitments of traders reports', *Energy Economics* **26**, 425 – 445.
- Sargent, T. J. (1986), *Rational expectations and inflation*, Harper and Row, New York.

- Sarno, L. and Valente, G. (2006), 'Deviations from purchasing power parity under different exchange rate regimes. do they revert and if so how?', *The Journal of Banking and Business* **30**, 3147 – 3169.
- Schumpeter, J. A. (1934), *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle*, OUP, New York.
- Schwarz, G. (1978), 'Estimating the dimension of a model', *Annals of Statistics* **6**(2), 461 – 464.
- Shackle, G. (1952), 'On the meaning and measure of uncertainty', *Metroeconomica* **4**(3), 87 – 104.
- Shackle, G. (1965), *A scheme of economic theory*, Cambridge University Press.
- Shah, A., Kapoor, A. and Balasubramanian, V. (2011), 'Eventstudies: Infrastructure for performing event studies with R', *Journal of Statistical Software* .
- Shiller, R. J. (1981), 'Do stock price move too much to be justified by subsequent changes in dividends?', *American Economic Review* **71**(3), 421–436.
- Sidelsky, R. (1983), *John Maynard Keynes: A Biography, vol 1, Hopes Betrayed 1883-1920*, Penguin, New York.
- Silverman, B. (1986), *Density Estimation*, Chapman and Hall, London.
- Simon, H. H. (1955), 'A behavioural model of rational choice', *The Quarterly Journal of Economics* **69**(1), 99–118.
- Sims, C. A. (1972), 'Money, income, and causality', *The American Economic Review* **62**(4), 540–552.
- Sims, C. A. (1980), 'Macroeconomics and reality', *Econometrica* **48**(1).
- Sims, C. A. (1986), 'Are forecasting models usable for policy analysis?', *Federal Reserve Bank of Minneapolis Quarterly Review* **10**(Winter), 2 – 16.
- Sims, C. A., Stock, J. and Watson, M. W. (1990), 'Inference in linear time series models with some unit roots', *Econometrica* **58**, 113–44.
- Siourounis, G. (2004), 'Capital flows and exchange rates: An empirical analysis', *Social Science Research Network Working Paper Series* .
- Smets, F. and Wouters, R. (2002), 'An estimated stochastic, dynamic, general equilibrium model of the euro area', *ECB Working Paper* (171).



- Spence, M. (1973), 'Job market signaling', *The Quarterly Journal of Economics* **87**(3), 355–374.
- Spronk, R., Vershoor, W. F. and Zwinkels, R. C. (2013), 'Carry trade and foreign exchange rate puzzles', *European Economic Review* **60**, 17–31.
- Stein, J. (1989), 'Overreactions in the options market', *The Journal of Finance* **44**(4), 1011–1022.
- Taleb, N. N. (2007), *The Black Swan: the impact of the highly improbable*, Penguin, London.
- Taylor, A. and Taylor, M. (2004), 'The purchasing power parity debate', *Journal of Economic Perspectives* **18**(4), 135–158.
- Taylor, J. B. (1980), 'Aggregate dynamics and staggered contracts', *Journal of Political Economy* **88**(1), 1–23.
- Taylor, M. P. (2003), 'Purchasing power parity', *Review of International Economics* **11**, 436–452.
- Taylor, M. P. and Allen, H. (1992), *Journal of International Money and Finance* **11**(3), 304 – 314.
- Thaler, R. (1988), 'Anomalies: The winner's curse', *Journal of Economic Perspectives* **2**(1), 191 – 202.
- Tobin, J. (1958), 'Liquidity preference as behavior towards risk', *The Review of Economic Studies* **25**(2), 65 – 86.
- Tovar, C. (2008), 'DSGE and central banks', *BIS Working Papers* (258).
- US Treasury (2012), 'Treasury international capital (TIC) system'.  
**URL:** <http://www.treasury.gov/resource-center/data-chart-center/tic/Pages/index.aspx>
- Venables, W. N. and Ripley, B. (2002), *Modern Applied Statistics with S*, Springer, New York.
- Von Neumann, J. and Morgenstern, O. (1944), *Theory of games and economic behaviour*, Princeton University Press, Princeton.
- Wang, C. (2004), 'Futures trading activity and predictable foreign exchange market movements', *Journal of Banking and Finance* **28**, 1023 – 1041.
- Welch, B. (1951), 'On the comparison of several mean values: An alternative approach', *Biometrika* **38**, 330 – 336.

- White, J. S. (1961), ‘Asymptotic expansions for the mean and variance of the serial correlation coefficient’, *Biometrika* **48**(1 and 2), 85 – 94.
- Woodford, M. (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press.
- Working, H. (1925), ‘The statistical determination of demand curves’, *The Quarterly Journal of Economics* **39**(4), 503–543.
- Working, H. (1934), ‘A random difference series for use in the analysis of time series’, *Journal of the American Statistical Association* **29**(11).
- World Bank Quarterly External Debt Statistics* (2012).  
**URL:** <http://web.worldbank.org/datastatistics/extdecqeds>
- Zeileis, A., Hornik, F. and Kleiber, K. (2002), ‘Strucchange. an R package for testing for structural change in linear regression models’, *Journal of Statistical Software* **7**(2), 1–38.
- Zhou, S. and Kutan, A. M. (2011), ‘Is the evidence for PPP reliable? a sustainability examination of the stationarity of real exchange rates’, *Journal of Banking and Finance* **35**, 2479 – 2490.