AN INVESTIGATION INTO THE INFLUENCE OF EXCHANGE RATE VARIABILITY ON UK EXPORT VOLUMES AND PRICES

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Abstract

Uncertainty about future movements in the exchange rate leads to uncertainty about the prices importers will have to pay, or exporters will receive, in domestic currency terms. As a result, exchange rate variability may influence agents' decisions to engage in foreign trade and could act as a deterrent to foreign trade.

The empirical literature has provided no definitive conclusions on the question of whether exchange rate variability is detrimental to international trade. This thesis identifies that one of the main reasons for this ambiguous conclusion is that there is little consensus regarding the most appropriate way of measuring exchange rate variability; and careful attention is given to the nature of the variability captured by the range of proxies used.

From this basis the thesis develops into an investigation regarding the empirical influence of three measures of exchange rate variability on the prices and volumes of UK aggregate exports to its eight main trading partners, over the period 1973 Q2 to 1990 Q3. The empirical results are generated from two very recent approaches to cointegration analysis. Firstly, the ARDL approach (Pesaran, Shin and Smith, 1996) is used to estimate the long-run structural equations. Secondly, in order to test for identification of the structural system a restricted VECM (Pesaran and Shin, 1997b; Pesaran and Smith, 1998) is estimated. Given that exchange rate variability may have different impacts on UK exports across the eight countries we also utilise one of the measures of exchange rate variability to investigate its impact on bi-lateral UK exports. The estimation results indicate that none of the measures of exchange rate variability had a statistically significant influence on either aggregate or bi-lateral UK exports.

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DECLARATIONS

I confirm that no part of the material offered has previously been submitted by me for a degree in this or any other university. None of the work has been generated through joint work and in all cases the work of others has been acknowledged and quotations and paraphrases are suitably indicated.

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Chapter One

Introduction

Since the formal abandonment of the Bretton Woods system in March 1973 economists have been concerned that the move to floating exchange rates resulted in increased exchange rate volatility (Kumar and Whitt, 1992; Frenkel, 1992). Furthermore, higher exchange rate variability could act as a deterrent to the participation in international trade and could lead to increased protectionism. Economic theory (see for example Clark, 1973; Ethier, 1973) suggests that exchange rate variability creates uncertainty about the future movements in the exchange rate. This results in uncertainty about the prices importers will pay, or exporters will receive, in their domestic currency terms, at a date in the future. Assuming economic agents are risk averse, this will lead to exporters and importers preferring the relatively certain profits from trading in their domestic economies compared to profits earned from foreign trade whose value could be subject to adverse exchange rate fluctuations.

The traditional approach to modelling the decision making process of firms operating under conditions of exchange rate uncertainty has been to use mean-variance analysis (Tobin, 1958; Markowitz, 1959). In this framework rational utility maximising agents trade-off expected profits against risk, measured by the standard deviation (variance) of profits. The extent of the negative influence of exchange rate variability on international trade will depend upon the degree of exchange rate variability and the extent to which exporters or importers are averse to foreign exchange risk.

In addition, the literature has also identified a number of long-term influences resulting from persistent exchange rate uncertainty. For example, persistent exchange rate variability may lead to governments adopting protectionist policies, which in itself could lower the volume of international trade. Exchange rate uncertainty could also hinder long term planning and decision making of firms and may deter investment in plant and equipment if the trading environment of exporters or importers is uncertain. In chapter two of the thesis we analyse the main reasons why exchange rate uncertainty may influence international trade. This discussion is placed into context by comparing the degree of exchange rate variability under the Bretton Woods system with that in the floating exchange rate period, as well as comparing the trade performance of the major industrialised and developing countries.

A large amount of literature has developed in an attempt to quantify the sign and magnitude of the variability effect on the volumes and prices of exports and imports. Unfortunately, the studies when taken together have provided no decisive conclusions as to whether exchange rate variability (uncertainty) deters participation in international trade. A survey of the empirical studies undertaken in chapter two (and a summary of the research presented in appendix A) suggests that nearly as many studies find no significant empirical influence of exchange rate variability on international trade as the number of studies which find a significant variability effect. In this literature review we discuss the seminal contribution of Hooper and Kohlhagen (1978) in detail and from this framework compare and contrast the significant findings from the empirical literature. The survey classifies the major studies in the field so that the results from similar approaches can be compared.

Two possible reasons may account for the mixed empirical results: firstly, the literature has provided no clear guidance regarding how to measure exchange rate uncertainty nor about identifying the circumstances about which one particular proxy is more appropriate than another. Secondly, many of the empirical studies made the assumption that the data used for estimation is stationary. We take each in turn: **(i) measuring exchange rate uncertainty.** The current proxies have attempted to measure the uncertainty regarding the direction and magnitude of future exchange rate movements. Proxies of exchange rate uncertainty typically measure the deviation of the actual exchange rate from its expected value in a given time period. Researchers have to assume a proxy for the expected future spot rate: for example, Hooper and Kohlhagen (1978) use the average absolute difference between the current spot rate and the lagged forward rate for the thirteen weekly observations of a given quarter. However, rather than relying on an assumed definition of the expected future spot rate, many researchers have opted to use measures of exchange rate variability to capture exchange rate uncertainty, such as the standard deviation of the exchange rate (Makin, 1976; Thursby, 1981; Medhora, 1990); moving average standard deviations (Cushman, 1988b; Chowdhury, 1993; Arize, 1995 a,b); or GARCH processes of the squared residuals from a model of the exchange rate (Kroner and Lastrapes, 1993; Holly, 1995; Arize, 1997a). However, it is important to note that the extent to which variability proxies accurately depict exchange rate uncertainty depends crucially upon the extent to which exchange rate movements are predictable (Akhtar and Hilton, 1984). For example, if exchange rate movements are relatively predictable, despite being highly volatile, then variability measures may overstate the 'true' degree of exchange rate uncertainty.

In chapter three, we survey the various measures of exchange rate variability and compare and contrast the characteristics of the numerous proxies. To the best of this author's knowledge a complete survey of the proxies has not yet been undertaken, so careful attention is given to the nature of the variability captured by the range of proxies. The fact that each proxy has it own particular set of characteristics may mean that the measured impact of exchange rate variability on international trade may vary according to the measure adopted. We also discuss the factors researchers should consider when measuring exchange rate variability, such as the sample frequency of the data used; the distribution of the exchange rate; whether nominal or real exchange rates should be utilised; and the influence of exchange rate policy regimes on variability measurement.

(ii) The assumption that the data is stationary. Many of the empirical studies have made the assumption that the data used in the estimation is stationary. Recent developments in the cointegration literature have allowed for the modelling of long-run equilibrium relationships when the data used is non-stationary. A few recent studies have used the Johansen (1988) procedure to estimate the number of cointegrating vectors consistent with a long-run model of international trade incorporating exchange rate variability (see for example Chowdhury, 1993; Arize, 1997a,b). To the best of this author's knowledge, only one study has estimated a model of both export volumes and prices using cointegration techniques. This is Holly (1995) which uses the Johansen procedure to estimate the impact of a GARCH measure of exchange rate variability on the prices and volumes of UK aggregate manufactured exports, over the sample period 1974Q4 to 1992Q4. The price and volume equations are assumed to represent the export demand and supply equations, assuming the supply of exports schedule is infinitely price elastic.

However, there are two main limitations of the econometric methodology adopted by Holly *loc. cit.* Firstly, unit root testing established that the variability measure was stationary and the variable was eliminated from the cointegrating vector so that the long-run impact of exchange rate variability was denied. The 'variability effect' is estimated from short-run error correction equations. Recent developments in the cointegration literature have concluded that stationary variables should be included in cointegrating vectors when economic theory indicates they play an important role in defining the long-run equilibrium relationship (Harris, 1995; Wickens, 1996).

Secondly, Holly applied the Johansen procedure to the volume and price equations separately, thus treating each as though it were a single structural equation, rather than being one equation from a structural system. The important contribution by Wickens (1996) has demonstrated that only by imposing *a priori* restrictions derived from economic theory is it possible to make structural inferences from the estimation of cointegrating vectors. Without these restrictions it is impossible to make a meaningful economic interpretation of cointegrating vectors, given that they are derived from a reduced form Vector Autoregressive Error Correction Model (VECM).

In chapter five we outline the econometric methodology that can be utilised to address these two limitations of Holly's study. Firstly, to interpret fully the role played by stationary variables in the cointegrating vectors, the ARDL approach to cointegration (Pesaran, Shin and Smith, 1996; Pesaran and Shin, 1997a) will be used for the purpose of structural estimation. This technique allows for the testing and estimation of long-run relationships irrespective of knowing whether the order of integration of each variable is I(0) or I(1). However, developments in the ARDL literature to date have currently only allowed for the estimation of single equations, not yet addressing the importance of system estimation. It is therefore necessary to supplement our research from the ARDL approach with a test for structural identification. Recent developments by Pesaran and Shin, (1997b) [see also Garratt *et al*, 1998; Pesaran and Smith, 1998; Pesaran, Shin and Smith, 1997] have provided an applied econometric framework which can be used to derive a structural representation by imposing restrictions on cointegrating vectors.

The empirical analysis presented in chapters six and seven investigates whether exchange rate variability had any statistically significant influence on either the demand for or supply of UK exports to its eight main trading partners. The sample period for estimation is 1973Q2 to 1990Q3, a period of floating exchange rates for the UK. In chapter six we estimate the impact of three measures of exchange rate variability on aggregate UK exports to its eight main trading partners. The three measures have been commonly used in the literature and are adopted to examine whether the relationship between export volumes (prices) and exchange rate variability is sensitive to the particular proxy chosen. While this research does not aim to develop new measures of exchange rate variability in order to more accurately depict the concept of exchange rate uncertainty, it hopes to illustrate how different characteristics of particular measures may possibly alter the perceived relationship between trade volumes and exchange rate variability.

However, the use of aggregate trade data is subject to the problem that measures of exchange rate variability may have different impacts across countries of destination and even different sectors of the economy. The same products exported to different countries may be subject to different influences from exchange rate variability depending upon the particular price elasticity of demand, and thus on the extent to which fluctuations in the price of exports in domestic currency terms (due to fluctuations in the exchange rate) have an impact on the demand for exports. In chapter seven we use disaggregated data to examine the impact of one of the measures of exchange rate variability used in chapter six on the bi-lateral exports to each of the UK's eight main trading partners. As well as hoping to establish whether different variability effects exist, it is also interesting to discover whether the identification of the structural relationships is sensitive to the country of destination.

Chapter eight provides an overall summary of the findings from this research and details the significant conclusions from it. Limitations of the work are considered and possible suggestions for future research are provided.

Chapter Two

Exchange Rate Variability and International Trade I

Abstract

This chapter provides a rationale for the possibility of exchange rate variability having a deterrent effect on international trade. To place the debate in context the trade performance of the main industrialised and developing countries are compared during sample periods of the recent float (1976-1987) and the Bretton Woods era (1955-1970). Economic theory and recent evidence are then used to outline the main reasons why exchange rate variability could influence international trade.

2.1 Introduction

The abandonment of the Bretton Woods system in 1973 led to concerns that excessive short-run fluctuations in exchange rates could be harmful to international trade. The move to floating exchange rates was generally characterised by a higher degree of exchange rate volatility (Kumar and Whitt, 1992; Frenkel, 1992; Macdonald, 1988). Economic theory suggests that exchange rate variability creates uncertainty concerning the prices importers would have to pay, or exporters would receive, in their respective domestic currency terms, at some date in the future. Under the assumption of risk aversion, participants in international trade tend to prefer the relatively certain profits which may be obtained from trading in domestic markets compared to foreign markets where uncovered profits earned are subject to exchange rate fluctuations. The uncertain revenues would thus encourage them either to switch away from foreign markets to domestic economic activities or attempt to insure against exchange rate fluctuations through hedging techniques.

Following the seminal work of Hooper and Kohlhagen (1978), economists have attempted to estimate the sign and magnitude of the effect of exchange rate variability on trade volumes and prices. In 1984 the International Monetary Fund concluded from a survey of the literature that there was no systematic significant relationship between exchange rate variability and international trade volumes. Since then, however, further research has provided evidence of a statistically significant 'variability' effect.

This chapter takes a step back from the debate concerning the sign and magnitude of the exchange rate variability effect to provide a rationale as to why exchange rate variability could influence trade flows. Section 2.2 analyses the recent trade performance of the main industrialised and developing countries over recent fixed and floating rate periods. The data presented suggest that the move to floating exchange rates was coincident with a fall in the growth of trade volumes and that trade prices were far more volatile.

We also consider some of the main reasons as to why exchange rate variability may influence international trade (section 2.3). The arguments are based both on economic theory and recent evidence concerning the operation of the international trading system.

2.2 Exchange Rate Variability and International Trade: an overview.

Over the post-war period the international monetary system of the developed countries can be divided into two distinct periods. Firstly, the Bretton Woods system, which existed from July, 1944 to March, 1973, established a target zone of ±1 per cent of either side of a central parity with respect to the US dollar. Secondly, the collapse of the Bretton Woods system since 1973 resulted in a period of floating exchange rates. Recent evidence suggests that the resulting floating exchange rate period has since been characterised by a lower volume of international trade and a higher degree of exchange rate variability compared to the Bretton Woods era (Kumar and Whitt, 1992).[1] Many of the developed economies have since attempted to reduce excessive exchange rate volatility and long term misalignments of the exchange rate through formal institutional policy agreements. For example, the member countries of the European Exchange Rate Mechanism established target zones for their respective currencies, allowing fluctuations of ±15% either side of a central parity.[2] The Louvre Accord, 1987 provided co-ordinated intervention among the G7 countries to prevent a fall in the value of the US dollar.

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1. IMF (1984) note that the volume of world trade grew at an average rate of 8.5 per cent over the period 1963-1972, compared to an average annual growth rate of 6 per cent over the remainder of the 1970s, only to remain relatively stagnant during the early 1980s.

2. From the outset the ERM established two forms of currency bands. Firstly, narrow bands of ±2.25% and secondly, wider bands with fluctuations of ±6%. Speculative pressures in July, 1993 led to the bands being widened to ±15%.

Table 2.2.1: Mean and Standard Deviation of Real Effective Exchange Rate Variability for Selected Countries

AVERAGE			
	1961-1971	**1975-1988**	**1979-1988**
Canada	0.55	1.05	1.06
United States	0.39	1.43	1.57
Japan	0.88	2.57	2.88
France	0.93	1.17	1.08
Germany	0.85	1.16	0.97
Italy	0.57	1.40	1.13
Netherlands	1.07	0.86	0.76
United Kingdom	1.07	2.03	2.17
STANDARD DEVIATION			
	1961-1971	**1975-1988**	**1979-1988**
Canada	0.32	0.24	0.24
United States	0.11	0.41	0.34
Japan	0.09	0.76	0.55
France	0.86	0.35	0.35
Germany	0.63	0.44	0.19
Italy	0.10	0.56	0.17
Netherlands	0.43	0.25	0.17
United Kingdom	1.05	0.41	0.34

Source: Kumar and Whitt (1992). Exchange rate volatility for a given year was measured by the standard deviation of the eleven monthly percentage changes in the real effective exchange rate in that year. All numbers have been scaled up by a factor of 100. The figures are based on figures from the Federal Reserve Bank of Atlanta using International Monetary Fund International Financial Statistics.

Table 2.2.1 presents evidence for the mean and standard deviation of the standard deviation measure of exchange rate variability for the G7 countries, over sub-periods of the Bretton Woods and the floating rate eras (Kumar and Whitt, 1992).[3,4] Data is also presented from 1979 to 1988, which includes both fixed and floating

3. It should be noted that between 1975 and 1978 the Netherlands and Germany participated in the European Currency Snake where member currencies could fluctuate ±2.25% around a central parity with respect to the US Dollar. France was also a member of this system from 10th July 1975 to March 15th 1976 (Shone, 1989).

4. An attempt was made to up date these figures to encompass the period 1989-1997. However, a consistent data set for all of the countries could not be found from the available sources.

exchange rate periods.[5] In this study Kumar and Whitt calculate the standard deviation of the eleven monthly changes in the real effective exchange rate for each given year in the sample. The average and standard deviation of the standard deviations were then calculated. The evidence suggests that for each of the G7 countries, except the Netherlands, following the move to floating exchange rates there was a rise in average exchange rate variability. This rise was particularly large for Japan, which experienced nearly a three fold increase. The United States, Japan and Italy also experienced an increase in the standard deviation of variability. From 1979 to 1988 the average of the standard deviations fell for France, Germany, Italy and the Netherlands, which was also accompanied by either the same or a decline in the standard deviation of variability. This result could mainly be explained by the dampening effects of the European Exchange Rate Mechanism. By contrast the floating currencies experienced increases in mean volatility, while the standard deviation of volatility fell for the US, Japan and the United Kingdom.

The extent to which the movements in trade volumes and prices (unit values) for the industrialised countries has been influenced by the move to floating exchange rates is illustrated in table 2.2.2. Data on the movements in unit values and the volume of exports and imports are presented for a number of sub-periods over the Bretton Woods and floating eras. The growth in export volumes increased from 6.8% over the period 1955-1960 to 9.6% for the period 1966-1970. By contrast during the floating era, the growth in export volumes fell to 6.5% for the period 1976-1980, falling again to 3.4%

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5. Over the period 1979-1988 the US Dollar, Canadian Dollar, Japanese Yen and UK pound all floated, whilst the French Franc, German Mark, Italian Lira, and Netherlands Guilder were members of the European Monetary System. Consequently these currencies were fixed in a target zone relative to some currencies included in the effective exchange rate index.

for the period 1981-1985. A similar problem is found for the growth in import volumes, which peaked at 10% over the period 1966-1970. During the floating era import volume growth fell from 5.9% (1976-1980) to 3.7% (1981-1985), although there was an increase to 6.9% for the period 1986-1987.

Table 2.2.2 Volume and Unit Value of Exports and Imports for the Industrialised Countries (percentage changes).

	Exports		Imports	
	Volume	Unit Value	Volume	Unit Value
1955-1960	6.8	0.7	7.7	-0.9
1961-1965	7.6	0.8	8.5	0.4
1966-1970	9.6	2.0	10.0	1.5
1971-1975	6.1	14.1	4.0	16.5
1976-1980	6.5	9.8	5.9	12.1
1981-1985	3.4	-2.9	3.7	-3.4
1986-1987	3.2	12.7	6.9	7.5

Source: International Monetary Fund (1988), International Financial Statistics - Supplement on Trade Statistics.

It is also interesting to examine what influence, if any, the move to floating exchange rates had on the pattern of trade price movements, as measured by export and import unit values. The evidence would suggest that trade prices became more volatile during the floating era. For example, for the period 1955-1960 the changes in export and import unit values were 0.7% and -0.9% respectively. The growth in export and import prices rose moderately during the period 1966-1970 to 2.0% and 1.5% respectively. However, during the floating era, the growth in export and import unit values increased to 6.5% and 9.8% for the period 1976-1980. Over the period 1971-1975 (which includes periods of fixed and floating rates) the growth in export and import unit values peaked at 14.1% and 16.5%. By 1986-1987 the growth in export and import unit values was 12.7% and 7.5% respectively.

Table 2.2.3 Volume and Unit Value of Exports and Imports for the Developing Countries (percentage changes).

	Exports		Imports	
	Volume	Unit Value	Volume	Unit Value
1955-1960	3.8	-0.9	-	-
1961-1965	7.9	0.9	4.3	0.9
1966-1970	7.4	1.2	6.2	1.5
1971-1975	3.8	26.9	10.2	16.3
1976-1980	2.4	16.4	6.8	10.7
1981-1985	-3.2	-2.8	0.9	-3.0
1986-1987	6.8	-	-	-

Source: International Monetary Fund (1988), International Financial Statistics - Supplement on Trade Statistics.

A very similar picture is found for the growth in trade for the developing countries (Table 2.2.3). The growth in export volumes peaked at 7.9% (1961-1965), compared to 2.4% for the period 1976-1980. By contrast, import volume growth rose from 4.3% (1961-1965) to a peak of 10.2% (1971-1975), falling then to 6.8% (1976-1980). Export and import unit values were also more volatile during the floating era. For example, for the period 1961-1965 the growth in export and import unit values was 0.9%, compared to 16.4% and 10.7% respectively from 1976 to 1980.

However, caution should be used when analysing both data sets to make definitive conclusions as to how much of the slow down in the growth of trade volumes can be attributed to the increased exchange rate variability resulting from the move to floating exchange rates. Economists analysing this question have relied on regression analysis to measure the sign and magnitude of the exchange rate variability effect. A survey of these studies is presented in chapter three.

2.3 Why Should Exchange Rate Variability Influence International Trade?

In attempting to demonstrate a link between exchange rate variability and international trade, economists are essentially concerned with illustrating how uncertainty regarding future exchange rate movements influences the decision making of exporters and importers. This section suggests a number of possible reasons why exchange rate variability may influence international trade. However, it should be noted from the outset that research in this field is limited to a consideration of the link between exchange rate variability and international trade *ceteris paribus*. Firms are often subject to other forms of uncertainty such as political instability; interest rate instability; uncertainty about capital or exchange controls; and trade barrier factors, which are often not considered. These forms of uncertainty are likely to be interlinked both amongst themselves and with exchange rate uncertainty and so separate effects may prove to be very problematic. Moreover, establishing a statistically significant relationship between a measure of exchange rate variability and export (import) volumes, does not in itself demonstrate that traders were operating in an uncertain environment, that they were aware of this environment, and consequently changed their trading behaviour accordingly. For example, if exchange rate movements are relatively predictable, despite being highly volatile, then the variability measure may overstate any relationship with international trade because the measure of variability captures anticipated plus unanticipated movements.

2.3.1 Uncertainty regarding the effects on trade prices in domestic currency terms.

Table 2.3.1 presents evidence by Tavlas (1997) on the currency denomination of export and import contracts for a selection of countries. The data suggests that for a number of countries a significant proportion of their trade contracts are denominated in foreign currency. For example, the dollar invoicing of imports, over the period 1992-1996, varied from 18.1% (Germany) to 28.0% (Italy), up to 70.4% (Japan). The percentage of imports denominated in home currency, for all the countries except the USA, varied from 22.5% (Japan) to 53.3% (Germany), while the percentage of exports denominated in home currency varied from 35.7% (Japan) to 76.4% (Germany). The US dollar maintains a strong position as a currency frequently used for invoicing trade contracts. Thus US trade is less directly affected by fluctuations in the price of foreign currency. 98% of US export contracts and 88.8% of US import contracts are denominated in US dollars.

It is interesting to compare the results presented by Tavlas (1997) with an earlier study by Page (1981). The results by Tavlas suggest that there has been a move by importers and exporters to increasingly denominate their contracts in domestic currency. This occurrence may have arisen from the increased exchange rate variability resulting from the move to floating exchange rates, as discussed in section 2.2. Page (1981) shows that the percentage of export contracts denominated in home currency, for all countries except the USA, varied from 29.4% (Japan) to 82.3% (Germany), while the percentage of import contracts varied from 2.4% (Japan) to 42.8% (Germany).

Table 2.3.1 Currency Denomination of Exports and Imports for Selected Countries, 1992-1996 (Percentage Terms)

EXPORTS

	US Dollar	Deutsche Mark	Japanese Yen	Pound Sterling	French Franc	Italian Lira	Other
United States	98.0 (97.0)	0.4 (1.0)	0.4 (-)	0.3 (1.0)	- (1.0)	-	9.0 (-)
Germany	9.8 (7.2)	76.4 (82.3)	0.6 (-)	2.4 (1.4)	2.8 (2.8)	- (1.3)	8.0 (4.8)
Japan	52.7 (65.7)	- (1.9)	35.7 (29.4)	- (1.1)	- (0.6)	- (0.1)	1.6 (1.2)
United Kingdom	22.0 (17.0)	5.0 (3.0)	0.7 (0.1)	62.0 (76.0)	3.5 (2.0)	1.7 (0.5)	5.1 (2.4)
France	18.6 (13.2)	10.6 (9.4)	1.0 (-)	4.2 (3.2)	51.7 (62.5)	3.1 (-)	10.8 (11.7)
Italy	23.0 (30.0)	18.0 (14.0)	-	-	7.0 (8.0)	40.0 (36.0)	3.0 (12.0)

IMPORTS

	US Dollar	Deutsche Mark	Japanese Yen	Pound Sterling	French Franc	Italian Lira	Other
United States	88.8 (85.0)	3.2 (4.1)	3.1 (1.0)	- (1.5)	- (1.0)	- (1.0)	4.9 (6.9)
Germany	18.1 (13.1)	53.3 (42.8)	1.5 (1.5)	1.9 (3.1)	4.4 (3.3)	- (2.4)	20.8 (13.8)
Japan	70.4 (93.1)	2.8 (1.4)	22.5 (2.4)	- (0.9)	- (0.9)	- (0.2)	4.3 (1.1)
United Kingdom	22.0 (29.0)	11.9 (9.0)	2.4 (1.3)	51.7 (38.0)	5.3 (5.0)	2.2 (1.7)	4.5 (16.0)
France	23.1 (33.1)	10.1 (12.8)	1.0 (0.1)	2.9 (3.8)	48.4 (34.1)	3.7 (3.0)	10.8 (13.1)
Italy	28.0 (45.0)	13.0 (14.0)	- (0.5)	- (3.2)	8.0 (9.0)	37.0 (18.0)	14.0 (10.4)

Source: Tavlas (1997). The figures in parentheses are those presented by Page (1981).

Given the above evidence it would seem that fluctuations in the price of foreign currency may create uncertainty regarding the prices exporters will receive or importers will have to pay at some date in the future, on at least a proportion of the trade contracts which are denominated in foreign currency and are not covered through hedging techniques. Most international trade contracts incorporate a payment lag from the contract date to allow time for delivery or to provide trade credit. Fluctuations in short term exchange rates can influence the profits of exporters and importers by making the future revenue from international trade uncertain. For example, an importer may have to pay a trade contract in foreign currency at some date in the future. If the price of foreign currency increases, this raises the cost of imported goods, which could influence the profitability of importing if the higher costs cannot be passed onto the final consumer. The reduction in profitability is likely to lower the demand for imports.[6] If export contracts are denominated in foreign currency, then exporters may also face uncertainty about the price they will receive in domestic currency terms for their goods or services at the end of the contract period, if there are large unanticipated, adverse movements in the exchange rate.

The extent of the uncertainty effect on trade will generally depend upon the size and predictability of exchange rate fluctuations; how averse exporters (importers) are to the effects of exchange rate uncertainty (i.e. the degree of risk aversion); the degree of market power (and thus to what extent the variability costs can be passed onto the final consumer); the presence of substitute goods and markets with more stable exchange rates; and finally the price elasticity of demand and supply for exports (imports).

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6. Risk aversion is also assumed for this result to occur, so that importers would prefer to operate under a certain environment rather than expose their profits to exchange rate fluctuations.

Companies involved in international trade can insure against the adverse consequences of exchange rate variability through a number of internal and external hedging techniques. The most common form of external mechanism is the use of forward markets. This allows exporters and importers to buy or sell foreign currency at the contract date for delivery at some point in the future. Companies may also use leads and lags, whereby the timing of payments and collections are adjusted in anticipation of favourable currency movements. The use of this technique is dependent upon a number of factors including market expectations; the invoicing currency position (i.e. whether the contract is invoiced in the exporter's or importer's currency); and the degree of stability of the invoicing currency. Internal hedging techniques are generally used by multinational firms and generally involve a subsidiary company being used to cover the foreign exchange risk exposure. For example, a parent company may use the funds of a foreign subsidiary, so that it can pay for a contract in the subsidiary's currency. Parent companies may also provide a loan of their domestic currency to a foreign subsidiary to pay contracts, which could be repaid in the foreign subsidiary's currency. Such a technique is known as a swap loan.

At the macroeconomic level, the creation of a monetary union either by a system of quasi-fixed exchange rates or a single currency is one mechanism by which exchange rate uncertainty can be eliminated. This instrument can promote price transparency, thus assisting trade and competition between the member countries. However, this solution only eliminates internal fluctuations in exchange rates. Exchange rate uncertainty with respect to currencies in the rest of the world still remains, and this can still deter external trade, although it would assist trade diversion to member countries. A common currency also only eliminates nominal exchange rate uncertainty. Real exchange rate uncertainty may still exist if fluctuations in relative prices are relatively large.

2.3.2 The Cost of Forward Cover

Although the difficulties in anticipating future movements in export or import prices in domestic currency terms can be overcome by hedging forward, there are many reasons why exporters or importers may decide not to use forward markets or why forward cover may be incomplete. Firstly, exporters or importers may be risk loving or have a sufficiently low degree of risk aversion that they choose not to cover forward. Secondly, forward markets can only provide complete cover if the foreign currency denominated sales receipts or expenditures are known with certainty. If the foreign currency price is allowed to vary over the contract period forward markets may only provide limited cover.

In developing countries particularly, forward markets are less well established, so that hedging is very difficult or impossible. The thinness of the forward markets in these countries could mean that the forward premium will be relatively high.[7] Forward markets also have maturities which are very rigid and may be limited to a maximum of one year in length. Thus forward protection may only be available partially on long term trade contracts.

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7. In attempting to reduce their exposure to foreign exchange risk, many developing countries have tied the value of their currency to a developed country, which is a major trading partner. For example, Assane and Konan (1994) note that the member countries of the West African Monetary Union have tied the value of their currency to the French Franc. However, while this eliminates exchange rate uncertainty from trade with France and other trading partners invoicing in this currency, these countries are still exposed to exchange rate uncertainty indirectly through fluctuations in the franc compared to other currencies.

In order to bear the risk associated with uncertain movements in the spot exchange rate, those selling forward foreign currency generally demand a risk premium, which inserts a wedge between the current forward exchange rate and the expected future spot rate. Higher forward risk premiums contribute to the transaction costs of using these markets.[8,9] Empirical evidence also suggests that the transaction costs of using forward markets are an increasing function of the degree of foreign exchange risk.[10] Moreover, the longer the maturity length the greater is the forward risk premium. This means that the cost of forward cover typically increases the longer the period of forward cover required. Longer forward contracts also tend to be less reliable in predicting future spot rates. To use the forward market also often requires a minimum deposit balance. The cost of forward cover may also be prohibitively expensive if it accounts for a significant proportion of the profit margin on the trade contract.[11]

2.3.3 The Nature of Competition and Industrial Concentration

The recent literature has also suggested a number of reasons as to why exchange rate uncertainty has a greater influence on the trading performance of smaller firms. Firstly, larger firms tend to have more market power and thus are more able to pass any hedging costs onto the final consumer. Larger firms also tend to have more facilities in

8. The transaction costs are defined as the bid-offer spread.

9. However, in examining the overall impact on international trade, it should be noted that while the cost of forward cover are positive for some traders, on the opposite side, other traders also benefit from a forward discount.

10. Mckinnon (1974) shows that the transaction costs for forward cover can increase by 5 per cent to 10 per cent in periods of excessive currency turbulence.

11. Gosling (1987) also notes that a National Economic Development Office (NEDO) survey indicated that many firms regarded the costs of forward cover as prohibitive.

terms of financial departments and financial reserves, through which they can reducreduce their foreign exchange exposure. These hedging costs also essentially fixed, in terms of management time involved, which makes them more difficult to absorb for smaller firms.

Secondly, larger firms typically have a wider selection of products and markets by which they can diversify their currency exposure. Each market and product is likely to have a different elasticity of demand and so the exchange rate variability effect is likely to vary across markets and products. Furthermore, if raw materials are imported the greater degree of market power to re-negotiate contracts with suppliers, enables larger firms to absorb uncertainty costs into the negotiated prices, or to switch to suppliers in markets with more stable exchange rates.

Thirdly, larger firms may also be multinational corporations which can use their foreign subsidiaries to pay trade contracts without the need to be exposed to exchange rate fluctuations.

Each of these factors could mean that smaller firms are deterred from either entering foreign markets or cause them to leave them foreign markets and switch to domestic economic activities. This could lead to a rise in industrial concentration. Companies may also tend to specialise in products or services for which they have sufficiently large profit margins, so as to cover the costs of hedging.

Maskus (1986) also notes that an industry's exposure to exchange rate uncertainty is likely to depend upon the degree of foreign exchange exposure. Thus the proportion of total sales revenues and costs subject to exchange rate fluctuations will influence the profitability of international trade. Furthermore, if concentrated industries are highly profitable, they may be more able to absorb the costs of forward cover without reducing the volume of trade. If firms have a high degree of market power their exposure to foreign exchange risk may also be relatively low, if they are able to denominate contracts in domestic currency. Risk exposure is also dependent upon the quantity of foreign inputs used in the production of exports. For example, if a UK producer receives payments in French Francs, but also purchases factor inputs from France invoiced in sterling, then adverse movements in the price of French Francs could be counterbalanced by advantageous movements in UK pounds.

2.3.4 Protectionism

Early proponents of floating exchange rates (Friedman, 1953; Sohmen, 1961) suggested that they would act as a stabilising force by which trade imbalances would be eliminated. As a consequence there would be less need for governments to adopt protectionist policies, in order to protect their economies from import penetration, following a misalignment of the domestic currency. Consequently, instantaneous adjustment of the exchange rate would promote more free trade compared to the Bretton Woods era.

However, if short term adverse movements in exchange rates persist over time, so that the domestic currency becomes overvalued, this may have a detrimental effect on the volume of exports and lead to an inflow of cheaper imported goods (in domestic currency terms). Conversely, an undervaluation of the foreign currency will create a boom in the export sectors. Consequently, the overall impact on trade will depend upon the relative magnitude of the two effects. Furthermore, persistent exchange rate variability may generate a tendency for governments to resort to protectionist policies, in order to protect domestic producers from import penetration or to assist exporters entering foreign markets.

Protectionist policies may take the form of direct quantitative restrictions such as tariffs or quotas, subsidies or other forms of assistance for exporters (e.g. infant - industry assistance). Alternatively, governments may undertake competitive devaluations of their own currency. Indirectly they may simply slow down the pace of free trade reforms through signing less free trade treaties and agreements. Such policies have been termed *'The Political Economy of Exchange Rate Variability'* (De Grauwe, 1988), which result in markets becoming more protected, so that opportunities for international trade to take place are reduced.

Bergsten and Williamson (1983) also suggest that an overvaluation of the domestic currency[12] encourages governments to adopt protectionist policies in order to prevent any reduction in manufacturing capacity and employment, arising from an influx of imports from countries with an undervalued currency. Furthermore, governments have less of a tendency to remove these trade barriers when the domestic currency is undervalued. These asymmetries in protectionism lead to a 'trend-like' increase in protectionism and will negatively affect international trade (De Grauwe, 1988).

The magnitude of the 'Political Economy' effect has been empirically analysed by De Grauwe (1988). De Grauwe shows that the size of the misalignment effect on international trade volumes is relatively small for a study of intra-EMS and extra-EMS trade. Despite the European Exchange Rate Mechanism being successful in reducing

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12. Overvaluation is defined in terms of a misalignment of the currency relative to the economic fundamentals (this is usually defined as the purchasing power parity exchange rate).

exchange rate misalignments, De Grauwe found the EMS countries experienced significant reductions in the average yearly growth of intra-EMS and extra-EMS trade volumes over the period 1979-1992 compared to the floating era. Specifically, the average yearly growth of intra-EMS trade fell from 6.7% over the period 1973-1978 to 2%, 1979 to 1992. Extra-EMS trade (excluding US trade) fell from 7.8% over the same floating period to 2%, 1979-1992. Despite the introduction of more stable exchange rates having a positive influence on international trade, it was counterbalanced by the negative effect of restrictive fiscal policies followed by the main EMS countries and the supply-side problems experienced by many countries. Consequently, stable exchange rates are not a sufficient condition to improve the volume of international trade.

2.3.5 Can exchange rate variability have a positive influence on international trade?

The theoretical literature (for example Ethier, 1973; Clark, 1973; Hooper and Kohlhagen, 1978) suggests that under the assumption of risk aversion, exchange rate uncertainty will exert a negative influence on international trade. De Grauwe (1988), however, shows that the theoretical effects of increased exchange rate uncertainty are unclear, in that the sign of the uncertainty effect depends upon the degree of risk aversion rather than agents being risk averse *per se*. De Grauwe considers a model of a representative exporter who faces the choice between supplying goods to domestic and foreign markets. The only source of risk faced by the exporter is assumed to be the price received from export sales due to fluctuations in the exchange rate. Thus all export contracts are assumed to be denominated in foreign currency. Thus the export price, $\tilde{p}_f$

is a random variable since $\tilde{p}_f = p^* \tilde{e}$, where p^* is the price of output in foreign currency and $\tilde{e}$ is the exchange rate, which is a random variable. De Grauwe then uses expected utility analysis to derive the conditions by which unanticipated fluctuations in the exchange rate can have either a positive or negative influence on export volumes. The optimal condition is given as follows:

$$EU'_f \tilde{e} = \frac{U'_d \, p_d \, q'(x-x_f)}{p^* \, q'(x_f)} \qquad ..2.3.5.1$$

where U'_f is the marginal utility from export revenue; U'_d is the marginal utility from domestic sales revenue[13]; p_d is the price of output from domestic sales; $q'(x-x_f)$ is the marginal product of labour for the output produced for the domestic market and $q'(x_f)$ is the marginal product of labour for exported output. The production functions for the domestic and export markets are $q_d = q(x-x_f)$ and $q_f = q(x_f)$ respectively, where $x_d=x-x_f$ and x_f are the units of labour input, where $x = x_d + x_f$.

De Grauwe uses this condition to show why an increase in exchange rate uncertainty may have a positive or negative influence on export volumes. This result is derived by examining the 'mean-preserving' spread in $\tilde{e}$ on $EU'_f \tilde{e}$. If this rise in exchange rate uncertainty raises $EU'_f \tilde{e}$, then the right side of 2.3.5.1 will have to increase also, which can only arise from an increase in export sales i.e. an increase in x_f. By contrast, if $EU'_f \tilde{e}$ falls, then export sales will decline.

13. It is assumed that U'_f and U'_d are independent of each other. It may be the case, however, that the utility obtained from exporting is dependent upon the utility obtained from domestic sales.

De Grauwe shows that this result depends upon the convexity or concavity of the marginal utility function. This result can be found by differentiating 2.3.5.1 twice with respect to e:

$$\frac{\partial^2 U_f' \tilde{e}}{\partial e^2} = \underline{1}\ [R\,(1\text{-}R) + R'\ \tilde{Y}_f] \qquad ..2.3.5.2$$

where R is the coefficient of relative risk aversion i.e. $R = U_f'' \ Y_f / U_f'$ and $\tilde{Y}_f = p^* \tilde{e}\, q$.

Thus if producers are sufficiently risk averse then $U_f' \tilde{e}$ will be convex, which it can be shown infers R>1, so that exporters will export more. By contrast, if exporters have a small degree of risk aversion, then R<1, inferring $U_f' \tilde{e}$ will be concave, so that exports fall.

These results are shown in figures 2.1.1 and 2.1.2. In figure 2.1.1 since the marginal utility function is convex, then an increase in the 'mean preserving' spread of $\tilde{e}$, from $\tilde{e}_1$-$\tilde{e}_2$ to $\tilde{e}_3$-$\tilde{e}_4$, this will lead to a rise in expected marginal utility from $EU_f' \tilde{e}_1$ to $EU_f' \tilde{e}_2$. The economic intuition behind this result is that a very risk averse exporter, would have a negative substitution effect resulting from higher exchange rate variability outweighed by a positive income effect. The very risk averse exporter worries about the worst possible outcome and exports more so as to allow for the lost possible revenue resulting from higher exchange rate variability.

Alternatively, a less risk averse exporter will export less following higher exchange rate variability. In this instance the expected marginal utility of export revenue will fall, which consequently reduces the quantity of trade volumes. Thus the marginal expected utility function is concave. In figure 2.1.2 a similar increase in the mean-preserving spread leads to a reduction in the expected marginal utility. Intuitively, given the exporter is less concerned with the worst possible outcome, the expected marginal utility falls (i.e. the exporter is less concerned with the loss of revenue from a fall in trade). Here the negative substitution effect from higher exchange rate variability outweighs the positive income effect, so that the quantity of trade falls.

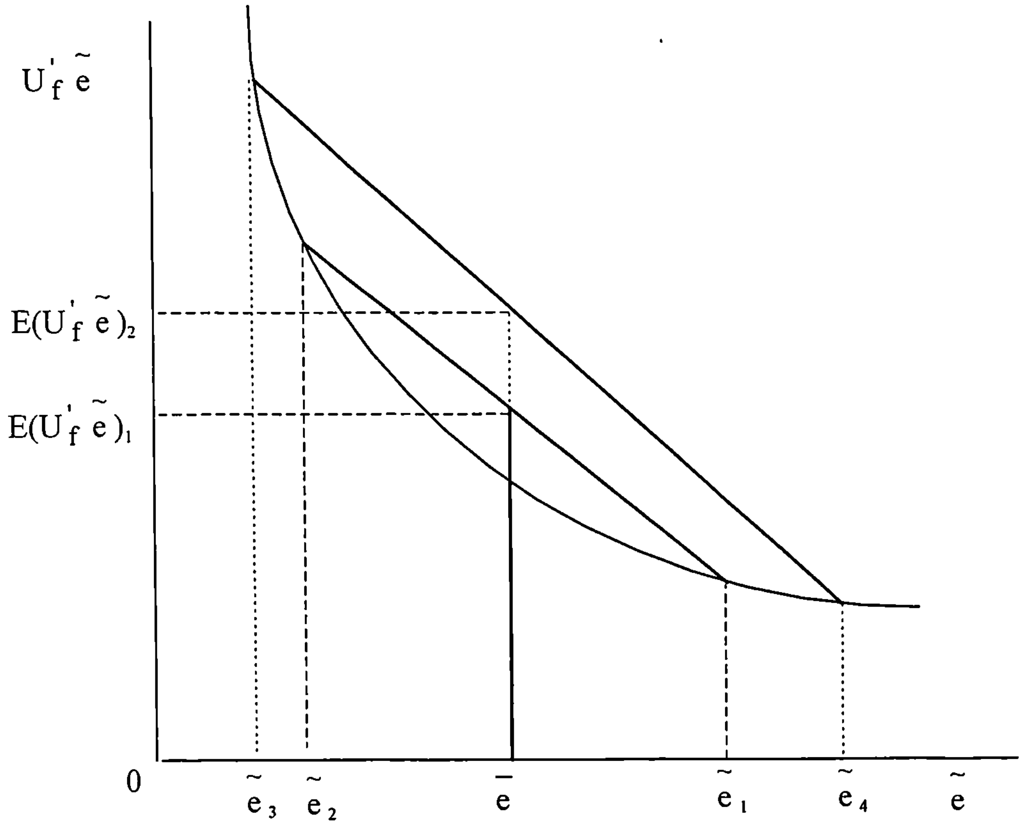

Figure 2.1.1: A Strictly Convex Marginal Utility Function: The Case of a Very Risk Averse Exporter.

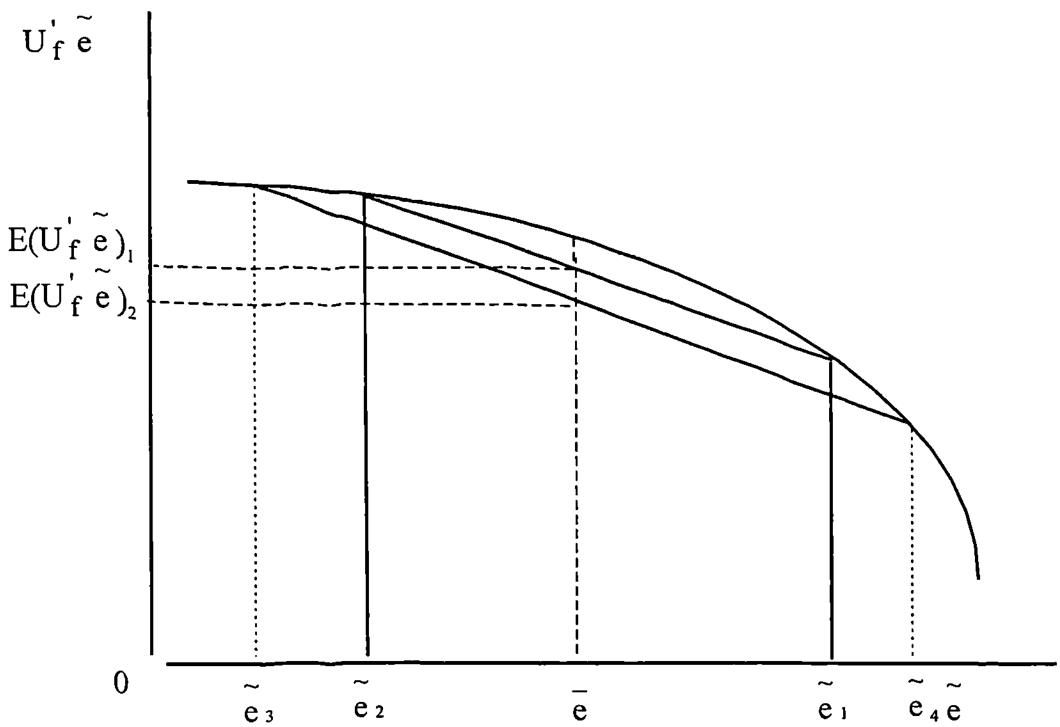

Figure 2.1.2: A Strictly Concave Marginal Utility Function: The Case of a Less Risk Averse Exporter.

2.3.6 The Long Term Effects of Exchange Rate Variability

Exchange rate uncertainty may also influence long term trade patterns. Firstly, persistent exchange rate variability may influence the location decisions of firms. IMF (1984) suggest that the costs of exchange rate variability could be sufficiently high to encourage multinational firms to locate in a number of different locations, as a means of diversifying their exposure to foreign exchange risk. Companies may also be concerned with currencies which are misaligned, which could influence the long term competitiveness of exports.

Exchange rate uncertainty may deter long term investment patterns through dampening business confidence and hence hindering long term planning. Cushman (1988c) also presents evidence of a statistically significant link between exchange rate variability and foreign direct investment flows from the US to UK, France, Germany, Canada and Japan for the sample period 1963-1972. A positive relationship is found which indicates that US firms who experience a reduction in their exporting capacity following an appreciation of the US Dollar, have a tendency in the long term to locate overseas in these markets, to recoup some of the lossed revenues, through a stream of profits from overseas subsidiaries. Cushman (1988) also considers the effects of exchange rate variability on direct investment flows into the US from UK, France, Germany, Canada and Japan from 1963 to 1986. The results suggest a 25.3% rise in foreign direct investment can be attributed to the influence of exchange rate variability over the sample period.

2.4 Conclusions

The purpose of this chapter was to place into context the debate concerning the influence of exchange rate variability on international trade and to suggest possible reasons for exchange rate uncertainty being a potential hindrance to trade.

From the evidence presented it is apparent that the move to floating exchange rates in 1973 was characterised by a higher degree of exchange rate volatility for most of the major trading nations. Furthermore, over the floating period these economies have experienced a significant reduction in the growth of trade volumes and increased fluctuations in trade prices (unit values).

Economic theory, as well as recent observation of the international trading system have suggested that in the short term, contract lags and the absence of suitable hedging techniques can create uncertainty over the prices exporters and importers will receive or pay, in domestic currency terms, at some date in the future. However, De Grauwe (1988) has shown that the direction of the exchange rate variability effect on exporters, depends on the degree of risk aversion and thus the concavity or convexity of the exporter's marginal utility function. In the long term, persistent exchange rate volatility makes it more difficult for smaller firms to cover their transactions and may create a tendency for increased protectionism. Short term exchange rate uncertainty also hinders long term planning by firms, thus deterring the incentive for investment in the plant and equipment used in the production of exports or the finished goods produced using imported raw materials.

However, the discussion so far provides no evidence as to the direction and strength of the exchange rate variability effect. To acquire this information a model explaining the behaviour of importers and exporters operating under conditions of exchange rate uncertainty must be formulated, which can then be subject to empirical testing. How the recent literature has conducted this research will be the focus of the next chapter.

Chapter Three

Exchange Rate Variability and International Trade II:

A Survey of the Empirical Literature

Abstract

This chapter surveys the recent literature examining the influence of exchange rate variability on international trade. A theoretical framework is introduced which can be used for empirical estimation. Empirical research is then critically evaluated with a view to highlighting common themes and methodologies in the literature.

3.1 Introduction

Since the advent of floating exchange rates in 1973 economists have attempted to estimate the impact of exchange rate variability on international trade flows. The purpose of this chapter is to survey the recent empirical literature on the effect of exchange rate variability on international trade. The theoretical foundations for much of the empirical work have been derived from the mean-variance framework (Tobin, 1958; Markowitz, 1959) which can be used to characterise the behaviour of exporters and importers operating under conditions of exchange rate uncertainty (see for example Ethier, 1973; Clark, 1974).

A seminal contribution to the empirical literature was provided by Hooper and Kohlhagen (1978). These authors were the first to derive a theoretical model which could be subject to empirical testing. The theoretical model considers the case of profit maximising exporters and importers, who set profits so as to maximise utility, which is an increasing function of expected profits and a decreasing function of the standard deviation of profits. The optimal conditions for import demand and export supply are then derived, from which the price and volume equations can be obtained. The model for representative exporters and importers are then aggregated to derive the price and volume equations for trade flows between economies. The price and volume equations are specified in a reduced form and include each of the determinants of import demand and export supply.[14]

Hooper and Kohlhagen estimate the impact of a measure of nominal exchange rate uncertainty[15] on bi-lateral and multilateral trade flows for the USA and West Germany with France, Japan, UK and Canada for the period 1965 Q1 to 1975 Q4. The empirical research suggests that the variability measure had a significant positive influence on trade volumes in 1 case out of 16, while for trade prices a significant positive influence was found for 2 cases and a significant negative effect in 6 cases. Cushman (1983) has utilized the Hooper and Kohlhagen framework to measure the impact of real exchange rate variability on the same trade flows used by Hooper and Kohlhagen. 6 cases showed evidence of a negative relationship between real exchange rate variability and trade volumes; while two cases found a significant positive exchange rate variability effect for trade prices. This example illustrates how sensitive the empirical results can be to the chosen measure of exchange rate variability.

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14. The reduced form specification used by Hooper and Kohlhagen (1978) is somewhat different to the more recent empirical literature (for example Akhtar and Hilton, 1984; Gotur, 1985; Holly, 1995), which has tended to specify a structural system, where the determinants of export (import) demand are estimated separately from the determinants of export (import) supply.

15. The uncertainty measure used is the average over a given quarter of the thirteen weekly absolute deviations between the current spot rate and the lagged forward rate.

Since the Hooper and Kohlhagen study a large amount of research has been produced to measure the influence of exchange rate variability on a wide variety of trade flows. IMF (1984) concluded from a survey of 9 papers that there was no significant relationship between exchange rate variability and international trade. Unfortunately, further research has provided no unambiguous conclusions as to the sign and magnitude of the exchange rate variability effect.

The summary of empirical literature presented in appendix A, surveys 59 studies published since 1976. Overall, 33 studies present evidence of a statistically significant negative 'variability' effect, while 26 studies suggest no significant relationship between exchange rate variability and trade. However, the balance of opinion has changed over time and can be separated into three distinct segments. Up to the study by Cushman (1986) the majority of studies found no statistically significant 'variability' effect. Between the Cushman study and the work of Bahmani-Oskooee and Ltaifa (1992) opinion was balanced with roughly as many studies finding an influence from exchange rate variability as those finding no effect. Since 1992, published work has overall tended to find evidence of a statistically significant negative relationship between exchange rate variability and international trade. The balance of opinion has changed over time mainly as a result of the different estimation techniques and proxies of exchange rate variability used. Unfortunately, the empirical literature provides no guidance as to what proxy should idcally be used to measure exchange rate variability.

Section 3.2 outlines the mean - variance framework, which is followed by an analysis of the Hooper and Kohlhagen model. Section 3.3 provides a comprehensive overview of the empirical literature. The survey classifies the major studies in the field so that the results from similar approaches can be compared.

3.2 A Theoretical Framework: Mean - Variance Analysis

The mean - variance analysis (Tobin, 1958 and Markowitz, 1959) is the theoretical framework that has generally been adopted to analyse the effects of exchange rate uncertainty on international trade. This framework assumes that individuals are only concerned with two quantities: expected profit and risk. Thus the objective of an exporter or importer would be to maximise utility $U(\pi)$, which is a function of expected profits (μ_π) and the standard deviation (or variance) of the profits (σ_π):

$$U(\pi) = \mu_\pi + \gamma/2\,(\sigma^2_\pi)^{1/2} \qquad ..3.2.1$$

The mean of a normal distribution of profits[16] is used to reflect the firm's expected profits and the standard deviation or variance is used to characterise the uncertainty. The utility function is assumed to be of a quadratic form, with respect to π.[17] γ is a constant coefficient of risk aversion, which characterises the firm's risk preferences. Typically it is assumed that the firm is risk averse, which means that $\gamma<0$, so that certain profits are preferred to those which are subject to exchange rate uncertainty.[18]

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16. The normality assumption is problematic since recent evidence suggests that the distributions of exchange rates tend to be non-normal, in particular are leptokurtic (has 'fat tails'). If the distribution is not normal, information concerning the degree of skewness and kurtosis in the distribution would have to be included in the estimation of expected profits. The standard deviation can act as an erratic and misleading measure if the exchange rate distribution is leptokurtic, since it gives more weight to the extreme observations (see McFarland, Petit and Sung, 1982; Rana, 1981 and Westerfield, 1977). It should also be noted that the functional form of the quadratic utility function can be very restrictive. Further analysis of these problems will be provided in chapter three.

17. The quadratic function has two major drawbacks. Firstly, the function infers that utility will decrease as profit increase beyond $\gamma/2$ and secondly *'the individual will be more risk averse to constant additive risks about high wealth [profit] levels than about low wealth levels - in contrast to the observation that those with greater wealth take greater risks (see for example Hicks (1962) or Pratt (1964))'*, (Machina, 1987, p. 205).

18. If $\gamma>0$ then the firm is risk loving, while if $\gamma=0$ the firm is risk neutral. The concepts of risk and risk aversion will be considered more closely in chapter three.

Ethier (1973) adopts the mean - variance model to consider the effect of exchange rate uncertainty on international trade, from the viewpoint that importers' attitude to exchange rate uncertainty influences the level of forward cover rather than the level of international trade directly. The model describes the case of a perfectly competitive firm who imports a given quantity of goods at an agreed foreign currency price for delivery n periods in the future. The importer is assumed to cover only a fraction of the transactions on the forward market and exposes the remainder to fluctuations on the spot exchange market.[19] The firm is assumed to be risk averse and gains more utility from higher expected profits but less utility from a higher standard deviation of the profits. It is assumed that perfect forward cover is available i.e. forward cover is available for every possible length of import contract. Thus the importer either covers forward completely or partly exposes their profits to movements in the future spot rate, according to risk preferences. This model investigates the relationship between expected profits and the standard deviation of the profits. As the firm exposes itself to higher exchange rate uncertainty expected profits will increase. The firm can hedge against this risk, but the higher costs of forward cover reduce the profitability of international trade. Thus the objective of the firm is to find the optimal combination of expected profits and standard deviation of profits that maximise their expected utility and determine the optimal amount of forward cover.

However, many firms may not have the knowledge or resources to allocate their foreign exchange funds to derive an optimal amount of forward cover. Moreover, it is

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19. A limitation of the model proposed by Ethier is that the proportions of the import contract covered and exposed are assumed to be constant, when in reality we would expect them to be control variables which the firm can change according to their exposure to risk.

not often realistic to assume that an importer will expose some of their transactions to exchange rate fluctuations and cover the remainder on the forward market. There may also only be a limited amount of forward cover available for longer import contracts e.g. greater than one year in length.

Some of these issues have been addressed by Clark (1973) who examines the effect of exchange rate uncertainty on the demand for exports produced by a perfectly competitive firm. The significant contribution made in this paper is that it demonstrates that even if a firm can hedge perfectly on the forward exchange market, it will still be exposed to uncertainty regarding movements in the forward exchange rate. This occurs, firstly, because the forward exchange market may not be sophisticated enough to ensure complete cover, when the length of the exporter's contract period is greater than the maximum forward contract available. Secondly, the firm may be uncertain as to the amount of forward cover needed until the end of the contract period, if the foreign price is a random variable. It is assumed that the exporter knows the mean and variance of the export earnings, but only knows how much forward cover is needed a fixed period before payment is due. Thus a fraction of the foreign earnings are hedged in anticipation of the amount of forward cover required and another fraction is covered when the required amount of forward currency becomes known with certainty, towards the end of the contract period. The exporter is thus exposed to foreign exchange risk because of uncertainty about future movements in the forward exchange rate, since complete hedging is not available.

More recently Gagnon (1993) has extended the traditional expected utility framework by using dynamic optimisation to analyse the response of a representative exporting firm who faces exchange rate variability between the contract and settlement dates. Again the exporter is assumed to maximise expected utility, but adjustment costs and rational expectations are incorporated into the decision making process. From simulations using data for the pre and post Bretton Woods periods Gagnon concludes that the effect of exchange rate variability on trade is small and insignificant, for a variety of model specifications. He concludes that the increased exchange rate variability resulting from the collapse of the Bretton Woods system resulted in a 3.1% reduction in trade volumes.

3.3 The Hooper and Kohlhagen Model

Hooper and Kohlhagen derive a theoretical model to examine the influence of exchange rate uncertainty on trade flows for the USA and West Germany with its major trading partners. The model incorporates both the import demand and export supply of trade flows simultaneously. Each of the determinants of import demand and export supply are included in a reduced form model of trade volumes and prices, which is then subject to empirical testing. This paper represents an advance over earlier work, for example by Clark (1973) and Ethier (1973), which consider only export supply or import demand separately. Moreover, previous studies had only consider the influence of exchange rate uncertainty on trade volumes, ignoring the effect on trade prices. This model allows the currency denomination of trade contracts to be an additional factor in determining the response of exporters and importers to exchange rate uncertainty.

3.3.1 Import Demand

Hooper and Kohlhagen (1978) assume that the demand for imports is a derived demand from the demand for the importer's final output (Q), which is a function of its own price (P), the price of other goods (PD), nominal income in the domestic economy (Y) and non-price rationing (CU)[20] of its output:

$$Q = a\,P + b\,PD + c\,Y + d\,CU \qquad ..3.3.1$$
$$\text{-ve} \quad \text{+ve} \quad \text{+ve} \quad \text{-ve}$$

The demand for final output is also assumed to be equal to the quantity supplied, so that there is no stock-building of goods following fluctuations in demand. The importer's objective is to maximise utility, which is a function of the expected profits ($E(\pi)$) and the standard deviation of profits $(\sigma^2_\pi)^{1/2}$:

$$U(\pi) = E(\pi) - \gamma\,(\sigma^2_\pi)^{1/2} \qquad ..3.3.2^{21}$$

where γ is a positive constant coefficient of relative risk aversion. The profit function of the importer is given as follows:

$$\pi = P \cdot Q - UC \cdot Q - HP^{*}iQ \qquad ..3.3.3$$

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20. Capacity utilization is treated as a demand variable since as demand increases in the domestic economy and therefore capacity utilization increases, *'available supply is rationed through such techniques as longer order-delivery lags and tighter customer credit conditions, thereby depressing quantity demanded.'*, (Hooper and Kohlhagen, 1978, p. 486). However, we may expect that capacity utilization influences the supply of the importer's final output and thus could be included in the importer's final output supply schedule.

21. Hooper and Kohlhagen (1978) note that *'This* [quadratic] *utility function has indifference curves that are linear in mean and standard deviation space which implies that there is not sufficient risk aversion for an interior solution to a simple portfolio problem. This drawback is not relevant in our case since the firm is not faced with the problem of allocating its wealth over a set of risky and riskless assets.'*, (Hooper and Kohlhagen, 1978, p. 487). However, as noted in section 3.2, the analysis of decision making under risk using mean-variance analysis is dependent upon the assumptions that either the distribution of profits is normal (Tobin, 1958; Markowitz, 1959) or a quadratic utility function. The quadratic utility function also has the problem of reduced risk taking as profit increases (Hicks, 1962).

where P·Q is the total revenue from the sale of the firm's output in the domestic economy; UC is the unit costs of production (defined as labour and domestic raw material costs per unit of production)[22]; P^* is the foreign currency price of the imports used in the production of Q[23]; *i*Q is the total imports used in the production process (where *i* is the fixed proportion required to produce Q) and H is the cost of foreign exchange.[24] A fraction of the imports are exposed to exchange rate fluctuations, while the remainder are covered on the forward exchange market:

$$H = \beta(\alpha F + (1-\alpha)S_1) + (1-\beta)F \qquad 0\leq\alpha\leq1;\ 0\leq\beta\leq1 \qquad \textbf{..3.3.4}$$

β is the fraction of imports denominated in the exporter's currency and $(1-\beta)$ is the fraction denominated in the importer's currency. α is the fraction of import costs which are hedged against risk using the forward exchange market[25] (F is the current forward

22. Hooper and Kohlhagen make no reference to the relationship between UC and the level of production, Q. We therefore assume that UC remains constant for all Q i.e. there are constant returns to scale.

23. The importer is a price taker and consequently takes the price of imports, P^* as given. The importer also knows the foreign foreign currency price with certainty. Uncertainty regarding the domestic currency price only arises from fluctuations in the exchange rate.

24. One weakness of the profit function specification is that the importer is assumed to sell output to the domestic market only. This assumption is made for simplicity since incorporating export revenues would add an additional element of exchange rate uncertainty from fluctuations in the price of foreign currency, if the export contract is denominated in the currency of the importing country. While exchange rate uncertainty exposure would increase, movements in the level of the exchange rate could benefit importers if they sell part of their output overseas. For example, a rise in the price of foreign currency will increase the cost of import contracts denominated in the exporter's currency. This rise, however, would coincide with a fall in the price of domestic currency making the importer's overseas output more competitive.

25. As mentioned earlier the assumption that β and α are constants is problematic given that importers are likely to change the proportion of forward cover to factors such as foreign exchange risk exposure, cost of forward cover, political instability etc.

exchange rate for delivery one period in the future), while the fraction (1-α) relates to the import costs which are subject to fluctuations in the future spot exchange rate, S_1. Using 3.3.3 and 3.3.4 the variance of the importer's profits are shown to be a function of the degree of future spot rate variability:

$$\sigma_{\pi}^{2} = [P^{*}iQ\ \beta(1-\alpha)]^{2}\ \sigma_{s1}^{2} \qquad ..3.3.5$$

where σ_{s1}^{2} is variance of the future spot rate[26]. To derive the demand for imports, q (where q=iQ) the first order conditions of the utility function are derived. Substituting for $\partial P/\partial Q$ from 3.3.1, and using π and σ_{π}^{2} from 3.3.3 and 3.3.5, assuming price taking behaviour, and differentiating 3.3.2 twice with respect to Q gives:

$$[Q/a + P - UC - P^{*}i\ (EH + \gamma\delta\sigma_{s1})] = 0 \qquad ..3.3.6a$$

where $\delta=\beta(1-\alpha)$ and $a<0$ from $\partial P/\partial Q$. E(H) is the expected cost of foreign exchange to the importer, where the expected future spot rate (ES_1) is incorporated into 3.3.4. The demand for imports is then derived as follows:

$$q = \frac{i}{2}(aUC + bPD + cY + dCU) + \frac{ai^{2}}{2} P^{*}\ (EH + \gamma\delta\sigma_{s1}) \qquad ..3.3.6b$$

26. Hooper and Kohlhagen in deriving this specification assume that Cov(P, S_1)=0 i.e. that equation 3.3.5 implies that the price of substitute goods sold in the domestic market are uncorrelated with changes in the future spot rate. Bini-Smagi (1988) notes that this assumption is quite restrictive since one may expect domestic substitute goods to be composed both of domestically produced and imported products, and hence their prices can be expected to be sensitive to changes in the exchange rate. In particular, importers may ask compensation for the costs of higher exchange rate uncertainty, through passing them on in the form of higher prices for the final consumer. Moreover, the greater the covariance between the price of domestic substitutes and the exchange rate, the greater the incentive importers have to raise their prices in the face of higher exchange rate uncertainty.

The first bracketed term shows how the factors that influence the demand for a firm's output will result in an effect on the demand for imports: an increase in domestic output will increase the demand for imports, while an increase in the importer's unit costs will lower the demand for imports, since a<0. The second bracketed term shows the effect of exchange rate uncertainty on the demand for imports. It can be shown that higher exchange rate uncertainty will lower the demand for imports, since a<0.

3.3.2 Export Supply

The exporter sells a proportion (β) of the total output overseas (q^*) at price (P^*), while the remainder is sold in the importer's currency at price FP^*.[27] The demand for exports is derived from an identical set of n importers demand schedules, given by equation 3.3.6 i.e. $q^*=nq$. Exporters are assumed to maximise utility, which is also a function of expected profits ($E(\pi^*)$) and the standard deviation of the profits ($(\sigma^2_{\pi^*})^{1/2}$):

$$U(\pi^*) = E(\pi^*) - \gamma^* (\sigma^2_{\pi})^{1/2} \qquad ..3.3.7$$

where * denotes a foreign magnitude. The exporter's coefficient of risk aversion, γ^* may or not be different from the importer's *'depending on differences in tastes, level of domestic capital markets and access to foreign capital markets'* (Hooper and Kohlhagen, 1973, p. 490).

Exporter's profits are assumed to be determined as follows:

27. Although not stated explicitly in the Hooper and Kohlhagen model, the β coefficient is assumed to be different from the coefficient used in the importer's model.

$$\pi^* = q^*P^*H^* - q^*UC^* \qquad ..3.3.8$$

which is identical to the importer's profit function except that there are no imported units of production and therefore costs are not subject to foreign exchange risk. The revenues of the exporter, however, are subject to foreign exchange risk, given that a fraction of the export contracts are likely to be denominated in the importer's currency, of which only a fraction (α) are hedged on the forward market, with the remaining fraction ($1-\alpha$) subject to fluctuations in the future price of importing country's currency, $1/S_1$. Hooper and Kohlhagen derive a cost of foreign exchange equation as follows:

$$H^* = \beta + \alpha^*(1-\beta) + (1-\alpha^*)(1-\beta^*)\, F/S_1 \qquad ..3.3.9$$

The variance of the exporter's profits are also dependent on the uncertainty regarding movements in $1/S_1$:

$$\sigma^2_{\pi} = [P^*q^*\,(1-\beta)(1-\alpha^*)S]^2\, \sigma^2_{1/S1} \qquad ..3.3.10$$

where $\sigma^2_{1/S1}$ is the variance of the spot rate facing the exporter $1/S_1$ i.e. the price of domestic currency in foreign currency terms. Again the exporter's pricing strategy is assumed to be independent of movements in $1/S_1$ i.e. Cov (P^*, $1/S_1$)=0.

To solve for the optimal supply of exports we again use a first order condition derived from equations 3.3.7, 3.3.8 and 3.3.10 and solve for q^* to derive:

$$q^* = \left(1 \big/ \partial P^* / \partial q^* \right) \left(\frac{1}{EH^* - \gamma^* \delta^* \sigma_{1/s1}} \quad -P^* \right) \qquad ..3.3.11$$

Again a higher level of foreign exchange risk lowers the quantity of exports supplied, given that $\gamma^{*}>0$.

3.3.3 Market Equilibrium

Hooper and Kohlhagen use the above framework to derive a joint market equilibrium model of the prices and volume of international trade for the n markets, which are given as follows:

$$P^{*} = \frac{UC^{*}}{2(EH^{*}-\gamma^{*}\delta^{*}\sigma_{1/S1})} - \frac{aUC + bPD + cY + dCU}{2ai(EH+\gamma\delta\sigma_{S1})} \qquad ..3.3.12$$

$$q^{*} = \frac{ni}{4}(aUC + bPD + cY + dCU) + \frac{nai^{2}}{4}\frac{UC^{*}(EH + \gamma\delta\sigma_{S1})}{(EH^{*} - \gamma^{*}\delta^{*}\sigma_{1/S1})} \qquad ..3.3.13$$

Using a Taylor-series expansion of 3.3.12 and 3.3.13, Hooper and Kohlhagen show that $\sigma_{1/S1}$ is approximately equal to $[\sigma_{S1}S_{1}^{-2}]$[28], so that under the assumption of risk aversion ($\gamma>0$; $\gamma^{*}>0$), higher exchange rate uncertainty unambiguously lowers the volume of international trade (i.e. $\partial q^{*}/\partial\sigma_{S1}<0$). The effect on trade prices is shown to be dependent upon the currency denomination of the contract, and thus whether the exchange rate uncertainty is faced by the importer or the exporter. If the exporter faces the uncertainty since the contract is denominated in the importing country's currency, then the supply of exports will contract, resulting in a positive influence on export prices ($\partial p^{*}/\partial\sigma_{S1}>0$). If importers face the exchange rate variability so that the trade contract is denominated in

28. Without this restriction then changes in S_1 would also change $1/S_1$, so that the partial derivative could not be calculated.

the exporting country's currency, then the demand for exports will fall, thus exerting a negative influence on export prices ($\partial p^*/\partial\sigma_{s1}<0$).

3.3.4 Estimation Results

Equations 3.3.12 and 3.3.13 were initially estimated using non-linear estimation techniques. However, As Hooper and Kohlhagen note:

> *'The results of the non-linear estimation estimations are not reported here because they provided no consistent evidence on the hypothesis we were testing. Coefficients and t-ratios on similar variables across different equations ranged from high to low values often, with the wrong sign and with no apparent explanation (one memorable t-statistic was larger than one million). We concluded that the non-linear estimation techniques must be very sensitive to certain statistical difficulties, most importantly collinearity among variables, and decided therefore to concentrate on estimating the linear approximations to the model'.*
>
> (Hooper and Kohlhagen, 1978, p. 493).

The following linear approximations were estimated:

$$P^* = c_0 + c_1\,UC^* + c_2\,UC + c_3\,PD + c_4\,Y + c_5\,CU + c_6\,EH^* + c_7\,EH + c_8\,\sigma_{1/s1} + c_9\,\sigma_{s1}$$

..3.3.14

$$q^* = d_0 + d_1\,UC^* + d_2\,UC + d_3\,PD + d_4\,Y + d_5\,CU + d_6\,EH^* + d_7\,EH + d_8\,\sigma_{1/s1} + d_9\,\sigma_{s1}$$

..3.3.15

Before turning to the empirical results it is useful to comment on the linearization of 3.3.12 and 3.3.13. Firstly, Hooper and Kohlhagen's rationale for not presenting the non-linear estimation results was that *'the non-linear estimation techniques must be very sensitive to certain statistical difficulties, most importantly collinearity among variables'*. However, linearization is unlikely to solve the collinearity problem, which Hooper and Kohlhagen later note is still a difficulty with the linear estimation results.

Secondly, the multicollinearity problem is likely to be a product of the reduced form model. In particular, there is likely to be high degree of multicollinearity between the EH^* and EH variables and the $\sigma_{1/s1}$ and σ_{s1} variables. Interpretation of the estimated coefficients is also made difficult, given that 3.3.14 and 3.3.15 are the reduced form solution to a four equation structural system. Underlying the price and volume equations for a given trade flow are the export demand and export supply equations and the import demand and supply equations. Economic interpretation could therefore be enhanced through estimation of the structural equations.

Thirdly, given the equations from the reduced form model are only linear approximations, it is not clear what relationship we can infer from the linear estimates and their relationship with the non-linear coefficients specified in 3.3.12 and 3.3.13.

Finally, the comment that *'Coefficients and t-ratios on similar variables across different equations ranged from high to low values often'*, may simply reflect that the estimation results were sensitive to a range of trade flows, and the non-linear model may not be appropriate to all the cases examined.

Hooper and Kohlhagen suggest that c_1, c_3, c_4, c_8, d_3, d_4 and d_6 are positive and all other coefficients except c_0 and d_0 are expected to be negative. However, interpretation of the sign of each coefficient in line with economic theory requires analysis of the underlying structural system.

The linear equations specified were estimated using OLS for 16 trade flows for the US and Germany with France, Japan, UK and Canada, with most independent variables incorporating a one period lag to allow for delays between orders being made and payments being received.[29] The sample period was 1965 Q1 to 1975 Q4 and the measure of exchange rate uncertainty used was the average absolute difference between the current spot rate and the lagged forward rate for the 13 weekly observations of a given quarter.

The estimation results for US imports and West German exports and imports, suggest that the measure of exchange rate uncertainty had a negative influence on prices at the 95% level in 9 out of 11 cases and in 6 cases at the 90% level. In 2 out of 5 US import cases exchange rate uncertainty had a significant positive influence on prices. Hooper and Kohlhagen conclude that in the case of US exports and German exports and imports exchange rate uncertainty was dominant on the importer's side, so that foreign exchange risk led to a fall in import demand and thus resulted in a fall in import prices. By contrast, US imports tend to be invoiced in US Dollars, so that foreign exchange risk was faced by the exporter, resulting in a contraction of export supply and an increase in prices. This result is consistent with most of the evidence that suggests US imports tend to be invoiced in US dollars (Grassman, 1973, Allen *at al*, 1987).

29. Contemporaneous independent variables were also included in some cases. As Hooper and Kohlhagen note *'we also estimated the equations with no lag, testing for lags of less than one quarter or the possibility that firms anticipate the demand and supply determinants'*, (Hooper and Kohlhagen, 1978, p. 495).

The measure of exchange rate uncertainty only had a significant influence on trade volumes in one case at the 90% level, US exports to the UK. This conclusion was robust to the estimation of volume equations incorporating different measures of exchange rate uncertainty and various lag structures, as well as estimation of structural import equations.

One of the main difficulties found with the linear estimation was the problem of multicollinearity. In an attempt to remedy this problem, Hooper and Kohlhagen omitted the unit cost, price and income variables that were statistically insignificant or incorrectly signed and which they believed caused the multicollinearity. However, while the elimination of the relevant independent variables may solve the multicollinearity problem, bias will influence the estimates of the coefficients for the remaining independent variables, if as we expect they are significantly correlated with the omitted variables. Serial correlation was shown to be a problem in the final set of estimation results.[30]

Thus the overall conclusion of the empirical research is that exchange rate uncertainty can have a positive or negative influence on trade prices, depending upon the currency denomination of the export or import contract, but tends to have no significant influence on trade volumes. They explain this result either by the presence of a short-run price inelastic export supply schedule in the case of a price fall, or a price inelastic import demand schedule in the case of a price increase.

30. In an attempt to eliminate the serial cortrelation problem the model was re-estimated using the Cochrane - Orcutt iterative procedure. Clearly this is an inaccurate remedy for the serial correlation problem, which is likely to be caused by model misspecification.

Hooper and Kohlhagen use figure 3.3.1 to illustrate the case of an importer bearing the uncertainty from future exchange rate movements, under monopoly market conditions.[31] A reduction in import demand from D to D′ (and hence marginal revenue) leads to a relatively large drop in import prices (P to P′)and a relatively small reduction in quantity (Q to Q′).

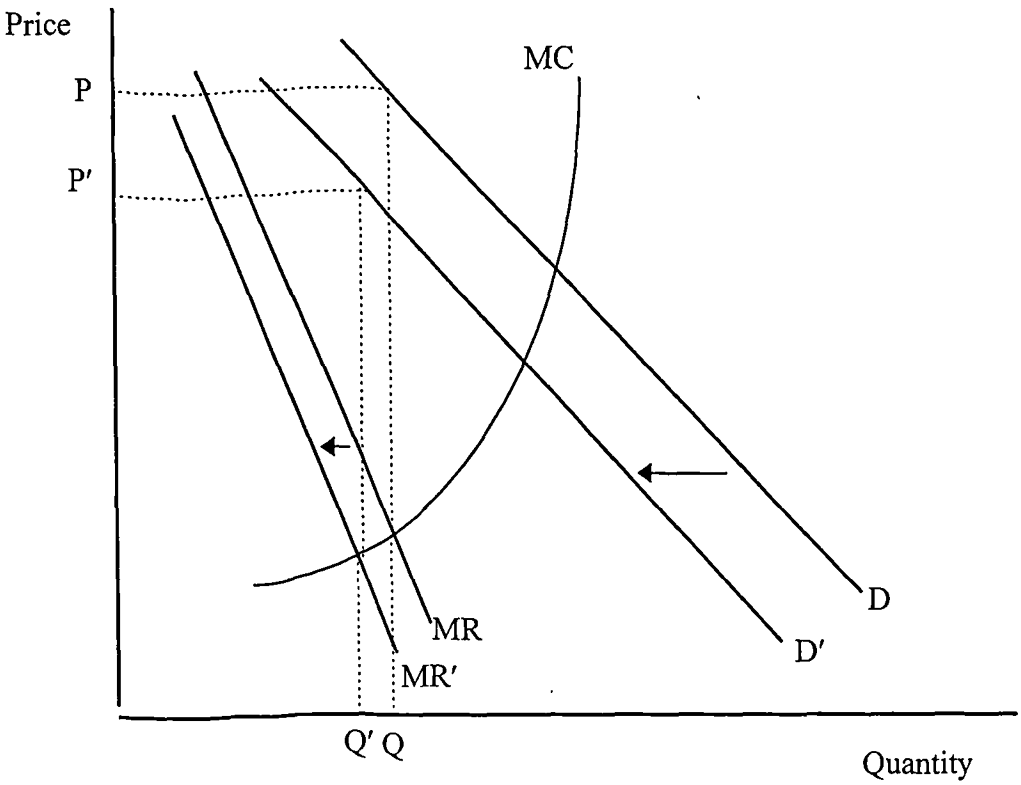

Figure 3.3.1: Effect of an increase in exchange rate uncertainty on a risk bearing importer under monopoly market conditions.

31. Hooper and Kolhagen also present a similar result for perfectly competitive market conditions.

3.4 Overview of the Empirical Literature

Following the seminal work of Hooper and Kohlhagen (1978), a large amount of research has been published in an attempt to discover a robust relationship between exchange rate variability and international trade. Early empirical research suggested that there was no statistically significant variability effect. A now well known quote from the IMF (1984) states:

> *'The large majority of empirical studies on the impact of exchange rate variability on the volume of international trade are unable to establish a systematically significant link between measured exchange rate variability and the volume of international trade, whether on an aggregated or on a bi-lateral basis',* [IMF (1984), p. 36].

However, a review of more recent research indicates that the overall direction and statistical significance of the exchange rate variability effect is ambiguous. Appendix A to this chapter presents a summary of empirical literature in this area, the vast majority of which (over 75%) has been published since IMF, 1984. It can be seen from Appendix A that 33 studies present evidence of a statistically significant negative relationship between exchange rate variability and international trade, while 26 studies suggest no significant 'variability effect'. However, the balance of opinion has changed over time and can be separated into three distinct segments. Up to the study by Cushman (1986) the majority of studies found no statistically significant 'variability effect'. Between the Cushman study and the work of Bahmani-Oskooee and Ltaifa (1992) opinion was balanced with roughly as many studies finding an influence from exchange rate variability as those finding no effect. Since 1992, published work has overall tended to find evidence of a statistically significant variability effect.

The ambiguity of the empirical results could possibly be explained by two factors. Firstly, it can be seen from Appendix A that there is little consensus about the appropriate measure of exchange rate variability to be used in these studies. 25 studies have used the standard deviation (or variance) of the exchange rate (or its percentage changes), measured either in nominal or real terms. However, the use of the standard deviation measure is dependent upon the assumption that the distribution of the exchange rate is normal. Empirical evidence (McFarland, Petit and Sung, 1982; Rana, 1981; and Westerfield, 1977) however, has suggested that the distribution of many exchange rates can be leptokurtic and that changes in the exchange rate tend to be extended over time so that 'volatility clustering' occurs. Consequently, the distribution of the exchange rate (changes) may include a larger number of extreme observations than is expected from a normal distribution. It has also been suggested that if the timing and magnitude of exchange rate changes are relatively predictable, the degree of exchange rate uncertainty will be overstated by the standard deviation measure (Akhtar and Hilton, 1984). A detailed survey of the factors influencing the measurement of exchange rate variability is presented in chapter three.

A number of studies have attempted to refine the definition of exchange rate variability, in an attempt to overcome some of the difficulties with the standard deviation measure. For example, measures to detect unanticipated exchange rate movements have been proposed, such as the average deviation of the spot rate from the lagged forward rate (Justice, 1983; Cushman, 1988); the variance of the exchange rate around its estimated trend (Kenen and Rodrik, 1984; Thursby and Thursby, 1987; Perée and Steinherr, 1989) and the estimated residuals from a unit root process of the exchange rate (Kenen and Rodrik, 1986). More than 15 studies have used the moving average standard deviation, which has been a popular choice of proxy in recent research (Chowdhury, 1993; Arize, 1995a,b and Arize, 1995a,b). This method takes account of lags of the variability measure, ranging from four quarters (Cushman, 1983; Justice, 1984) to eight quarters (Chowdhury, 1993). However, this proxy has the difficulty is that it tends to smooth the fluctuations in the standard deviation and consequently may understate the 'true' degree of exchange rate uncertainty (Pagan and Ullah, 1986).

Recent research has attempted to measure exchange rate variability as a conditional variance process (Kroner and Lastrapes, 1993; Arize, 1995; Arize, 1997a). The conditional variance processes can measure exchange rate variability from the squared residuals derived from a model of the exchange rate, which are dependent upon the lagged squared residuals and perhaps lagged values of the conditional variance. The conditional variance approach has the advantage of accounting for leptokurtosis in the exchange rate distribution (Pesaran and Robinson, 1993) and 'volatility clustering'.

A second factor is that later research has tended to rely less on the traditional OLS estimation technique to make inferences. For example, since the late 1980s, researchers have adopted estimation techniques such as Zellner's Seemingly Unrelated Regression Estimator (SURE) (de Grauwe, 1988; Stokman, 1995); Polynomial Distributed Lag models (Anderson and Garcia, 1989; Bailey, Tavlas and Ulan, 1987); Vector Autoregressions (VAR) (Koray and Lastrapes; Lastrapes and Koray, 1990) and the Johansen Cointegration methodology (Chowdhury, 1993; Holly, 1995; Arize, 1995a and 1997). The development of empirical modelling in this field, however, has not generally been accompanied by significant developments of the underlying economic theory. For example, many studies still utilise simple linear trade models including: usually a proxy for economic activity (e.g. GNP, GDP or industrial production);

possibly a definition of capacity utilisation; a proxy for relative prices; and a measure of exchange rate variability. Further developments in economic theory and modelling could therefore be necessary to clarify the debate as to the sign and magnitude of the exchange rate variability effect.

To further highlight some of the issues in this debate, it is useful to classify studies, so that similar methodologies can be compared more effectively. Four categories are proposed: aggregate trade studies; bi-lateral trade studies; disaggregated - industry specific studies and cointegration analysis.

3.4.1 Aggregate Trade Studies

One of the most conventional approaches is to test for the effect of exchange rate variability on aggregate trade flows of a particular country or even a collection of economies. A significant number of studies have adopted this approach, primarily for convenience, since aggregate data is usually far more plentiful for longer periods of time and a larger number of countries. Studies of this kind often require a 'global' measure of variability, which is usually calculated by trade weighting the relevant exchange rates, according to the percentage of trade occurring with the country being analysed.[32]

This methodology, however, has its difficulties since as the IMF (1984) note it may fail to take account of switching trading patterns, as trade is diverted from countries of high volatility to those of low volatility within the aggregate measure. Moreover, a particular country may be trading with a large number of economies, with a variety of

32. Lanyi and Suss (1982) note, however, that there is no uniform weighting scheme. Weights are sometimes based on the number of external transactions, weighted according to the percentage of trade with the economy being analysed or derived from an econometric model such as the IMF Multilateral Exchange Rate Model (MERM).

exchange rate agreements and regimes, which introduces interpretation difficulties into the analysis of the exchange rate variability effect. Bini-Smaghi (1991) also notes that data aggregation constrains the variability elasticities to be similar across countries and indeed sectors of the economy. Aggregate studies may fail to recognise that the response of importers and exporters to a change in variability may be different for economies experiencing a high degree of exchange rate volatility compared to one with relatively stable exchange rates. Furthermore, some sectors may have less market power to pass the costs of exchange rate variability on to the final consumer, depending upon the price elasticity of demand. Aggregate data studies also face the difficulty of finding appropriate proxies for the other independent variables in the model to the exchange rate variability measure. For example, proxies for world income and price indices for substitute goods from the rest of the world have to be found.

Akhtar and Hilton (1984) examine the influence of exchange rate variability on the prices and volumes of US and West Germany exports and imports, over the sample periods 1974Q1-1981Q4 and 1974Q1-1982Q4.[33] Akhtar and Hilton specify a two equation structural system, modelling export volumes as a function of foreign (domestic) income; relative prices and a measure of nominal exchange rate variability.[34] Export prices are assumed to be a function of unit costs and exchange rate variability. The nature of the structural system infers an infinitely price elastic export (import)

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33. Akhtar and Hilton start the sample period at 1974Q1 to allow for lagged values of the independent variables in the regression equations, using a polynomial lag specification. Gotur (1985) however, has criticized the starting period of 1974Q1, since by using an eight - quarter lag for exchange rate variability, the Akhtar and Hilton analysis includes observations from periods of fixed and floating exchange rates. Gotur (1985) notes *'Thus it is possible that bias in specification may be introduced owing to the change in exchange rate regime'*, (Gotur, 1985, p. 488).

34. The measure of exchange rate variability used is the standard deviation of the daily observations in the nominal effective exchange rate for a given quarter.

supply schedule, so that export (import) prices are determined independently of export (import) volumes. For the 1974Q1 - 1981Q4 period, Akhtar and Hilton found a statistically significant negative variability effect on West German export and import volumes and US export volumes, but no significant effect on US import volumes. The US export price equation had a negative variability coefficient, with a positive coefficient for West Germany, although neither was statistically significant. A positive variability coefficient was also found in the West German export and import price equations, although again no statistically significant results were found. When the sample period was extended to 1982 all of the results remained robust except a statistically significant, positive variability coefficient was found in the West German import price equation.

Over the original sample period, Akhtar and Hilton also found a statistically significant negative relationship between US and West German export volumes and real exchange rate variability, with similar signs and magnitudes to the coefficients obtained using the measure of nominal exchange rate variability. This result is not surprising given that Akhtar and Hilton suggest that most of the movements in real exchange rates over the floating period could be explained by movements in nominal exchange rates rather than movements in relative prices.

The empirical methodology of Akhtar and Hilton, however, has been strongly criticised by Gotur (1985) who extends their original work to include additional countries and a longer sample period. Gotur tested the Akthar and Hilton model for France, Japan and the UK over the sample period. For each case the volume equation has a variability coefficient which is insignificant and 'incorrectly' signed. For the price equations, the UK case suggested an insignificant and 'incorrectly' signed variability coefficient, while for France and Japan the relevant coefficient was 'correctly' signed and significant.

Gotur also provided further specific criticisms of the Akhtar and Hilton approach. Firstly, Akhtar and Hilton systematically applied a one step Cochrane - Orcutt (CO) procedure to all regression equations, without pre-checking for serial correlation. Furthermore, Gotur argues in favour of using the CO iterative procedure, as opposed to the CO one-step procedure. When the Akhtar and Hilton regression results were re-examined, the results for the US export volume equation suggested no serial correlation moreover, the variability coefficient was no longer significant.

Gotur also raises the difficulty that since an eight quarter lag structure was imposed on the exchange rate variability measure, the estimation period of 1974Q1-1984Q4 ranges over both fixed and floating exchange rate periods. Consequently, when the sample period began in 1975Q1, Gotur found that there were significant changes in the sign and magnitude of the variability coefficients for the US and West Germany.

The empirical results from the Akhtar and Hilton study were also found to be sensitive to the order of polynomial lag used. Failure to correctly specify the correct order of polynomial may render the estimates to be biased and inconsistent, as well as possibly leading to standard hypothesis tests giving misleading conclusions. Akhtar and Hilton use a second order lag polynomial for all cases. Gotur shows with the use of a third order lag polynomial the significant 'variability' effect on US export volumes and US import prices disappears.

The Akhtar and Hilton model was consequently re-estimated taking account of the above modifications, over the sample period 1975Q1-1983Q4, calculating the quarterly standard deviation from the daily observations of an alternative effective exchange rate index.[35] The modified results suggest only the German export volume equation remains robust. Results for France, Japan and the UK suggest no effect on trade volumes or prices.

Bailey, Tavlas and Ulan (1986) have also estimated the effect of the absolute value of the quarter to quarter changes in the nominal effective exchange rate using a similar group of countries and sample period to that used by Akhtar and Hilton (1984). The results suggest no significant effect on aggregate trade volumes. In a later study, Bailey, Tavlas and Ulan (1987) consider the effect on aggregate exports by extending the original sample of countries from their 1986 study, by using the absolute value percentage changes in the nominal and real effective exchange rate plus an eight quarter moving average standard deviation of the percentage changes in the effective exchange rate, both in nominal and real forms. In only 3 out of 40 cases analysed were the estimated variability coefficients negative and statistically significant, while five variability coefficients were positive and significant.

More recently Asseery and Peel (1991), Bahmani-Oskooee (1991), Bahmani-Oskooee and Ltaifa (1992), Chowdhury (1993), Kroner and Lastrapes (1993) and Caporale and Doorodian (1994) have all demonstrated a statistically significant negative relationship between a variety of exchange rate variability measures and aggregate trade flows. The difference in conclusion, with respect to the effect of exchange rate variability on trade volumes, from these studies compared to the work of Akhtar and Hilton (1984), Gotur (1985) and Bailey, Tavlas and Ulan (1986, 1987) can possibly be

35. Specifically, the effective exchange rate index is calculated from weights derived from the IMF Multilateral Exchange Rate Model. Akthar and Hilton simply use trade weights.

explained by examination of a wider sample of countries, longer sample periods, use of different variability measures and use of other estimation techniques than OLS.

3.4.2 Bi-lateral Trade Studies

In order to avoid some of the problems associated with using aggregate trade data, some studies have analysed trade flows between two specific countries. This approach, however, does not avoid the problem of there being separate variability effects for different sectors of the economy.

Cushman (1983, 1986 and 1988b) attempted to test the robustness of the empirical results found in Hooper and Kohlhagen (1978). Cushman (1983) adapts the Hooper and Kohlhagen framework by assuming the utility of exporters and importers depends upon real rather than nominal profits. Consequently, this study attempts to examine how sensitive the results of Hooper and Kohlhagen are to a different choice of exchange rate variability based on movements in the real exchange rate and denoting the majority of the independent variables in real terms. The proxy of exchange rate variability used is a four quarter moving average standard deviation of the changes in the real exchange rate. The rationale for using the real exchange rate is that movements in the exchange rate which influence international trade may be offset by movements in relative prices. The sample period used is 1965Q1-1977Q4, which is two years longer than that used by Hooper and Kohlhagen. A number of lag structures were also tried, on the basis that the effects of exchange rate uncertainty will be extended beyond the firms current planning horizon. The more flexible dynamic specification was successful in solving some of the serial correlation problems found in the Hooper and Kohlhagen study, where a one period distributed lag was applied to all cases. In an attempt to overcome the mutlicollinearity problems found in the Hooper and Kohlhagen results, the EH and EH^* variables from 3.3.14 and 3.3.15 were deleted and a proxy of the expected real exchange rate changes included instead.[36] The PD variable was also replaced by the real exchange rate.

Cushman's empirical results somewhat contradict those of Hooper and Kohlhagen, in that 6 out of 16 cases for the US and West Germany show a negative relationship between real exchange rate variability and real export volumes. 3 out of 16 cases show a significant effect on real trade prices, one case being negative and two cases being positive. However, it can be difficult to directly compare the results of Cushman with Hooper and Kohlhagen. Cushman's moving average standard deviation proxy can only directly measure exchange rate variability rather than uncertainty. If movements in exchange rates are relatively predictable then this proxy may overstate the true degree of exchange rate uncertainty. By contrast, the uncertainty proxy used by Hooper and Kohlhagen measures the dispersion between a proxy for the market's expectation of the future spot exchange rate (the current forward rate) and the actual spot rate one period in the future.

In Cushman (1988b) the sample period; measures of exchange rate variability; and number of countries used in the Hooper and Kohlhagen study are extended; and the focus of the paper is the robustness of the variability effect to a wider spectrum of measures. Cushman considers four measures: firstly, four and twelve quarter moving average standard deviations of the changes in the real exchange rate. Secondly, a twelve month moving average of the unanticipated real exchange rate. The expected nominal

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36. The expected real exchange rate was calculated from a four quarter moving average of the real exchange rate.

exchange rate is determined by the lagged forward rate; while the expected inflation differential is determined from an autoregressive equation over a 10 year period, using monthly observations of 3 months. Both of these components are used to calculate the expected real exchange rate (see Cushman, 1988b for sepcific details). The difference between the actual real exchange rate and the lagged real forward rate, defines the unanticipated real exchange rate. This measure is based on the following unbiasedness equation, derived from the Efficient Markets Hypothesis (Fama, 1970):

$$(S_t - S_{t-3})/ S_{t-3} = \alpha + \beta\ (F_{t-3} - S_{t-3})/S_{t-3} + \varepsilon_t \qquad \textbf{..3.4.1}$$

where: S = real spot exchange rate;
F = real forward exchange rate;
ε = 'white noise' error term.

It is assumed that α=0 and β=1, so that ε_t reflects the unanticipated exchange rate. The monthly observations are then used to calculate a 12 month moving average standard deviation of the deviations of the actual from the anticipated real exchange rate. Monthly observations are averaged to derived a quarterly measure.

Measures were then calculated using the framework from 3.4.1, firstly, by removing the restriction that α=0[37] and secondly, assuming $\alpha \neq 0$ and $\beta \neq 1$.

Cushman (1988b) examined the influence of each variability (uncertainty) measure on the US export and import volumes with the UK, the Netherlands, France, West Germany and Japan, for the period 1974Q1-1983Q4. A total of 60 trade flows were examined. Significant negative exchange rate variability effects were found in 5 out of 6 US import flows, and robust conclusions for the various proxies being found for

37. The Efficient Markets literature suggests that if $\alpha \neq 0$, this may reflect the presence of a significant risk premium (see for example Domowitz and Hakkio, 1985).

the Netherlands, UK and Japan. US exports to the UK and Canada were the only 2 cases were negative 'variability' effects were found.

One of the main difficulties of bi-lateral trade studies is that the variability measure included often ignores the influence of uncertainty from other trading partners. In an important contribution, Cushman (1986, 1988a) examines the effect of the co-variance between two bi-lateral exchange rates on bi-lateral trade,[38] or what he terms third-country risk. Cushman estimated an econometric equation, similar to that specified by Hooper and Kohlhagen, for bi-lateral trade flows to and from the United States with a number of countries, over a period of fixed and floating exchange rates. Over the fixed rate period, 1965 Q1 - 1977 Q4, in three out of six cases, coefficients were negative and significant when third country risk was included, in four out of six cases the coefficients were negatively signed and significant when the third country risk variable was excluded. From 1973 Q1 - 1983 Q4, for two out of six cases the variability coefficients were negative and significant when third country risk was included. Three out of six cases were negatively signed and significant when third country risk was excluded.

A difficulty, however, for the third country risk measure is that it can only consider the inter-relationship between two bi-lateral exchange rates. Some firms may be able to diversify their risk exposure to a number of currencies. Furthermore, for individual countries or sectors of the economy, a wider portfolio of currencies need to be accounted for.

In an interesting approach, Brada and Méndez (1988) pool time series data over a cross section of thirty developing and developed countries over the period 1973-

38. The co-variance is usually calculated by using the exchange rate from the bi-lateral trade flow being estimated and the bi-lateral exchange rate of a close trading partner.

1977.[39] The empirical results suggest the presence of a significant negative relationship. This paper uses a gravity model of trade flows. Thus in addition to the conventional independent variables, the following variables are included: the population of the exporting and importing countries; the distance between the two countries being analysed; and dummy variables to capture membership of a preferential trading regime or a fixed or floating exchange rate regime. An interesting finding of this paper is that bi-lateral trade flows seem to be higher among countries under a floating exchange rate regime compared to fixed rates. Thus while the exchange rate variability effect is detrimental to international trade, its effect is shown not to be as strong as the trade reducing effects of protectionist policies imposed by fixed rate countries.

3.4.3 Disaggregated - Industry Specific Studies

A number of authors have examined the influence of exchange rate volatility on trade for individual industries or sectors of the economy. This approach has the advantage of avoiding the problem of data aggregation mentioned earlier, where the variability elasticities are constrained to be similar across industries. Furthermore, disaggregated trade data allow external factors which are specific to a particular industry to be incorporated into a regression equation. For example, a period of very bad weather could possibly account for a significant reduction in the exports of agricultural produce. If these products account for a large proportion of an economy's total exports, we might incorrectly infer a decline in aggregate external trade was caused by high exchange rate variability.

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39. This approach is often adopted since the data may only be available for some countries at low frequencies. The approach also has the advantage that it enables researchers to test the variability effect on a number of countries simutaneously through using one econometric equation.

Industry specific data also enables researchers to examine the relationship between industrial concentration (and hence market power) and the influence of exchange rate variability on international trade. As Gosling (1987) notes, in markets which are significantly price competitive, higher exchange rate variability would force exporters invoicing in foreign currency to raise export prices, and as a consequence of the high price elasticity of demand, experience a reduction in the volume of exports, if the costs of hedging are significant. If, however, firms have some market power by which they can raise their export price or are able to invoice in their own currency, and the own price and cross price elasticities are relatively low, the costs of higher exchange rate uncertainty are likely to be borne by the consumer, with little effect on the volume of international trade.

Coes (1981) analysed exports of 22 products for Brazil ranging from agricultural products such as Beef and Fish to Metals and Machinery, using annual data over the sample period 1957 to 1974. An interesting feature of this paper is that it adopts a non-conventional measure of exchange rate variability, in the form of the integral difference between the cumulative distribution of the monthly real exchange rate and a "certain" exchange rate. Coes presents evidence to suggest that the exchange rate variability proxy used had a significant negative effect on trade volumes in 16 out of 22 cases at the 95% significance level and in an additonal 2 cases at the 90% level. Furthermore, the evidence indicates that there were significant differences in the variability effect across sectors of the Brazilian economy. In one case, for example, the overall elasticity of export volumes with respect to exchange rate variability (i.e. the sum of the variability elasticities for the contemporaneous and three lagged variables) for Rice was -0.24 compared to an overall elasticity of 0.028 for Electrical and Communications equipment. However, there are two difficulties for interpretation of this study. Firstly, no definition of the 'certain' exchange rate is provided; it is not clear what proxy has been used. Secondly, because annual data and lagged variables are used, the estimated results are produced with insufficient degrees of freedom. In some cases there are just eight or fewer degrees of freedom.

A number of authors have concentrated on aggregate trade within the manufacturing sector of the economy (see Justice, 1983; Kenen and Rodrik, 1986 and Bini-Smaghi, 1991). Gosling (1987) analysed UK manufactured exports for seven products, over the period 1977 Q2 - 1988 Q2. Using a quarterly standard deviation of the daily nominal effective exchange rate, in five out of seven cases analysed, the variability measure had a significant negative effect, whilst 1 product suggested a positive relationship between variability and trade. For the price equation, two out of seven cases suggested a significant positive variability effect, four cases indicated the presence of a significant negative variability effect. This study also demonstrates that there were significant differences in the estimated variability coefficients across different sectors of the economy. The effect on trade volumes was strongest for the Chemicals sector, with an elasticity of -0.23, compared to the Textiles sector, with an elasticity of -0.091. The variability elasticity in the price equation was largest for the Road Vehicles sector (0.07) and smallest for Manufactures (-0.004).

Stokman (1995) uses trade data for five European Countries, over the period 1980 Q1 to 1990 Q4 and examines the influence of a standard deviation measure of exchange rate variability on aggregate exports to the EU in Food, Raw Materials, Chemicals, Manufactures and Machinery sectors. Using a SURE estimation method, the empirical results indicate the presence of a significant negative influence on export volumes in 23 out of 25 cases. However, the direction and magnitude of the variability effect varies across sectors and countries. For example, Food Products generally tend to have a larger variability elasticity than capital goods, such as Machinery and Manufactured Products. Stokman partly explains this result by the fact that producers of capital goods tend to be less risk averse, due to their greater market power. Furthermore, for these producers, short term exchange rate variability is likely to be less relevant, given that they usually have longer delivery and contract payment lags.

A difficulty, however, for this study is that the aggregate export data used extends across countries operating under both fixed and floating rate periods. This may influence the distribution of the exchange rate variables used in the regression, since the distribution is likely to change between periods of fixed and floating exchange rates. Also an interesting extension to this paper would have also been to consider the percentage of trade accounted for by the products examined in the study. The policy conclusions derived from the Stokman paper could then be considered in the light of the negative variability effect on the total trade of a particular country. The logical extension of this conclusion is that some products may be more relevant to some countries, rather than using a fixed category of products. It is also useful to consider the interlinkages between the different sectors, and the impact of a decline in trade in one sector on other sectors of the economy, particularly if some products are used as raw materials in the production of final goods. Some sectors may also be able to cushion the effects of exchange rate variability through higher profit margins or their market power enabling them to pass the hedging costs onto the final consumer.

3.4.4 Cointegration Analysis

A lot of studies in the empirical literature have made the assumption that the data used for estimation were stationary i.e. I(0) (the time series fluctuates around a constant mean with a finite variance). It is now apparent, however, that many economic time series may in fact be non-stationary or I(1) (where the mean, variance or co-variance of the series fluctuates over time), thus making standard inferential methods inappropriate. In an attempt to overcome these problems recent research has utilised the Johansen cointegration procedure (Johansen, 1988), which accommodates non-stationary variables and permits multiple cointegrating vectors.

Chowdhury (1993), uses the Johansen procedure to examine the impact of an eight quarter moving average standard deviation of the changes in the real effective exchange rate on the volume of real exports. The aggregate export volume equation was estimated for the G7 countries, over the period 1973-1990. In each case a unique cointegrating vector was found together with a statistically significant, negatively signed long-run normalised coefficient for the variability measure. Interestingly, the long-run variability coefficients were similar across the G7 countries. Chowdhury also found a statistically significant negative relationship between the movements in export volumes and movements in exchange rate variability, when a short-run error correction model was estimated.

Arize (1995a) also uses the Johansen approach to examine the influence of an ARCH measure of exchange rate variability on the volume of US real aggregate exports, over the period 1973Q2 - 1991Q3. A unique cointegrating vector is found and a long-run normalised variability elasticity of -0.066. Hypothesis testing also suggests that the variability measure plays a significant role in the determination of the long-run equilibrium relationship, when an exclusion restriction is imposed on the relevant coefficient. The short-run movements in exchange rate variability also played a significant role in determining the movements in real export volumes from an estimated error correction model. Arize (1995b) estimates the previous model of real aggregate export volumes for Denmark; the Netherlands; Sweden; and Switzerland. The estimated unique cointegating vectors indicate that an 8th order moving average standard deviation of the changes in the real effective exchange rate had a significant influence on export volumes. The measure of exchange rate variability also had a significant influence on short-run movements in export volumes.

Arize (1997a) later tested the robustness of the model used in earlier papers for the UK, US, Denmark, Germany, Italy, Japan and Switzerland. The results confirm the findings of the 1995 papers, where in each case a unique cointegrating vector and statistically significant negative long-run variability coefficient are found. However, in comparison to Chowdhury (1993) the magnitude of the long-run variability coefficient varies significantly across countries, for a similar sample period and range of countries. For example, Switzerland has a long-run variability coefficient of -0.72, compared to -3.72 for Japan. Arize (1997a) also compares the performance of the ARCH measure of variability with a moving average standard deviation. He concludes from the empirical work that the moving average standard deviation understates the 'true' degree of exchange rate uncertainty, as originally suggested by Pagan and Ullah (1986).

In conclusion, the majority of studies using cointegration analysis, support the hypothesis that exchange rate variability has a negative influence on international trade.[40] A common feature of the above studies is that they only examine the influence of exchange rate variability on trade volumes, ignoring the effect on trade prices. In an important contribution, Holly (1995) presents a model of UK export volumes and prices. This study is not discussed at this stage since it is considered further in chapter 6 of the thesis. The model suggested by Holly is also tested extensively in chapters 6 and 7 to examine the influence of a range of variability measures on the prices and volumes of UK exports over the period 1973Q2 - 1990Q3.

3.5 Conclusions

The empirical literature surveyed in this chapter has provided little clear guidance as to whether exchange rate variability is detrimental to international trade. One of the most significant reasons for this conclusion is that there appears to be no definitive proxy for exchange rate uncertainty. A large number of measures have been developed, but the literature provides little guidance on their appropriateness or the conditions under which a particular measure should be used. It is also difficult to make an overall conclusion given that different results are found according to the specific countries being analysed; the specification of the trade model being analysed; the estimation technique being used and the format of the trade data.

The problems relating to non-stationarity of variables has brought into question many of the economic inferences made from the vast majority of studies which have utilised standard OLS estimation techniques. Recent research has attempted to overcome some of these difficulties through using cointegration analysis either by using

40. Appendix A also provides a summary of further stuides which have used cointegration analysis.

the Engle-Granger two-step approach (Engle and Granger, 1987) or the Johansen multivariate cointegration procedure (Johansen, 1988). Most of these papers support the conclusion that exchange rate variability had a negative influence on international trade volumes for a large number of countries and measures of exchange rate variability. However, to the best of this author's knowledge, only one study using cointegration analysis (Holly, 1995), has produced a model of trade volumes and prices. This approach is analysed extensively in chapters 6 and 7 of the thesis. However, at this stage it is important to note that when estimating a system of equations using cointegration analysis, identification of the underlying long-run economic relationships can be difficult from estimating cointegrating vectors. Wickens (1996) has demonstrated that structural relationships cannot be identified from cointegrating vectors, unless *a priori* restrictions are imposed on the cointegrating vectors.

In Chapter 5 these identification problems are considered in depth and a restricted Vector Autoregressive Error Correction Model (VECM) approach is suggested to acquire structural inferences from the estimation of reduced form VECMs. The estimation results from applying the restricted VECM approach to the model used in Holly (1995) will then be presented in chapters 6 and 7. The purpose of this research is to discover what influence exchange rate variability (as measured by a variety of proxies) had on UK export volumes and prices, over the period 1973 Q2 to 1990Q3.

Chapter Four

The Measurement of Exchange Rate Variability

Abstract

This chapter begins with a formal definition of risk and uncertainty following the work of Knight (1921). The relevance of the standard deviation is then considered by using the mean - variance framework. A survey of the exchange rate variability (uncertainty) measures used in the international trade literature is then undertaken by discussing the main issues which applied researchers should consider when attempting to measure variability (uncertainty). The conclusions suggest a list of characteristics that measures of variability should at least partly encompass.

4.1 Introduction

One of the main conclusions of chapter two was that the ambiguity concerning the effect of exchange rate variability on international trade volumes and prices arises because the literature provides no clear guidance on the measurement of exchange rate variability. A plethora of measures have been suggested but there is little indication of the appropriateness of one measure relative to another, or the circumstances in which particular measures are relevant. To the best of this author's knowledge a comprehensive survey of the measures has not yet been completed in the literature, nor have the advantages and disadvantages of each proxy been considered. The purpose of this chapter is to review the various proxies used in the literature and to discuss the factors which applied researchers should consider when measuring exchange rate variability.

The vast majority of empirical studies have used measures of exchange rate variability as a proxy for the uncertainty faced by importers and exporters about future movements in the exchange rate. One of the most common measures is the standard deviation (or variance) of the exchange rate (or movements in the exchange rate) (see for example, Makin, 1976; Akhtar and Hilton, 1984; Klein, 1990). Alternative measures include the moving average standard deviation (see for example, Cushman, 1986, 1988a; Lastrapes and Koray, 1990; Chowdhury, 1993) and conditional heteroscedasticity processes of the errors (residuals) from a defined model of the exchange rate (Kroner and Lastrapes, 1993; Holly, 1995; Arize, 1995a, 1997a).

Akhtar and Hilton (1984) have argued that measures of exchange rate variability are likely to understate the degree of exchange rate uncertainty. Their conclusion is based on the argument that movements in exchange rates have some elements which are predictable and others which are not. Exchange rate variability measures the dispersion of exchange rate movements *ex-post*, whereas exchange rate uncertainty depicts *ex-ante*, the unpredictable direction and magnitude of future changes in exchange rates. Low levels of *ex-post* observed variability may be associated with high exchange rate uncertainty, if the timing and magnitude of exchange rate movements are very unpredictable. By contrast, if exchange rate variability is relatively high but the timing and magnitude of exchange rate movements are relatively predictable, measures of exchange rate variability are likely to overstate the degree of exchange rate uncertainty.

The measurement of exchange rate uncertainty requires a definition of the expected future spot rate to be assumed by the researcher and the proxy measures the dispersion of the actual exchange rate at time period t from its expectation for period t, formulated on an information set available at time period t-n. The forward exchange rate has been used as a proxy for the expected future spot rate (Hooper and Kohlhagen, 1978; Justice, 1983; Cushman, 1988).[40] Hooper and Kohlhagen (1978) use the average absolute difference between the current spot rate and the lagged forward rate for the thirteen weekly observations of a given quarter. This measure therefore proxies exchange rate uncertainty by the average absolute forward forecast error. The standard deviation of the residuals from an AR(1) model of the exchange rate has been used by Kenen and Rodrik (1986). The residuals are assumed to represent the exchange rate forecast errors from the model, assuming the lagged spot rate acts as a proxy for the expected future spot rate, so that the proxy for exchange rate uncertainty is calculated from the variability of the forecast errors. Similarly, Asseery and Peel (1991) have used the squared residuals from an ARIMA process fitted to the real effective exchange rate.

In order to provide a benchmark from which to compare the different measures of exchange rate variability (uncertainty) section 4.2 provides a formal definition of risk and uncertainty following the work of Knight (1921). The distinction between risk and uncertainty arises from the information base which agents have when calculating the probability of an event occurring. Under risk, the information set is insufficient to calculate probabilities, whereas under uncertainty the level of information is insufficient. In section 4.3 we begin our survey of the variability measures by discussing the significance of the standard deviation measure in the context of the mean-variance

40. The use of the forward exchange rate as a proxy for the expected future spot rate follows the literature on the Efficient Markets Hypothesis (Fama, 1970), which when applied to the foreign exchange market suggests that the forward exchange rate should be an unbiased predictor of the future spot rate. Deviations between the current spot rate and the lagged forward rate reflect new information between the time period the expectation was formed and the actual realization of the future spot rate.

model (Tobin, 1958 and Markowitz, 1959). The model is applied to the problem of the decision making process of exporters operating under conditions of foreign exchange risk. This section ends with a critical analysis of the mean-variance model. Section 4.4 reviews the advantages and disadvantages of the various measures of exchange rate variability suggested by the literature. The main factors to be noted when selecting a variability measure are also considered. Section 4.5 provides concluding comments.

4.2 Risk vs Uncertainty

The original distinction between risk and uncertainty was made by Knight (1921). Knight argued that risk refers to events when the probability of a particular outcome occurring could be calculated, while uncertainty refers to events when it is not possible to calculate probabilities.

In order to clarify the distinction between risk and uncertainty Knight defined three types of probability. Firstly, *a priori* probability, which is a mathematically based calculation derived deductively from a homogenous group of outcomes. This definition of probability can only be calculated mathematically, for example from games of chance e.g. a toss of die.

Secondly, statistical probability, which is calculated from empirical interpretation of relative frequencies, for example as in car insurance. Such probabilities are usually estimated from the results of a sample of possible outcomes based on past experience and from a classification of outcomes which are not homogenous. Given the non-homogenity of possible outcomes the calculation of probabilities also needs to be supplemented with a subjective judgement, so as to establish whether the event being analysed is significantly different from the sample of events used to estimate the statistical probability. The accuracy of statistical probabilities is dependent upon the level of available information.

The difference between *a priori* and statistical probability thus depends upon the accuracy of classifying groups of outcomes. With the *a priori* methodology, probability can be calculated from general principles using a groups of outcomes which are known with certainty. Statistical probability can only be calculated empirically from a range of outcomes, the precise details of which are not clear.

The third type of probability are estimates, which are calculated when there is insufficient information to calculate statistical probabilities, either from a homogenous or non-homogenous classification of outcomes. However, Knight argued that with such events agents would calculate probabilities which are subjective in nature, but which cannot be related to a classification of possible outcomes. As Knight notes:

> *'The subjective probabilities are similar to the true probabilities: "The individual..........throws his estimate of the value of an opinion into the probability form of 'a successes in b trials' (a/b being a proper fraction) and feels toward it as toward any other probability situation'.*
>
> (Knight, 1921, p. 234).

Knight also classified the above three types of probability into either objective or subjective probabilities. Objective probabilities are calculated either deductively or because there is a sufficiently large sample of events that differences in outcomes are negligible. Subjective probabilities are estimated in cases where statistical or deductive methods cannot be used. Knight argued that many business decisions would deal with situations which are sufficiently unique that the probability of success or failure cannot be calculated, since a range of possible outcomes cannot be derived.

The original interpretation of Knight's work identified objective probabilities as being consistent with conditions of risk and subjective probabilities being consistent with conditions of uncertainty. As Friedman (1976) notes:

> *"In his seminal work, Frank Knight drew a sharp distinction between* risk, *as referring to events subject to a known or knowable probability distribution and* uncertainty, *as referring to events for which it was not possible to specify numerical probabilities."*
>
> (Friedman, 1976, p. 282)

LeRoy and Singell (1987), however, have argued that the significance of Knight's risk-uncertainty distinction is not demonstrated by the calculation of either objective or statistical probabilities but whether insurance markets are present or not. Under conditions of risk, probabilities can be calculated from a classification of possible outcomes, so that insurance markets exist to avoid risk. Under conditions of uncertainty the uniqueness of events means that only individuals can formulate their own subjective probabilities and the information set used for calculation is not publicly verifiable. As supporting evidence they quote from Knight that:

> *'...insurance markets fail when there exists no public way to verify whether the event insured against has occurred or evaluate the magnitude of the loss'.*
>
> (Knight, 1921, p. 234).

Under risk the information set can be verified from a known probability distribution.

LeRoy and Singell also argue that Knight's work can be viewed as providing an early interpretation of the economics of asymmetric information. For example, they note that in explaining why insurance markets could not cover most business decision making Knight commented:

> *'The classification or grouping [required for insurance cover] can only to a limited extent be carried out by any agency outside the person himself who makes the decisions, because of the peculiarly obstinate connection of moral hazard with this sort of risk'.*
>
> (Knight, 1921, p. 251)
> [Taken from LeRoy and Singell, 1987, p.400]

The uninsurability of business enterprise was also explained through adverse selection:

> *'We have assumed ...that each man in society knows his own powers as entrepreneur, but that men know nothing about each other in this capacity....The presence of true profit, therefore, depends...on the absence of the requisite organization for combining a sufficient number of instances to secure certainty through consolidation. With men in complete ignorance of the powers of judgement of other men it is hard to see how such organization could be effected'.*
>
> (Knight, 1921, p. 284-285)
>
> [Taken from LeRoy and Singell, 1987, p.401]

Another interpretation of Knight has been provided by Langlois and Cosgel (1993), who argue that uncertainty arises out of partial knowledge, which in turn occurs because of the inability of economic agents to classify states of nature i.e. the known outcomes of events. As a result uncertainty may still exist when there is asymmetric information. For example, in the presence of adverse selection, it is possible for buyers and sellers of cars to be aware of the instances of good cars and bad cars (lemons) and thus to classify these instances, although they are not easily detected. Consequently, *'uncertainty as Knight understood it arises from the impossibility of exhaustive classification of states'* (Langlois and Cosgel, 1993, p. 459).

How can these interpretations be applied to the foreign exchange market and international trade? Following the LeRoy and Singell (1987) interpretation, risk would exist when forward markets are available to cover foreign exchange transactions. Uncertainty arises when forward markets are not sufficiently sophisticated to provide complete cover or do not exist at all. Using the Langlois-Cosgel (1993) interpretation, risk would generally apply to international trade. For example, exporters and importers would be able to classify whether they would profit, break-even or lose money from international trade. Uncertainty would only arise when traders could not classify the possible outcomes.

4.3 Mean - Variance Analysis

The traditional approach to measuring risk / uncertainty was to rely upon the variance or standard deviation of a particular random variable, $\bar{\pi}$. This application was inspired by the development of the mean - variance analysis (Tobin, 1958 and Markowitz, 1959). Economic agents are assumed to maximize expected utility which is a function of expected profits (μ_π) and the variance of profits (σ^2_π). Each individual perceives a range of possible profits, each carrying with it a particular probability of becoming reality. The mean of the distribution is assumed to reflect the agent's expected future profit, the variance of the distribution reflects the risk / uncertainty that the expectation will be correct. To derive the main results of the mean - variance analysis we must assume that either the expected utility function is of a quadratic form[41] or that the distribution of the profit variable $\tilde{\pi}$ is normal (Borch, 1969 and Feldstein, 1969).[42] The expected utility function is defined as follows:

$$E[U(\pi)] = \alpha\mu_\pi + \gamma\,(\sigma_\pi^2)^{1/2}; \qquad \alpha,\gamma>0; \qquad U'(\pi)>0;\ U''(\pi)<0 \qquad \textbf{..4.3.1}$$

where α is a positive constant and γ is a constant which reflects risk preferences. Typically it is assumed $\gamma<0$, inferring risk aversion.[43] Economic agents are assumed to gain more utility from higher levels of profit, so that the marginal utility of profit, $U'(\pi)$ is strictly positive for all π. However, the marginal utility of profit tends to zero as profit increases, so that the rate of change of marginal utility with respect to profit is strictly negative i.e. $U''(\pi)<0$.

In maximising expected utility, each agent is assumed to trade off higher expected profits against higher variability of profits reflecting greater risk. Thus for example, an exporter or importer would determine the optimal allocation of a certain asset (e.g. domestic trade) and a risky asset (e.g. foreign trade which is subject to exchange rate fluctuations) at the point of maximum expected utility.

To apply the mean - variance analysis to the international trade literature, consider figure 4.1. A representative exporter is assumed to sell their production in both domestic and foreign markets. The only form of uncertainty facing the exporter is the unpredictable nature of exchange rate movements. Total profits are therefore a random

41. For a proof of why a quadratic utility function is a necessary condition see Machina and Rothschild (1987).
42. Because of the symmetry attached to the normal distribution, information about the mean and variance allows calculation of the probability for each profit. Without this symmetry the result does not hold. If the distribution was non-normal, information about the degree of skewness and kurtosis in the distribution would have to be incorporated into the estimation of the expected future profit rate.
43. If $\gamma=0$ the individual is risk neutral and if $\gamma>0$ the individual is a risk lover.

variable, $\tilde{\pi}$, consisting of deterministic profits earned on the domestic markets, π_D and stochastic foreign profits which are subject to exchange rate fluctuations, $\tilde{\pi}_F$. The objective of the firm is to trade off the higher expected profits from increased exports with the higher risk as the foreign profits are exposed to exchange rate fluctuations. The exporter's utility function is strictly concave, reflecting risk aversion and a diminishing marginal utility of profit i.e. $U''(\pi)<0$.

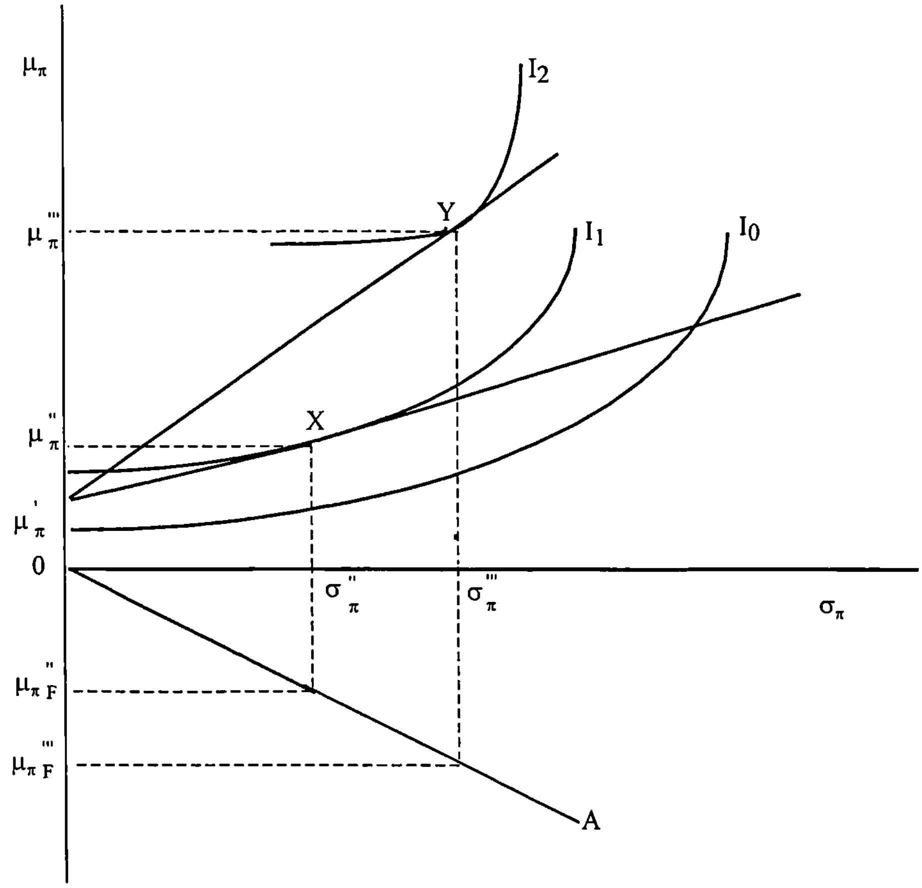


Figure 4.1: The Mean - Variance Model

Thus the indifference curves are strictly convex and the slope of each curve reflects the degree of risk aversion. The indifference curve map is upward sloping reflecting that higher risk (σ_π) may only be compensated by higher expected profits (μ_π). The greater the degree of risk aversion, the steeper the indifference curves and thus the greater the compensation needed to accept risk. The schedule labelled A in the lower portion of the diagram indicates the extent to which the exporter is willing to engage in foreign trade, from the ratio of expected profits from exporting to the standard deviation of profits. Expected profits are subject to no risk at the point μ'_{π}. Here the exporter will either be selling only on the domestic market or selling abroad subject to no risk e.g. because all profits are covered on the forward market. Any higher level of uncovered profit from exporting will involve taking a risk position. At the exporter's optimal position he (she) is compensated for bearing an additional unit of risk by higher expected profits. This utility maximising point occurs, for example, at X where the utility of a marginal increase in expected profits is just equal to the marginal loss in utility because of the increase in the share of expected profits exposed to risk. Here the expected profits earned from international trade are $\mu''_{\pi F}$. To further participate in international trade, the exporter would need to receive higher expected profits of say $\mu'''_{\pi F}$ to compensate for the higher degree of risk, σ'''_{π}, where Y is the utility maximising point. Any increase in risk or in the degree of risk aversion will lower the volume of exports.

It is useful to consider some of the limitations of the mean - variance framework. Firstly, the quadratic utility function is a restrictive specification, since Tobin (1958) notes that in order to ensure positive marginal utility the following conditions must hold:

$$\pi \geq -(\alpha/2\gamma) \text{ for } \gamma>0 \text{ i.e. risk lover} \quad \textbf{..4.3.2}$$

$$\pi \leq -(\alpha/2\gamma) \text{ for } \gamma<0 \text{ i.e. risk averter} \quad \textbf{..4.3.3}$$

The implication of this result is that if the profit level violates these requirements, then the individual would gain more utility from obtaining less profit than gaining more. Secondly, utility will decline as profit increases beyond $\gamma/2$, when an individual is risk averse. Thirdly, the quadratic utility function also imposes the restriction that all higher derivatives of the function than the second are zero.

A further problem is that if the individual's utility function is not quadratic then the indifference curves need not be convex to the origin, even if the subjective probability distribution is a member of a two parameter family (Feldstein, 1969). Feldstein has shown that if the utility function is log-normal, then the indifference curves will only be convex in part and concave after a point. The implication of this result is that the risk preferences of the individual will change from being risk averse at a low level of profit to being a risk lover for higher levels of profit. Rothschild and Stiglitz (1970) have also shown that if agents' preferences are partially ordered, then the risk aversion of an individual will change sign as σ_π changes i.e. there are individuals with concave utility functions who gain more utility with an increase in the amount of risk. By contrast the mean - variance quadratic utility function infers a complete ordering of preferences e.g. if the profit distributions, π_1 and π_2 have the same mean, the individual will prefer π_1 to π_2 if and only if $\sigma_{\pi 1}<\sigma_{\pi 2}$.

The quadratic utility function assumed in the mean-variance analysis produces the result that the second order derivative of utility with respect to profit is strictly negative. However, using $U''(\pi)$ as a measure of risk aversion suffers from the problem that if $U(\pi)$ is multiplied by a positive constant then $U''(\pi)$ changes in the same proportion. For the second order derivative to be a reliable measure of risk aversion, marginal utility should fall to reflect the aversion to risk from the greater risk attached to the higher profits. In an attempt to alleviate this problem Arrow (1965) and Pratt (1964) have devised coefficients of absolute and relative risk aversion which are invariant to the aforementioned problem:

$$R_A(\pi) = - U''(\pi)/ U'(\pi)\ U[\pi-E(\pi)] \qquad \text{absolute risk aversion} \qquad ..4.3.4$$

$$R_R(\pi) = - \pi U(\pi)''/ U'(\pi)\ U[\pi-E(\pi)] \qquad \text{relative risk aversion} \qquad ..4.3.5$$

If $U(\pi)$ is multiplied by a positive constant both $U(\pi)''$ and $U(\pi)'$ will change by the same amount. The coefficient of absolute risk aversion provides a direct measure of risk aversion while the coefficient of relative risk aversion is an elasticity measure of the marginal utility of profit. However, a problem with the absolute and relative risk aversion measures is that they cannot be used when agents have a portfolio with many risky assets. Cass and Stiglitz (1970) have extended the Arrow - Pratt measure to take account of a portfolio which has one safe asset and two risky assets where an investor has increasing relative risk aversion allocates more of his profit to risky assets as profit increases.

4.4 The Measurement of Foreign Exchange Risk / Uncertainty and Exchange Rate Variability

In producing the large number of proxies suggested by the international trade literature, economists have attempted to measure the degree of foreign exchange risk or exchange rate uncertainty. Akhtar and Hilton (1984) note that foreign exchange risk / uncertainty *'may be thought of as a state of doubt about the future behavior of exchange rates'*, (Akhtar and Hilton, 1984, p. 3). Empirical research has either attempted to derive a proxy for exchange rate risk/uncertainty directly or indirectly through using proxies for the variability of *ex-post* movements in the exchange rate.

The proxies for foreign exchange risk / uncertainty used in the literature have measured the deviation of the actual exchange rate from its expected value. A number of studies have used the lagged forward rate as a proxy for the expected future spot rate. Usually researchers take an average of the deviations over a period of time e.g. daily, weekly, or monthly spot-lagged forward rate deviations can be used to calculate a quarterly measure of exchange rate risk / uncertainty. For example, to estimate a quarterly measure, Hooper and Kohlhagen (1978) calculate the average of thirteen weekly spot-lagged forward rate deviations.

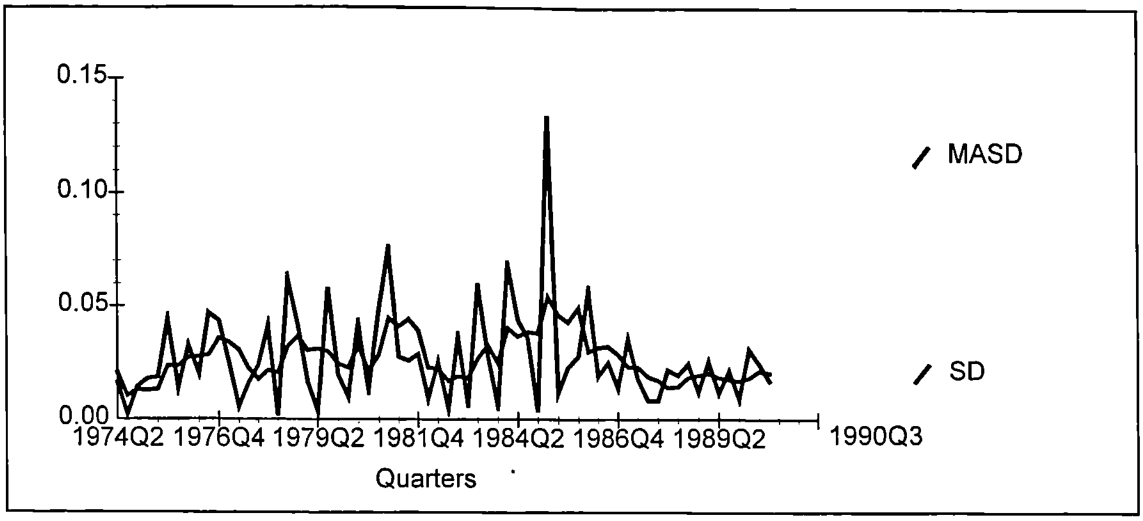
More commonly empirical studies have used measures of exchange rate variability in an attempt to depict the unpredictable movements of exchange rates. However, as we mentioned earlier, variability measures can only calibrate the dispersion of *ex-post* exchange rate movements, not the *ex-ante* forecast errors in predicting the future exchange rate. A significant proportion of the early empirical research used the standard deviation (or variance) of the exchange rate (or its percentage changes) measured within a specified period of time (see for example Abrams, 1980; Cushman, 1983; IMF, 1984; Kenen and Rodrik, 1984). Other measures used since then include the moving average standard deviation (Cushman, 1983; Koray and Lastrapes, 1989; Lastrapes and Koray, 1990) and deviations of the exchange rate from its estimated trend (Abrams, 1980; Thursby and Thursby, 1987). The Gini Mean Difference Coefficient (Kumar and Dhawan, 1991) and Generalised Autoregressive Conditional Heteroscedasticity processes (Kroner and Lastrapes, 1993; Caporale and Doroodian, 1994; Holly, 1995) have also been used to account for the distribution characteristics of the exchange rate.

Each of the various measures of exchange rate variability measures have their own specific characteristics and may therefore be expected to capture different impacts on trade volumes and prices. For example, consider figure 4.2, which plots the standard deviation of the Deutschemark/Sterling exchange rate based on monthly observations for a given quarter. The second measure is a four quarter moving average standard deviation. The sample period is 1974 Q2 to 1990 Q3. Comparing the two proxies it is apparent that the moving average measure produces a far smoother series than the standard deviation. The fluctuations in the moving average measure are far less extreme. The largest fluctuations in the standard deviation are significantly smoothed out by the moving average. The induced autocorrelation in the moving average also means that fluctuations in the standard deviation are prolonged for the next four time periods. For example between 84Q4 and 85Q1 there is a very large increase in the standard deviation. This very large increase only lasts one time period and the standard deviation returns to a lower value in the next time period. At 85Q1 the moving average is at its peak and remains around this level for the next four quarters.

The purpose of this section is to compare and contrast the various variability / uncertainty measures used in the literature. This survey is undertaken by means of considering the factors applied researchers should note when selecting an appropriate proxy. Unfortunately, the wide variety of circumstances in which the different measures need to be used and their varying characteristics means that it is impossible to derive an 'ideal' proxy for use in all cases.

A summary of the main measures of exchange rate variability and foreign exchange risk / uncertainty is provided in Appendix B, together with the characteristics of each proxy.

Figure 4.2 Standard Deviation of the Percentage Changes Deutschemark /Sterling Exchange Rate and Four Quarter Moving Average Standard Deviation, 1974Q2-1990Q3.



4.4.1 The Distribution of the Exchange Rate

As mentioned in section 4.3, when using the mean-variance framework to analyse the decision making of agents under conditions of risk / uncertainty, it was assumed that either the expected utility function was of a quadratic form or that the distribution of profits was normal. Similarly, to use the standard deviation as a measure of exchange rate reliability also depends on the assumption that the distribution of the exchange rate is unimodal and symmetric about the mean. The standard deviation can act as an erratic and misleading measure if the exchange rate distribution is asymmetric, since it gives more weight to extreme observations. Empirical evidence (McFarland, Pettit and Sung, 1982; Rana, 1981; and Westerfield, 1977) suggests that the distribution of many exchange rates can be leptokurtic (has 'fat tails') and that changes in the exchange rate tend to be extended over time so that volatility clustering occurs. Consequently, the distribution of the exchange rate may include a larger number of extreme observations than is expected to exist for a normal distribution. Fama and Roll (1971) show that when the exchange rate conforms to a non-normal distribution, the standard deviation is unstable and does not converge to a normal distribution as the sample size increases.

Westerfield (1977) found that the distribution of changes in a number of US dollar exchange rates were non-normal for periods of both fixed and floating exchange rates. The sample periods used were January, 1962 to April, 1971 and March, 1973 to July, 1975 and the weekly spot rate and one, two and three month forward exchange rates were calculated. The kurtosis measures (i.e. the fatness of the tails) of the distribution of exchange rate changes suggest a high degree of leptokurtosis compared to a normal distribution, although the distributions were found to be approximately symmetric. Using Chi-squared tests to measure the goodness of fit of alternative probability models, Westerfield found that the US-dollar exchange rate changes closely approximated a non-normal stable Paretian distribution. Furthermore,

> *'The sample distribution for rate changes appear to differ from a normal distribution in several ways. First of all, the number of observations in the tails is much larger than expected under the normal; that is, the probability of large positive and negative changes is greater. Secondly, the data distributions are more peaked in the center, and thus in the remaining areas between the center and the tails, the number of observations are fewer than expected'.*
>
> (Westerfield, 1977, p. 189).

To account for the 'fat tails' Westerfield utilised Gini's mean difference coefficient, which is a measure of absolute dispersion, calculated from the average of the absolute differences between the two observations in every possible pair of values.

Rana (1981) has also utilised the Gini coefficient to measure nominal and real variability of the effective exchange rates of eight developing countries.[44] Again leptokurtosis was found to be a significant problem for each exchange rate distribution analysed (i.e. the estimated kurtosis measure is significantly greater than three, the value for a normal distribution). Chi-squared tests also suggest a symmetric stable Paretian non-normal distribution. Rana estimated two alternative measures of variability: firstly, 44 per cent of an interfractile range and secondly, Gini's mean difference coefficient. Both measures indicate a significant increase in variability from fixed periods (July, 1967 to August, 1971) to floating rates (March, 1973 to May, 1977). The two measures indicate that nominal and real exchange rate variability increased over the floating period for all countries in the sample, while the standard deviation measure suggests a reduction in real terms for Malaysia, Nepal and the Philippines in both nominal and real terms. The distortion created by the standard deviation measure was found to be more pronounced under the pegged period, since a larger number of extreme observations existed in the tails of the distribution.

Brodsky (1984) has criticized the non-parametric measures used by Rana for ignoring the importance of extreme observations. Brodsky argues that the 44 per cent of an interfractile range excludes the lower 28 per cent of the distribution and the upper 28

44. The countries analysed are India, South Korea, Malaysia, Nepal, Philippines, Singapore, Taiwan and Thailand.

per cent. Secondly, the Gini coefficient gives equal weight to all observations regardless of size, again ignoring the importance of the extreme observations. Consequently,

> *'The choice of an appropriate measure of instability must instead be based on one's subjective value judgements concerning the nature of instability. In particular, if economic agents are risk averse, as is commonly assumed, then the 'erratic and misleading' results given by the standard deviation were seen to be entirely reasonable'.*
>
> (Brodsky, 1984, p. 301)

Some applied researchers have attempted to avoid the problem of extreme observations by smoothing the data series. One approach has been to calculate a moving average of the variability measure (see for example Bailey, Tavlas and Ulan (1987); Chowdhury (1993)). This method takes account of lags of the variability measure, ranging from four quarters (Cushman, 1983; Justice, 1984) to eight quarters (Chowdhury, 1993). However, Hsieh (1988) has argued that usually the standard deviation of the exchange rate does not usually exhibit a long pattern of serial correlation to justify incorporating lags of up to eight quarters.

A more recent approach has been to measure risk as a conditional variance process (see for example Pozo, 1992; Kroner and Lastrapes, 1993; Holly, 1995). The ARCH and Generalised ARCH processes measure exchange rate volatility from the squared residuals of a defined model of the exchange rate, which are assumed to be dependent on lagged squared residuals and perhaps lagged values of the conditional variance. The conditional variance approach has the advantage of accounting for leptokurtosis in the exchange rate distribution and 'volatility clustering', where small currency price changes tend to be followed by small changes and large changes are followed by large changes. However, conditional heteroscedasticity processes also have a tendency to smooth the variability series and like the moving average may lead to an understatement of the degree of exchange rate uncertainty.

4.4.2 The Sample Frequency of Data

An important consideration in estimating measures of exchange rate variability is the frequency of data used. Unlike many other economic series, exchange rate data is available in a wide variety of frequencies. Most studies in the international trade literature have utilised daily, weekly or monthly exchange rate data. Using higher frequency data has the advantage of more observations and thus a more comprehensive information set being used to calculate variability, in particular with respect to the trends and patterns in exchange rate movements over a given period.

However, a difficulty arising from the use of daily and weekly data concerns the day of the week effect on measurement. McFarland, Pettit and Sung (1982) examine the distributional characteristics of daily and weekly changes in spot and forward exchange rates, over a floating period, 2nd January, 1975 to 29th June, 1979. The empirical evidence suggests that there are significant differences in the distribution of exchange rates according to the day of the week. In particular, Monday and Wednesday foreign exchange trading were found to have higher average price changes than those of the rest of the week. The higher returns on Wednesday and lower returns on Thursday are due to settlement procedures existing in the foreign exchange market. The large movements in exchange rates on Monday are explained by a flow into the US dollar by the time Friday's price is announced through to the time Monday's price is reported. Statistics for weekly price changes also suggest a non-normal distribution. Moreover, the degree of non-normality varies significantly for weekly changes according to which day of the week and which currency is being used.

In addition to day of the week effects, the time of the day at which exchange rate data is measured should also be considered. For example, McFarland, Pettit and Sung (1982) measure their exchange rate data at 1:00 pm. on the trading day for the New York Interbank Market. Other published sources (e.g. Bank of England Quarterly Bulletin) measure daily exchange rate data at the close of trading. During a typical day of trading the volume of activity varies significantly, which clearly affects the reported currency price. Whether this creates a problem for the applied researcher, depends upon the frequency of data being used and the length of the sample period being used to examine the impact on international trade.

When using lower frequency data a number of factors need to be considered. Firstly, how the data is calculated. Published monthly and quarterly exchange rate data are usually calculated as an average of daily observations. The data may therefore smooth out the extreme fluctuations over the month or quarter and may consequently understate the degree of exchange rate variability, compared to higher frequency data. Lower frequency data, however, has the advantage of reducing the degree of distribution non-normality (Baillie and McMahon, 1989). If quarterly or annual data is used there may be a tendency to pick up medium term misalignments rather than purely short term exchange rate variability.

4.4.3 The Time Period of Variability

A related issue to the above concerns the length of the time period over which the exchange rate variability should be measured i.e. whether on a daily, weekly, monthly, quarterly or annual basis.

The advantage of using high frequency data is that it demonstrates how firms are affected by variability continuously on their day to day transactions. Risk exposure, however, may only need to be measured over a period of months, to reflect movements in exchange rates over a contract period. Alternatively, exporters and importers may only be concerned with persistently high levels of exchange rate variability which influence their long term strategic decision making (e.g. location decisions; market diversification etc.). In this instance annual movements in exchange rates may be more appropriate. This would especially be the case if firms can easily absorb the costs of forward cover on their transactions.

Consequently, since traders face different planning horizons, it is likely that there can be no single correct time period for gauging exchange rate variability.

4.4.4 Nominal vs Real Exchange Rates

In the measurement debate, the decision as to whether exchange rate variability should be based on the nominal or real exchange rate is also a key issue. The real measure allows changes in relative prices to offset movements in nominal exchange rates. Thus, real variability is believed to be lower than nominal exchange rate variability. This conclusion depends upon the extent to which Purchasing Power Parity (PPP) theory can be used to predict nominal exchange rate movements. However, some researchers (Lanyi and Suss, 1982; Justice, 1983; and Akhtar and Hilton, 1984) have discovered that over most of the floating period real exchange rate variability exceeded nominal variability. Empirical evidence also suggests persistent deviations of nominal exchange rates from PPP, so that the relationship between price movements and nominal exchange rates cannot be determined *ex–ante*. Akhtar and Hilton (1984) also argue that whether real exchange rate variability would be lower than nominal variability depends upon the magnitude of the negative co-variance between relative prices and nominal exchange rate changes.

> *'Given that domestic influences on national price levels are very large, it is entirely plausible that the negative co-variance would not be sufficiently large to provide a significant offset to nominal exchange rate variability. Recent studies by Kenen and Rodrik (1979) and Lanyi and Suss (1982) strongly confirm this impression'*
>
> (Akhtar and Hilton, 1984, p. 23)

Given this difficulty, Medhora (1989) has argued that the variability of exchange rates and relative prices should be measured individually so that their separate effects can be analysed. Combining these two elements together in a measure of real exchange rate variability can generate an unreliable proxy, since the aggregate measure conceals the individual elements of variability. For example, if a change in relative prices completely offsets the exchange rate changes, the real measure would indicate zero uncertainty, when in practice both elements are working in opposite directions. Evidence from the recent floating period (Lanyi and Suss, 1982; Akhtar and Hilton, 1984) also suggests that real and nominal exchange rates move closely together over time and that the majority of changes in real exchange rates are expected to occur because of changes in nominal exchange rates. One possible explanation for this phenomenon could be that many internationally traded goods are differentiated in their characteristics and sold in imperfectly competitive markets. Consequently, given the market power of exporters, goods prices, denominated in domestic currency terms, tend to be 'sticky' in their movement relative to nominal exchange rates (Bank of England, 1984).

4.4.5 Effective Exchange Rates

The effective exchange rate of a given currency is a weighted average of its exchange rate relative to a basket of currencies. The weights are often defined from the proportion of a country's trade with the trading partners defined from the basket of currencies used to calculate the exchange rate index. Effective exchange rates are often used in aggregate trade data studies to reflect the variability effect for a whole economy.

The first issue in measuring the variability of effective exchange rates is how to calculate the index. The effective exchange rate index is calculated by averaging in some way individual bi-lateral rates, using weights to reflect either the volume of trade or external transactions. Lanyi and Suss (1982) note that effective rate variability can be measured by estimating the individual variabilities and 'weighted-averaging' them in some way; or, alternatively, calculating the variability of a weighted index of bi-lateral exchange rates can be calculated (i.e. the variability of the effective exchange rate). While the latter method is generally the most common, as with other variability measures, the issue of whether the nominal or real (relative price adjusted) exchange rate should be used remains to be resolved. This choice will often be based upon the purpose for which the measure is being used for.

Using either method also raises the question of how to weight an index. A variety of weighting schemes have been used in the literature. Most commonly the weights are based on the volume of trade with partner countries[45] or the volume of use of currencies for external transactions. A number of studies have used the IMF's definition of the effective exchange rate index. The weights are calculated using the Fund's Multilateral Exchange Rate Model (MERM).

Whichever weighting scheme is used a certain quantity of information is removed from the averaging process of the individual bi-lateral exchange rates used to calculate the effective exchange rate index. Taking an extreme example, if an exchange rate index includes two major exchange rates, one appreciating and the other depreciating simultaneously a stable index may result. However, exporters or importers may face large swings in profits, depending on the degree to which they are linked to trade in the two specific markets during the relevant period.

Indices calculated from a weighted average of exchange rate variability also typically ignore the co-variance between the variability of two exchange rates. Using a simple weighted average ignores the fact that movements in exchange rates are correlated with other exchange rates. This co-variance could be usefully employed to isolate that proportion of variability of individual exchange rates which is independent of movements in other exchange rates.

45. These weights may include the volume of exports or imports, an average of import or export volumes over a sample period or global trade weights.

4.4.6 Exchange Rate Regimes

Applied research on the impact of exchange rate variability on international trade should also take account of any formal policy rules and arrangements which are likely to influence the pattern of exchange rate movements. Under floating exchange rates, the observed variability of exchange rates occurs because of movements in market fundamentals (e.g. money supply and real income) and market expectations about the future direction of currency prices. Under quasi-fixed or target zone systems expectations of currency realignments also need to be considered. As market participants continually revise their expectations about the timing and magnitude of a possible realignment, exchange rates can rise and then fall, thereby contributing to volatility. Ultimately these expectations are influenced by the credibility of the target zone system and whether policy makers will realign. Realignments are mainly expected to occur when the exchange rates diverge from the economic fundamentals. Between realignments, exchange rate variability will tend to be within 'normal' limits, but is likely to increase when realignments are expected to occur.

Thus, in measuring foreign exchange risk / uncertainty under a target zone system estimation of the expected spot rate should also incorporate some proxy of market expectations about possible realignments. One proxy is the forward exchange rate. Evidence from many of the EMS exchange rates suggests that the forward rate floats outside the upper and lower bands, reflecting market expectations about the future spot rate once a possible realignment occurs. If market participants believe that a realignment is imminent uncertainty about the future spot rate may be extreme. Researchers may therefore need to take account of a larger number of outlier observations than if the exchange rate was normally distributed. Indeed evidence suggests that the distribution of EMS exchange rates differs significantly from that of floating currencies (Vlaar and Palm, 1993). Consequently, it is also advisable to avoid mixing sample periods of fixed and floating regimes when attempting to derive a reliable variability measure.

4.5 Conclusions

This chapter has highlighted some of the key issues that applied researchers should consider when attempting to measure exchange rate variability or foreign exchange risk/uncertainty. The above survey of the literature has suggested that a number of characteristics of variability measures are important. Firstly, **the chosen measure should act as a proxy for exchange rate risk / uncertainty**. Thus a proxy for the unanticipated exchange rate could be utilised, such as the lagged forward exchange rate. If only variability is estimated then the 'true' degree of risk / uncertainty may be to be understated if movements in exchange rates are relatively predictable.

Secondly, **a decision should be made over whether to use nominal or real exchange rates**. If relative prices are likely to offset movements in nominal exchange rates, then the real exchange rate should be used. If, however, movements in goods prices are 'sticky' compared to nominal exchange rates, then little additional information will be provided by using the real exchange rate. In this instance it may be appropriate to enter the 'variability of nominal exchange rates' and 'relative prices' as separate independent variables in a model of trade volumes and /or prices so that the two effects can be isolated.

Thirdly, before proceeding to calculate a variability measure **it is useful to examine the distribution characteristics of the exchange rate**. If the distribution shows evidence of leptokurtosis, then the larger number of extreme observations should be accounted for. Exchange rate movements may also show evidence of volatility clustering in this case. Under different policy regimes the distribution of the exchange rate is likely to shift. It is therefore not advisable to mix sample periods of fixed and floating exchange rates, since the chosen measure is likely to give misleading results.

Fourthly, **the sample frequency of the exchange rate data should also be considered**. High frequency data has the advantage of a more comprehensive information set being used in the calculation of the variability measure. However, this may be at the expense of a greater degree of distribution non-normality, since a larger number of extreme observations may be included. Lower frequency data may reduce the non-normality since the chosen data series is likely to include fewer extreme observations, either because of smoothing the data series due to averaging or the time period of measurement e.g. end of the month. Applied research should also gauge the length of time period required to measure exchange rate movements e.g. day to day movements vs quarterly movements.

Finally, **using aggregate trade data applied researchers will most likely choose to utilise an effective exchange rate index**. Recent research has provided no definitive weighting scheme to calculate the effective exchange rate. The choice of weighting scheme is likely to depend upon the individual study.

Chapter Five

Econometric Methodology

Abstract

This chapter surveys the recent cointegration literature to provide a framework for the empirical research presented in later chapters. A formal analytical treatment of the Johansen procedure (Johansen, 1988) is provided, followed by a discussion of the structural identification problems associated with the estimation of unrestricted Vector Autoregressive Error Correction Models (VECMs) (Wickens, 1996). An empirical framework is then suggested which (i) provides long-run structural estimates using the recent ARDL approach to cointegration (Pesaran, Shin and R. J. Smith, 1996) and (ii) uses a restricted VECM approach to test for structural identification with systems of equations (Pesaran and Shin, 1997b).

5.1 Introduction

In this chapter we outline the econometric methodology to be used for the empirical research presented later in the thesis. The majority of empirical studies surveyed in chapter three made the assumption that the data used for estimation were stationary (i.e. the time series fluctuates around a constant mean with a finite constant variance and constant co-variance). The recent development of cointegration analysis has provided a framework which allows the modelling of long-run equilibrium relationships when the data used for estimation is non-stationary (where either the mean, variance or co-variance fluctuates over time). The spurious regression problem (Granger and Newbold, 1974) suggests that the use of standard inferential methods with non-stationary variables is inappropriate. A superficially statistically significant relationship may be detected in a regression model, when in fact no meaningful causal relationship exists, only contemporaneous correlations between the trends in the data. Following the work of Engle and Granger (1987), a statistically significant unique cointegrating vector can be found if the relevant variables are integrated of the same order[47] and the residuals from the cointegration equation (which define the convergence to long-run equilibrium) are I(0).

One of the main advantages of the Engle-Granger methodology is that OLS methods can be utilized to estimate the long-run model, from which an error correction model can be generated to model the short-run dynamics. However, the use of this methodology is conditional upon the assumption that the estimated cointegrating vector is unique. In a multivariate framework Johansen (1988) has shown there can be up to n-1 cointegrating vectors.[48] Consequently, the OLS estimates will be inefficient since the estimated equation will be a linear combination of all the possible cointegrating vectors. Johansen has developed a procedure that enables identification of the number of distinct cointegrating vectors. This approach utilizes a general VECM and a reduced rank regression method, where the rank of the long-run matrix determines the number of cointegrating vectors.

47. It is often expected that time series are integrated of order one [I(1)] or possess a unit root, although this assumption requires pre-testing using, for example Augmented Dickey-Fuller (ADF) tests (Dickey and Fuller, 1979) or the Phillips and Perron Z-test statistic (Phillips and Perron, 1988). If the relevant variables are I(d), where $d>1$ then the variables can only be included in a differenced form so that the cointegration equation remains balanced. However, it may still be possible to derive at least one cointegrating vector if a linear combination of the higher order variables is integrated to the same order as the remaining variables in the cointegrating vector(s).

48. Where n is the number of variables included in the system.

While cointegration analysis generally assumes all of the variables are I(1), in some instances stationary variables may need to be used. I(0) variables should be included in the cointegrating vectors, in particular if economic theory indicates they play an important role in defining a long-run relationship. Failure to include relevant stationary variables may result in the estimates from the cointegrating vectors being subject to finite sample bias. The recent Autoregressive Distributed-Lag (ARDL) approach to cointegration can be used to estimate long-run structural equations. This estimation technique has the advantage of allowing the estimation of long-run relationships incorporating both I(1) and I(0) variables simultaneously. The unit root tests presented in later chapters will demonstrate that the measures of exchange rate variability used are stationary, while the remaining variables in the estimated system of export volumes and prices are I(1).

However, developments in the ARDL literature to date have only allowed for the estimation of long-run structural equations. In the case of systems of equations a test for identification needs to be undertaken, to establish whether the restrictions imposed on the system to derive each structural equation are supported by the data (Wickens, 1996). Unrestricted cointegrating vectors from the Johansen (1988) procedure are estimated using a reduced form VECM where all variables are assumed to be endogenous. Wickens (1996) has demonstrated that unless *a priori* information is available to impose restrictions on a VECM then the structural equations cannot be identified. The coefficients from the unrestricted cointegrating vectors cannot also be given an economic interpretation, since they will be a linear combination of the structural coefficients. Also the common stochastic trends[49] cannot be identified from the cointegrating vectors without imposing additional restrictions to those needed to interpret the cointegrating vectors. If the system is misspecified through the omission of either endogenous or exogenous variables then economic interpretation becomes even more difficult.

The empirical model estimated in chapters six and seven consists of a two equation system, an export volume equation and export price equation. The supply of exports schedule is assumed to be perfectly price elastic, so that export prices are determined independently of the volume of exports. To establish whether this assumption is correct and therefore whether the price-volume system can be identified, structural restrictions need to be imposed on the estimated cointegrating vectors.

The recent approach to long-run structural modelling by Pesaran and Shin (1997b) provides a general framework by which linear restrictions can be imposed on each of the cointegrating vectors. Their approach has the advantage of allowing restrictions to be imposed on more than one cointegrating vector at a time, where either the restriction is the same for all cointegrating vectors or where individual restrictions are imposed. This represents an advance over previous work, for example by Johansen and Juselius (1992) and Johansen (1995), where linear homogenous restrictions are imposed on one cointegrating vector at a time. Pesaran and Shin derive the rank and order conditions which are necessary and sufficient for the exact- and over-identification

49. Common stochastic trends are the source of non-stationarity in each I(1) variable, which provide the permanent shocks to the system. Thus in a system of n non-stationary variables if there are r cointegrating vectors there will be n-r common stochastic trends. The I(1) variables in the system have stationary components a linear combination of which defines the cointegrating vectors. The common stochastic trends are a linear combination of the non-stationary components (See Stock and Watson, 1988 for further details).

of the long-run structural relationships from the cointegrating vectors. In the first instance, r^2 exactly - identifying restrictions[50] are imposed. Exclusion restrictions are then imposed on each relevant cointegrating vector for the variables which are absent from a structural equation but included in the relevant cointegrating vectors. A hypothesis testing procedure can then be used to establish whether the structural restrictions are supported by the data. If the null hypothesis for all of the restrictions suggested by economic theory is rejected, then structural restrictions can be removed from the system in order to find a structural representation which is data consistent. If none of the restrictions are data admissible then the cointegrating vectors can only be interpreted as being derived from a reduced form model, the estimation results from which may be difficult to interpret in line with economic theory.

Section 5.2 presents a formal analytical treatment of the Johansen reduced rank regression method and the testing procedure for identifying the number of cointegrating vectors. Section 5.3 discusses the framework suggested by Wickens (1996) to show why structural restrictions are required to enhance the economic interpretation of the cointegrating vectors. Section 5.4 discusses the estimation procedures used for identifying and estimating the structural relationships. Section 5.5 provides concluding comments.

5.2 The Johansen Multivariate Cointegration Procedure

The recent literature has suggested a number of approaches to multivariate cointegration, such as the Phillips-Hansen fully modified least squares or instrumental

50. For example, in the two equation system estimated in later chapters, four restrictions need to be imposed on the system, two restrictions for each cointegrating vector.

variable method (Phillips and Hansen, 1988); the common stochastic trends approach (Stock and Watson, 1988); the auxiliary regression procedure (Park, 1992) and the critical bounds test (Pesaran, Shin and R. J. Smith, 1996; Pesaran and Shin, 1997a). Most commonly, applied work has used the Johansen reduced rank regression method (Johansen, 1988) to identify the number of distinct cointegrating vectors. The foundations of Johansen's work lies in the 'atheoretical macroeconomics' of Sims (1980) who proposed the use of VAR models for the purpose of estimating dynamic relationships. The VAR model is estimated in a general form so that there are no identification (or exclusion) restrictions which are generally used for identification purposes in systems of equations. Indeed such restrictions have been labelled 'incredible' by Sims, which as a consequence means that the system is expressed in a unrestricted reduced form, with all the variables being endogenous to their own previous values and the current and lagged values of the remaining variables in the system. The lag length of the VAR is set to ensure the estimated residuals are white noise. The system also requires that all variables are stationary, so that for many economic time series at least first differencing is required.

The main purpose of the empirical research presented in this thesis is to extend the original Johansen procedure to show how restrictions can be imposed on cointegrating vectors to acquire structural inferences from the estimation of reduced form VECMs. However, we will firstly discuss the original model by initially assuming a general unrestricted VAR:

$$X_t = A_1 X_{t-1} + A_2 X_{t-2} + \ldots + A_k X_{t-k} + \varepsilon_t \qquad \textbf{..5.2.1}$$

where X_t is a $(n \times 1)$ vector of economic variables which are usually assumed to be I(1). Equation 5.2.1 can be re-expressed as a vector autoregressive error-correction model:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + ... + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \varepsilon_t \qquad ..5.2.2$$

where $\Gamma_i = -(I - A_1 - A_2 - .... - A_i)$, which shows the short-run adjustment in X_t and $\Pi = -(I - A_1 - A_2 - .... A_k)$, which defines the long-run equilibrium solution. Π can be factorised as $\Pi = \alpha\beta'$, where α is a matrix of speed of adjustment coefficients from disequilibrium to equilibrium and β is a matrix of long-run coefficients. The lag length of the VAR is set to ensure ε_t is a 'white noise' error term.

It follows that if X_t is I(1)[51] then all ΔX_{t-i} will be stationary, so that for equation 5.2.2 to determine a long-run equilibrium relationship, ΠX_{t-k} must be I(0) if ε_t is to be stationary. The number of r distinct cointegrating vectors can be found from estimating the rank of Π. If the rank of Π is zero then there are no cointegrating vectors. As Darnell (1995) demonstrates if X_t was I(1) and the rank $(\Pi)=0$ then it follows that ΔX_t is stationary and $\Pi X_{t-k} \sim I(1)$ (for $\Pi \neq 0$). Given 5.2.2 is balanced this infers $\varepsilon_t \sim I(1)$. Hence, to avoid this contradiction for $\varepsilon_t \sim I(0)$, Π must be a null matrix.

If Π is full rank (i.e. r=n) then there are no non-stationary cointegrating vectors and thus all variables are stationary. In this instance there is no need for a VECM since there is no spurious regression problem and a standard Sims-type VAR model may be used. The fact that Π is full rank means the matrix has a set of n linearly independent columns. Thus if $\Pi X_t = v_t \sim I(0)$, then $X_t = \Pi^{-1} v_t$, which infers X_t is also stationary. Hence if rank(Π)=n then X_t cannot be non-stationary (See Darnell, 1995 for further details of this proof).

51. In some cases the VECM may contain I(2) variables, which will require first differencing down to I(1) variables, so that the number of cointegrating vectors can be estimated using 4.5.1. Alternatively, Johansen (1994) has proposed a two-step generalisation of the Johansen (1988) procedure which allows direct estimation of the number of distinct cointegrating vectors. I(0) series may also be included in the long-run matrix, which simply increases its rank i.e. increases the number of linearly independent columns in Π. Failure to include a stationary variable in the long-run model, may impair the small sample properties of the estimated residuals from the cointegrating vectors (Wickens, 1996).

More usually, if 0<rank(Π)<n then there are r≤n-1 cointegrating vectors. For example, if rank(Π)=1 there is a unique cointegrating vector, while if rank(Π)>1 then multiple cointegrating vectors exist.

The number of cointegrating vectors can be identified through using a reduced rank regression method, which involves re-writing 5.2.2 as:

$$\Delta X_t + \alpha\beta' X_{t-k} = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \varepsilon_t \qquad ..5.2.3$$

The short-run dynamics are then regressed on ΔX_t and X_{t-k} individually:

$$\Delta X_t = P_1 \Delta X_{t-1} + P_2 \Delta X_{t-2} + \ldots\ldots\ldots\ldots + P_{k-1} \Delta X_{t-k+1} + \eta_{0t} \qquad ..5.2.4$$

$$X_{t-k} = T_1 \Delta X_{t-1} + T_2 \Delta X_{t-2} + \ldots\ldots\ldots\ldots + T_{k-1} \Delta X_{t-k+1} + \eta_{kt} \qquad ..5.2.5$$

5.2.4 shows the stationary first differences, ΔX_t adjusted for short-run dynamics, while 5.2.5 show how the stationary level term, X_{t-k} is corrected for short-run dynamics. The residuals η_{0t} and η_{kt} show the components of ΔX_t and X_{t-k} which are not explained by the short-run dynamics. OLS could be used to provide consistent estimates of the long-run parameters if 5.2.4 and 5.2.5 were estimated separately. However, the combination of the cointegrating vectors will link the variables together. Consequently, maximum likelihood estimation must be used. The concentrated log-likelihood function can be shown to be:

$$L(\alpha, \beta, \Lambda) = |\Lambda|^{-T/2} \exp\{-\tfrac{1}{2} \sum_{i=1}^{T} (\eta_{0t} + \alpha\beta'\eta_{kt})' \Lambda^{-1} (\eta_{0t} + \alpha\beta'\eta_{kt})\} \qquad ..5.2.6$$

where Λ is the co-variance matrix. For a fixed known value of β, both α and Λ can be shown to be functions of the long-run parameters:

$$\alpha(\beta) = -S_{0k}\, \beta(\beta' S_{kk}\, \beta)^{-1} \qquad ..5.2.7$$

$$\Lambda(\beta) = S_{00} - S_{0k}\, \beta(\beta' S_{kk}\, \beta)^{-1} \beta' S_{k0} \qquad ..5.2.8$$

where the residual (product moment) matrices, S_{ij}, are given as:

$$S_{ij} = T^{-1} \sum_{i=1}^{T} \eta_{it} \eta'_{jt} \qquad \text{for } i, j = 0, k \qquad ..5.2.9$$

The following likelihood function is then minimised:

$$L(\beta) = \min |S_{00} - S_{0k}\beta(\beta' S_{kk}\beta)^{-1} \beta' S_{k0}| \qquad ..5.2.10$$

which can be shown to be:

$$L(\beta) = \min |\beta' S_{kk} \beta - \beta' S_{k0} S_{00}^{-1} S_{0k}\beta| / |\beta' S_{kk}\beta| \qquad ..5.2.11$$

Using 5.2.11, the estimates of β can be obtained through estimating the n ordered eigenvalues $\hat{\lambda}_1$, $\hat{\lambda}_2$, ...,$\hat{\lambda}_n$ of $S_{kk}S_{00}^{-1}S_{0k}$ with respect to S_{kk} from the following equation:

$$|\lambda S_{kk} - S_{kk}S_{00}^{-1}S_{0k}| = 0 \qquad ..5.2.12$$

The corresponding n ordered eigenvectors are v_1, v_2, ...v_n. The r eigenvectors which have the highest statistically significant correlation with the $\Delta X_t \sim I(0)$ elements determine the number of distinct cointegrating vectors. Thus the magnitude of $\hat{\lambda}$ indicates how strong the correlation is between the cointegration relations $v_i X_t$ and the stationary part of the model. The estimates of the long-run coefficient matrix will also be super-consistent, so that as the sample size increases the estimates of β will converge to their true value at a much faster rate than the long-run OLS estimates with stationary variables. Given 5.2.7 and 5.2.8, the estimates $\hat{\alpha}$ and $\hat{\Lambda}$ are also shown to be a function of $\hat{\beta}$:

$$\hat{\alpha}(\hat{\beta}) = -S_{0k} \hat{\beta}(\hat{\beta}' S_{kk} \hat{\beta})^{-1} = -S_{0k} \hat{\beta} \qquad ..5.2.13$$

$$\hat{\Lambda}(\hat{\beta}) = S_{00} - S_{0k} \hat{\beta} \hat{\beta}' S_{k0} = S_{00} - \hat{\alpha} \hat{\alpha}' \qquad ..5.2.14$$

Likelihood ratio tests can be used to test for the number of cointegrating vectors. For the trace test, critical values are used to test the null of H_0: r=i against the alternative H_1: r>i+1:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \log(1-\hat{\lambda}_i) \qquad r=0,\ldots\ldots\ldots,n-1 \qquad ..5.2.15$$

The maximum eigenvalue test has a sharper definition, where the null of H_0:r=i is tested against the alternative of H_1:r=i+1:

$$\lambda_{max} = -T \log(1-\hat{\lambda}_{r+1}) \qquad r=0,\ldots\ldots\ldots,n-1 \qquad ..5.2.16$$

In both cases the number of cointegrating vectors is identified through a sequential testing procedure until the null hypothesis is accepted. Each likelihood ratio test has L(n-r) degrees of freedom equal to the number of linear zero restrictions imposed on the cointegrating vectors. For each null hypothesis the likelihood ratio test is calculated from the ratio of the value of a maximized log-likelihood where a particular cointegrating vector is restricted to equal zero to the value of the unrestricted maximum log-likelihood. The L-R test has a non-standard asymptotic distribution which is a function of an n-r Brownian motion. Consequently, adjusted critical values have to be used (Johansen and Juselius, 1990; Osterwald-Lenum, 1992). However, the likelihood ratio tests can have low power, especially if the order of the VAR is misspecified (Cheung and Lai, 1993), so it may be advisable to use finite-sample critical values.

The cointegrating vectors can then be normalized to enhance the economic interpretation of the long-run coefficients. Normalization is achieved by restricting one of the estimated coefficients to equal -1 and then dividing each of the remaining coefficients by the negative value of the chosen normalizing variable coefficient. However, the economic interpretation is only enhanced in the case of a single structural equation, since we expect a unique cointegrating vector (Wickens, 1996). When r=1, the only restriction required to identify the cointegrating relation is the 'normalizing' restriction. This restriction is usually imposed on the dependent variable from the structural equation. However, if at least one endogenous variable is omitted, but a complete set of exogenous variables are included in the system, then the coefficients of the cointegrating vector will be a linear combination of the structural and reduced form coefficients. With multiple cointegrating vectors, interpretation is impossible without imposing r^2-r additional restrictions (Pesaran and Shin, 1997b). The r^2 restrictions will enable exact-identification which provides a test for statistical identification of the system. Over-identification requires additional exclusion restrictions to be imposed on the cointegrating vectors. The over-identifying restrictions allow us to test whether from the cointegrating vectors of the reduced form VECM, a data-consistent structural representation can be found. Further details about the identification procedures will be provided in section 5.4.

5.3 Identification of Structural Relationships

One of the major difficulties associated with the estimation of unrestricted VECMs concerns the economic interpretation of cointegrating vectors. In many instances cointegrating vectors reflect an underlying structural system of equations. The reduced form representation of the Johansen procedure can only recognise the interrelationships between all of the variables in the system and assumes that all variables are endogenous. To estimate a system of structural equations requires a partition of variables into those which are endogenous and weakly exogenous, as well as discarding certain variables included in the system for the estimation of a reduced form

VECM but which are not relevant to a given structural equation. The Johansen procedure can only impose and test the same restriction across all the cointegrating vectors simultaneously.

In an important contribution Wickens (1996) has demonstrated that unless *a priori* information is available to impose restrictions on a reduced form VECM then a structural system cannot be identified. The cointegrating vectors also cannot be given an economic interpretation, given the relationship between the reduced form and structural coefficients.

This problem is analysed by initially specifying a structural system, consisting of I(1) endogenous and exogenous variables. After deriving the long-run structure, Wickens demonstrates how both the short-run and long-run reduced forms can be derived. For the purpose of cointegration analysis the system is then expressed as an unrestricted VECM, which demonstrates the relationship between the reduced form coefficients and the necessary and sufficient restrictions required to derive the structural equations from the cointegrating vectors.

To appreciate fully the economic implications of this research a formal analytical treatment of the model is presented. We begin by specifying the structural system:

$$B(L)\, y_t + C(L)\, x_t = u_t \qquad \textbf{..5.3.1}$$

where y_t is an $n \times 1$ vector of endogenous variables and x_t is an $m \times 1$ vector of exogenous variables. Thus all the variables in the system can be expressed as $z_t = (y_t, x_t')'$. B(L) and C(L) are lag polynomials[52,53] and u_t is a white noise error term.

52. $B(L) = B_0 - B_1L - B_2L^2 - \ldots - B_pL^p$ and $C(L) = C_0 - C_1L - C_2L^2 - \ldots - C_pL^p$.

53. $B(0)_{ii} = 1$ for all i. B(L) has all its roots outside the unit circle [i.e. $|B_0 - B_1\lambda_1 - B_2\lambda_2 - \ldots - B_p\lambda_p| = 0$], thus yielding stable solutions for y_t.

The long-run structural equations from 5.3.1 becomes:

$$B(1)\, y_t + C(1)\, x_t = \tilde{u}_t \qquad ..5.3.2$$

where B(1) and C(1) are the long-run coefficient matrices for the endogenous and exogenous variables respectively and $\tilde{u}_t$ is I(0).

The reduced form corresponding to 5.3.1 expresses the contemporaneous endogenous variable matrix i.e. y_t in terms of only current and lagged exogenous variables and the lagged endogenous variables. To achieve this objective Wickens partitions the lag polynomial $B(L) = B(0) + \tilde{B}(L)L$, so that $B(L)\, y_t$ is expressed as:

$$B(L)\, y_t = B(0)\, y_t + \tilde{B}(L)\, y_{t-1} \qquad ..5.3.3$$

substituting 5.3.3 into 5.3.1:

$$B(0)\, y_t + \tilde{B}(L)\, y_{t-1} + C(L)\, x_t = u_t \qquad ..5.3.4$$

dividing throughout by B(0) we obtain:

$$y_t + \Pi_1(L)\, y_{t-1} + \Pi_2(L)\, x_t = \nu_t \qquad ..5.3.5$$

where $\Pi_1(L) = B(0)^{-1}\tilde{B}(L)$; $\Pi_2(L) = B(0)^{-1}C(L)$ and $\nu_t = B(0)^{-1} u_t$.

In the long-run, since there is no lagged adjustment of y_t i.e. $y_t = y_{t-1}$ then $y_t + \Pi_1(L)\, y_{t-1}$ becomes $[I + \Pi_1(1)]\, y_t$. Dividing 5.3.2 throughout by B(1) we obtain the long-run reduced form:

$$y_t + \Pi\, x_t = \tilde{\upsilon}_t \qquad ..5.3.6$$

where $\tilde{\upsilon}_t = B(1)^{-1}\tilde{u}_t$ and $\Pi = B(1)^{-1}C(1)$, which can be shown to equivalent to $[I + \Pi_1(1)]^{-1}\, \Pi_2(1)$ from 5.3.5. The long-run reduced form becomes:

$$[I + \Pi_1(1)]\, y_t + \Pi_2(1)\, x_t = \nu_t$$

$$y_t + \Pi x_t = \tilde{\upsilon}_t \qquad ..5.3.7$$

where $\Pi = [I + \Pi_1(1)]^{-1} \Pi_2(1)$ and $\tilde{\upsilon} = [I + \Pi_1(1)]^{-1} \nu_t$

To use the above framework for cointegration analysis both structural and reduced forms need to be expressed as a VECM, so that the short-run movements in y_t and x_t are isolated from the long-run equilibrium relationship. To achieve this objective Wickens firstly partitions B(L) y_t and C(L) x_t from 5.3.1 as:

$$B(L)\, y_t = [B^*(L)\,(1\text{-}L) + B(1)L]\, y_t = B^*(L)\, \Delta y_t + B(1)\, y_{t-1} \qquad ..5.3.8$$

$$C(L)\, x_t = [C^*(L)\,(1\text{-}L) + C(1)L]\, x_t = C^*(L)\, \Delta x_t + C(1)\, x_{t-1} \qquad ..5.3.9$$

$B^*(L)\ \Delta y_t$ and $C^*(L)\ \Delta x_t$ reflects the short-run movements in both the endogenous and exogenous variables, while B(1) y_{t-1} and C(1) x_{t-1} determine the long-run equilibrium solution. Substituting 5.3.8 and 5.3.9 into 5.3.1 we acquire the structural VECM:

$$B^*(L)\, \Delta y_t + C^*(L)\, \Delta x_t + B(1)\, y_{t-1} + C(1)\, x_{t-1} = u_t \qquad ..5.3.10$$

and the corresponding reduced - form VECM becomes:

$$B^*(L)\, \Delta y_t + C^*(L)\, \Delta x_t + B(1)\, [y_{t-1} + \Pi\, x_{t-1}] = u_t \qquad ..5.3.11$$

noting again that $\Pi = B(1)^{-1}\, C(1)$.

To treat the estimates from z_t as a valid cointegrating vector(s) requires that the variables included in x_t are weakly exogenous, so that estimation of the parameters of interest, given z_t (and its past history), involves no loss of sample information relating to the joint distribution of y_t and x_t (Engle, Hendry and Richard, 1983). Weak exogenity infers that the joint distribution of $z_t=(y_t'\ x_t')'$ can be factorized as:

$$D(z_t / Z_{t-1}; \Theta) = D_1\, (y_t / x_t, Z_{t-1}; \Theta_1); D_2\, (x_t / Z_{t-1}; \Theta_2) \qquad ..5.3.12$$

where D_1 is the conditional distribution of y_t; D_2 is the marginal distribution of x_t; Z_{t-1} consists of lagged values of z_t; and $\Theta = (\Theta_1, \Theta_2)$, which are functions of the parameters of interest. In the long-run weak exogenity infers that the distribution for integrated variables D_2 does not depend upon y_t. Thus the transformations, Θ_1 and Θ_2 from the conditional and marginal distributions are not subject to cross-equation restrictions (what Hendry *et al*, 1983 call a sequential cut) and can be uniquely determined from the conditional model. Cross-equation restrictions linking the conditional distribution of y_t with the marginal distribution of x_t will lead to a violation of weak exogenity, and a loss of information when analysing the conditional distribution of y_t. Given the above assumption:

$$D(L)\,\Delta x_t + E(L)\,\Delta y_{t-1} = \varepsilon_t \qquad \text{..5.3.13}$$

where D(L) has all its roots outside the unit circle and $D(0)_{ii}=1$ for all i and E(L)=0 if x_t is strongly exogenous.

Combining 5.3.10 and 5.3.13 we obtain:

$$\begin{bmatrix} B^*(L) & C^*(L) \\ E(L)L & D(L) \end{bmatrix}\begin{bmatrix} \Delta y_t \\ \Delta x_t \end{bmatrix} + \begin{bmatrix} B(1) & C(1) \\ 0 & 0 \end{bmatrix}\begin{bmatrix} y_{t-1} \\ x_{t-1} \end{bmatrix} = \begin{bmatrix} u_t \\ \varepsilon_t \end{bmatrix} \qquad \text{..5.3.14}$$

The above system can then be expressed as a VECM:

$$A^*(L)\,\Delta z_t + A\,z_{t-1} = \varepsilon_t \qquad \text{..5.3.15}$$

where $A(L) = A^*(L)(1-L) + AL$. To derive the reduced form coefficient matrix for the whole system it is necessary to partition both B(L) and C(L), so that using $B(L)=B(0)+B^*(L)$ and $C(L) = C(0)+C^*(L)$ we derive:

$$A^*(L) = \begin{bmatrix} B(0) & C(0) \\ 0 & I_m \end{bmatrix}^{-1} \begin{bmatrix} B^*(L) & C^*(L) \\ E(L)L & D(L) \end{bmatrix} \qquad \text{..5.3.16}$$

where $A^*(0)_{ii} = 1$. The long-run coefficient matrix can be expressed in either a structural or reduced form since:

$$A = \begin{bmatrix} B(0) & C(0) \\ 0 & I_m \end{bmatrix}^{-1} \begin{bmatrix} B(1) & C(1) \\ 0 & 0 \end{bmatrix} \qquad ..5.3.17$$

$$= \begin{bmatrix} I_n + \Pi_1(1) & \Pi_2(1) \\ 0 & 0 \end{bmatrix} \qquad ..5.3.18$$

the solution for A specified in 5.3.17 consists of the coefficient matrices from the structural system, which are derived by partitioning both B(L) and C(L) and applying the method used to derive 5.3.5 to the whole system. The solution in 5.3.18 is the reduced form equivalent of the structural coefficient matrix in 5.3.17.

The above VECM framework can now be used to illustrate the relationship between the structural system specified in 5.3.1 and the restrictions that need to be imposed to provide an economic interpretation to the cointegrating vectors. As noted in section 5.2 the long-run matrix can be factorised as $A=\alpha\beta'$, where α is a matrix of adjustment coefficients and β is a matrix of long-run coefficients. From 5.3.18 we can write A as:

$$A = \begin{bmatrix} I_n \\ 0 \end{bmatrix} \left[I_n' + \Pi_1(1) \;\; \Pi_2(1) \right] \qquad ..5.3.19$$

where $A=\alpha H^{-1} H\beta$. The adjustment matrix α is multiplied by a $(n+m)\times(n+m)$ matrix of restrictions H^{-1}, where the restrictions are selected to ensure $\alpha H^{-1} = [I_n \;\; 0]'$ and $H\beta' = \left[I_n' + \Pi_1(1) \;\; \Pi_2(1) \right]$ provides estimates of the matrix of long-run coefficients. The above analysis suggests that estimation of the long-run reduced form coefficients is achievable through estimation of an unrestricted VECM, however, estimation of the long-run structure can only be achieved by transforming the original VECM to one with prior imposed restrictions. Wickens goes on to demonstrate that the common stochastic trends will also not be identified unless restrictions are imposed in addition to those specified for the identification of the structural equations. Moreover, without these restrictions the common stochastic trends cannot be uniquely derived from the cointegrating vectors. In order to identify the structural coefficients, Wickens (1996) advocates the estimation of a restricted VECM or even direct estimation of the structural equations. It is suggested that structural equations should include each variable in level and first difference form so that the short-run and long-run effects can be isolated. In the case of a single structural equation only one cointegrating vector is expected. In this instance the conventional 'normalizing' restriction will be sufficient for the purpose of identification.

When there is more than one cointegrating vector, applied researchers have often selected the cointegrating vector which is most consistent with economic theory (see for example Hataiseree and Phipps, 1996). However, this methodology is misplaced, since it ignores the information from the r-1 cointegrating vectors not selected in the modelling of the long-run equilibrium relationship. Each cointegrating vector can be viewed as a hyper-plane (Darnell, 1995; Rao, 1994), which intersects at a unique point to define the long-run equilibrium relationship. If there is a single cointegrating vector (r=1) this relationship will be defined along one hyper-plane. There will be n-1 common stochastic trends not defined by the cointegrating vectors. If r>1 there are multiple hyper-planes with n-r common stochastic trends. The existence of multiple cointegrating vectors is likely to reflect the presence of more than one endogenous variable, which are determined by an underlying structural system of equations.

5.4 Econometric Procedures

This section outlines two very recent procedures for cointegration analysis which are used for the empirical research presented later in the thesis. Firstly, the ARDL approach to cointegration will be discussed, which allows the estimation of long-run structural relationships, incorporating both I(1) and I(0) variables simultaneously. However, current developments in the ARDL literature have only allowed for the estimation of single structural equations. In chapters 6 and 7 we estimate a two equation system of export volumes and prices. In the case of a structural system therefore, it is necessary to establish whether the system is identified. We utilise the long-run structural modelling approach of Pesaran and Shin (1997b) whereby a restricted VECM is estimated to test for structural identification.

5.4.1 Structural Estimation: The ARDL Approach to Cointegration

In order to acquire the structural estimates we utilize the ARDL approach to cointegration developed by Pesaran, Shin and R. J. Smith (1996) and Pesaran and Shin (1997a). While Autoregressive Distributed Lag (ARDL) models have been suggested for de-trending trend-stationary variables (Wickens and Breusch, 1988), this approach allows the estimation of long-run relationships incorporating both I(1) and I(0) variables simultaneously. Pesaran *et al* (1996) generate a critical bounds test for the existence of a long-run equilibrium relationship, based on the conventional F or Wald test. The test encompasses two extreme cases: firstly, when all variables included in the model are I(1) and secondly, when all variables are I(0). Thus the critical value bounds allows the estimation of long-run structural relationships for all cases which are I(d), where

$0 \leq d \leq 1$.[54] If the estimated F or Wald statistic falls outside the critical values, then we can conclude a long-run equilibrium relationship exists, irrespective of knowing whether the order of integration is I(0) or I(1). If the statistic falls inside the critical values then no valid inferences can be made and further knowledge of the order of integration is required.

This procedure firstly specifies an unrestricted VECM form of a long-run structural model:

$$\Delta Z_t = b = c\,t + \pi\, Z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i\, \Delta Z_{t-i} + \varepsilon_t \qquad ..5.4.1$$

where: $b = \begin{pmatrix} b_1 \\ b_2 \end{pmatrix}$; $c = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix}$; $\pi = \begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \Pi_{22} \end{bmatrix}$; $\Gamma_i = \begin{bmatrix} \gamma_{11,i} & \gamma_{21,i} \\ \gamma_{12,i} & \Gamma_{22,i} \end{bmatrix}$; $\varepsilon_t = (\varepsilon_{1t}, \varepsilon'_{2t})'$

where π is the long-run matrix which is assumed to be defined by one cointegrating vector between all variables in the model. Z_t is a vector of variables, $Z_t = (y_t, x_t')'$; y_t is the dependent variable; x_t is a $(k \times 1)$ vector of 'long-run forcing' variables; and ε_t = is a matrix of white noise error terms.

Under certain general assumptions it is possible to express the error correction equations for y_t and the k variables included in the vector x_t as:

$$\Delta y_t = b_1 + c_1\, t + \pi_{11}\, y_{t-1} + \pi_{21}\, x_{t-1} + \sum_{i=1}^{p-1} \gamma_{11,i}\, \Delta y_{t-i} + \sum_{i=1}^{q-1} \gamma_{12,i}\, \Delta x_{t-i} + \varepsilon_{1t} \qquad ..5.4.2$$

$$\Delta x_t = b_2 + c_2\, t + \Pi_{22}\, x_{t-1} + \sum_{i=1}^{p-1} \gamma_{21,i}\, \Delta y_{t-i} + \sum_{i=1}^{q-1} \Gamma_{22,i}\, \Delta x_{t-i} + \varepsilon_{2t} \qquad ..5.4.3$$

where it is assumed $\pi_{21}=0$ from 5.4.1 for the purposes of assuming the variables included in x_t are weakly exogenous. Δy_t can be expressed as a general p-order autoregressive process and Δx_t is defined by an unrestricted VAR:

54. Fractionally or mutually integrated variables can also be included in the testing procedure.

$$\Delta X_t = P_1\, \Delta X_{t-1} + P_2\, \Delta X_{t-2} + \ldots\ldots\ldots\ldots + P_S\, \Delta X_{t-S} + \eta_t \qquad ..5.4.4$$

where P_i is a (k×k) matrix of coefficients and η_t is white noise error term. Under certain assumptions, it can be shown that the contemporaneous correlation between ε_{1t} and ε_{2t} is:

$$\varepsilon_{1t} = \omega'\, \varepsilon_{2t} + \zeta_t \qquad ..5.4.5$$

where ω is a matrix of coefficients and ζ_t is assumed to be independent of ε_{2t}. Using 5.4.2, 5.4.3 and 5.4.5 the following generalised error correction model can be derived:

$$\Delta y_t = \alpha_0 + \alpha_1\, t + \phi\, y_{t-1} + \delta'\, x_{t-1} + \sum_{i=1}^{p-1} \theta_i\, \Delta y_{t-i} + \sum_{i=1}^{q-1} \varphi_i\, \Delta x_{t-i} + \varepsilon_{1t} \qquad ..5.4.6$$

The solutions for the above parameters can be found in Pesaran *et al* (1996). If $\phi \neq 0$ and $\delta' \neq 0$ then there exists a long-run relationship between y_t and x_t which is defined as:

$$y_t = \Theta_0 + \Theta_1\, t + \Theta'\, x_t + \nu_t \qquad ..5.4.7$$

where the long-run parameters, after accounting for the short-run dynamics, are defined as $\Theta_0 = -\alpha_0/\phi$; $\Theta_1 = -\alpha_1/\phi$; $\Theta' = -\delta'/\phi$ (Θ' being a vector of long-run parameters).

The null hypothesis to test for the presence of a long-run relationship is:

$$H_0\colon \phi = \delta' = 0 \qquad ..5.4.8$$

This test hypothesis can also be extended to account for variables having non-zero means (i.e. $\alpha_0 \neq 0$ and $\alpha_1 = 0$) or significant linear deterministic trends (i.e. $\alpha_0 \neq 0$ and $\alpha_1 \neq 0$).

The presence of the long-run equilibrium relationship is tested by estimating 5.4.6 using standard OLS procedures and the using the F or Wald statistic to test the zero restrictions on the ϕ and δ' coefficients. The Wald statistic is shown to have a non-standard asymptotic chi-squared distribution with k+1 degrees of freedom.[55] Pesaran *et*

55. The asymptotic distribution and critical values are also shown to be independent of whether the variables are I(1) or I(0) (see Pesaran *et al*, 1996).

al provide two sets of critical values - one set assuming all regressors are I(0), the other assuming all I(1) regressors.[56] If the estimated statistic exceeds both critical values we can conclude that a long-run relationship exists, regardless of knowing the order of integration, I(d) for $0 \leq d \leq 1$. If the test statistic is less than either critical value then conclusive inferences cannot be drawn.

A particular problem for this approach concerns selecting the order of the lag length for the short-run dynamics in estimating 5.4.6 to derive the long-run estimates in 5.4.7. Pesaran and Shin (1997a) and Pesaran *et al* (1996) advocate the use of the Akaike Information Criterion (AIC) (Akaike, 1973) and the Schwarz Bayesian Criterion (SBC) (Schwarz, 1978) to derive estimates of the optimal lag length. The ARDL models based on both procedures are labelled ARDL-AIC and ARDL-SBC respectively.[57] After appropriate values of p and q are found and a statistically significant relationship is found, then the long-run parameters can be derived using 5.4.7. Pesaran and Shin (1997a) show that the long-run parameter estimates are super-consistent. In particular, the estimates of Θ_1 and Θ' converge to their true values at rates of $T^{3/2}$ and T respectively. The short-run parameter estimates are also shown to be $\sqrt{T}$-consistent. Thus the long-run parameter estimates converge at a faster rate than the short-run parameter estimates.

Pesaran and Shin (1997a) have also undertaken Monte-Carlo simulations to compare the finite sample performance of the ARDL-AIC and ARDL-SBC estimates

56. The critical values are calculated for 1% to 10% significance levels, as well as allowing for drift and/or trend components.

57. On the basis of Monte-Carlo simulations, Pesaran and Shin (1997a) show that with finite samples, the ARDL-SBC estimators perform slightly better than the ARDL-AIC estimators, for the majority of simulation experiments.

with those derived from the Phillips-Hansen (P-H) fully modified OLS estimator. The results suggest that the estimates from the ARDL approach tends to have a smaller degree of bias as well as having a higher degree of consistency. The Root Mean Square Errors were also found to be smaller for larger values of ϕ. Most importantly the power of the P-H cointegration tests tended to be lower, with a greater tendency to reject the null of no cointegration. Moreover, this finite sample bias declines at a slower rate as the sample size increases.[58]

While the ARDL approach to cointegration represents an important contribution to the modelling of long-run relationships there are three main factors that researchers need to be aware of in its use. Firstly, no account is made for non-stationary variables which do not contain unit roots. Consequently, pre-testing needs to be undertaken to ensure the first differences are stationary. Secondly, it is implicitly assumed that the rank of the long-run coefficient matrix is unity i.e. there is only one cointegrating vector. This assumption needs to be tested, for example, using the Johansen (1988) procedure, even if the underlying model derived from economic theory is characterized by a single structural equation. Thirdly, in the case of systems of equations, the ARDL approach needs to be supplemented by a test for structural identification. Unfortunately, developments in this literature to date have not encompassed a system-based ARDL approach. Therefore, in an attempt to overcome this problem a restricted VECM needs to be estimated and hypothesis testing used to discover whether the structural representation suggested by economic theory is data consistent.

58. These results were shown to be robust for a wide variety of data generating process for y_t and x_t (see Pesaran and Shin, 1997 for further details).

5.4.2 Estimation of Restricted VECMs

Recent literature has focused on the issue of identifying long-run structural relationships from cointegrating vectors. For example, Johansen and Juselius (1990, 1992) and Johansen (1995) have utilised a likelihood ratio testing procedure, in order to examine the statistical significance of restrictions imposed on cointegrating vectors. More recently, Greenslade, Hall and Henry (1998) have estimated a long-run structural model of wages and prices for the UK, using a test for weak exogenity and estimation of the long-run structure by Seemingly Unrelated Regression Estimator (SURE), in order to account for the simultaneity between the long-run restrictions. Over-identifying restrictions are then imposed on the long-run relations to establish whether the long-run relations can be identified. This procedure can then be used to estimate a dynamic system of equations which can be used for the purpose of short-run forecasting.

In this research we utilise the long-run structural modelling approach of Pesaran and Shin (1997b) (see also Garratt *et al* (1998); Pesaran and R. P. Smith (1998); Pesaran, Shin and R. J. Smith (1997)) is used to test for structural identification. To illustrate the implementation of this approach let us consider the model of UK export volumes and prices proposed by Holly (1995), which is estimated in chapters 6 and 7:

$$-\beta_{11} x_t = \beta_{12} p^x_t + \beta_{13} p^*_t + \beta_{14} y^*_t + \beta_{18} \sigma^e_t \qquad ..5.4.9$$ [59]

$$-\beta_{25} p_t = \beta_{26} (k/x)_t + \beta_{27} c_t + \beta_{28} \sigma^e_t \qquad ..5.4.10$$ [60]

5.4.9 and 5.4.10 can be re-expressed as a VECM:

---

59. where x = volume of exports; p^x = price of exports in foreign currency; p^* = price of domestic substitutes and y^* = proxy of foreign economic activity.

60. where p = price of exports in domestic currency; c = unit labour and raw material costs; k = an index of capital stock; σ^e = a measure of exchange rate variability.

$$\Delta z_t = a_0 + a_1 t + \sum_{i=1}^{p-1} \Gamma_i \Delta z_{t-i} + \Pi z_{t-1} + \varepsilon_t \qquad ..5.4.11$$

where: $z_t = (x^e_t, p^x_t, p^*_t, y^*_t\; p_t, (k/x^e)_t, c_t, \sigma^e_t)'$;

Estimation of the VECM by the reduced rank regression method outlined in section 5.2 can produce up to n-1 cointegrating vectors, from the reduced form representation of the structural system. However, as Wickens (1996) noted (see section 5.3) it is difficult to provide a meaningful economic interpretation of the cointegrating vectors without imposing restrictions. The structural coefficients can be obtained by subjecting β from Π to the following general linear restrictions:

$$\mathbf{R}\ \text{vec}(\beta) = \mathbf{b} \qquad ..5.4.12$$

where **R** and **b** are k×rm and k×1 matrices of known constants (with rank(**R**)=k) and vec(β) is a rm×1 vector of long-run coefficients. k is the number of restrictions required for identification. The matrix **R** can be written as:

$$\mathbf{R}_i\, \beta_i = \mathbf{b}_i \qquad \text{for } i=1, 2, \ldots, r \qquad ..5.4.13$$

where β_i is the ith cointegrating vector; $\mathbf{R}_i$ is the ith restriction in matrix **R** and $\mathbf{b}_i$ is the ith known constant which can be imposed as the restrictions. The necessary and sufficient conditions for system identification is given as:

$$\text{Rank}\ (R_i\, \beta_i) = r \qquad ..5.4.14$$

so that there must be r independent restrictions for each of the cointegrating vectors.[61] Thus for exact-identification $k=r^2$. From 5.4.9 and 5.4.10 and the VECM in 5.4.14 the long-run cointegrating vectors are given as follows:

$$\beta = \begin{pmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} & \beta_{16} & \beta_{17} & \beta_{18} & \beta_{19} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} & \beta_{25} & \beta_{26} & \beta_{27} & \beta_{28} & \beta_{29} \end{pmatrix} \qquad ..5.4.15$$

61. A formal proof of this condition is provided in Pesaran and Shin (1997b).

One null hypothesis for exact-identification is given as:

$$H_E: \begin{Bmatrix} \beta_{11} = -1 & \beta_{21} = 0 \\ \beta_{15} = 0 & \beta_{25} = -1 \end{Bmatrix} \qquad \textbf{..5.4.16}$$

In this instance the exact-identifying restriction can be viewed as a 'normalizing restriction' which links each cointegrating vector to a particular structural equation. The first cointegrating vector from 5.4.15 is assumed to represent the export volume equation, while the second cointegrating vector represents the export price equation. Thus a minus unity restriction is imposed on the β_{11} coefficient and an exclusion restriction is imposed on the β_{21} coefficient. For the cointegrating vector representing the export price equation $\beta_{15} = 0$ and $\beta_{25} = -1$. The maximized value of the-log-likelihood function estimated under the exactly-identifying restrictions with the equivalent log-likelihood value for the unrestricted VECM are then compared to establish whether the structural estimates are exactly identified from the reduced form VECM. However, it should be noted the exactly-identifying condition is not unique and could be derived in this case from imposing any four restrictions on the two cointegrating vectors. This restriction (which is essentially imposed for the purpose of statistical identification) has been derived in line with the 'normalizing' restrictions implied by economic theory.

The exact-identification condition while being necessary is not sufficient to provide a structural interpretation of the system. Exact-identification only provides a statistical identification condition. A valid economic interpretation requires additional restrictions to be imposed, suggested by economic theory. Over-identification requires

$k=m+r^2$ restrictions to be imposed, where m is the number of additional restrictions suggested by economic theory, in order to derive the structural representation. The null hypothesis for over-identification suggested by economic theory is given as follows:

$$H_O: \begin{pmatrix} -1 & \beta_{12} & \beta_{13} & \beta_{14} & 0 & 0 & 0 & \beta_{18} & \beta_{19} \\ 0 & 0 & 0 & 0 & -1 & \beta_{26} & \beta_{27} & \beta_{28} & \beta_{19} \end{pmatrix} \qquad ..5.4.21$$

The five additional over-identifying restrictions can be tested using the following L-R test statistic:

$$\text{L-R} = 2\,(LR_E - LR_O) \sim \chi^2_r\,(k-r^2) \qquad ..5.4.22$$

where LR_E is the maximized value of the log-likelihood function under the $k=r^2$ exactly-identifying restrictions and LR_O is the maximized value of the log-likelihood function under both exactly- and over-identifying restrictions. The L-R test statistic has a chi-squared distribution with $k-r^2$ degrees of freedom. The above framework can be extended to test over-identifying restrictions on only one cointegrating vector or a subset of cointegrating vectors, provided that the remaining cointegrating vectors are subject to exactly-identifying restrictions.

Acceptance of the null hypotheses from the above testing procedure allows us to move from the reduced form VECM to a structural representation. If the likelihood ratio test in 5.4.17 is significant then the reduced form VECM fails to encompass the structural system and the underlying theory cannot be implemented, since the restrictions implied by the structural system are not accepted by the testing procedure.

5.5 Conclusions

The purpose of this chapter was to present an empirical framework which will be used for the empirical research presented in later chapters. The procedures outlined allow us to overcome two difficulties with current approaches to cointegration analysis. Firstly, the ARDL approach allows for the testing and estimation of long-run structural relationships, incorporating both I(1) and I(0) variables simultaneously. Secondly, given the difficulties associated with the interpretation of multiple cointegrating vectors it is necessary to conduct a test for identification. The long-run structural modelling approach devised by Pesaran and Shin (1997b) allows exactly- and over-identifying restrictions to be imposed on a VECM in order to derive a structural representation and to establish whether the restrictions imposed on a system by economic theory are supported by the data..

In chapters six and seven the estimation results using both of these procedures are presented. Each technique is used to measure the extent to which exchange rate variability has a statistically significant influence on UK export volumes and prices.

Chapter Six

Acquiring Structural Inferences from Reduced Form VECMs -

An Application to Exchange Rate Variability and UK Exports

Abstract

In order to examine the influence of exchange rate variability on UK export volumes and prices, a structural system is estimated using the ARDL approach to cointegration (Pesaran, Shin and R. J. Smith, 1996; Pesaran and Shin, 1997a) over the period 1973Q2 to 1990Q3 and using three measures of exchange rate variability. To establish whether the structure is identified a restricted VECM is estimated (Pesaran and Shin, 1997b). This procedure allows us to test whether the set of restrictions implied by economic theory in order to derive a structural representation from a reduced form VECM are supported by the data.

6.1 Introduction

Previous chapters have shown that there still remains considerable debate within the empirical literature about whether exchange rate variability has a significant influence on trade volumes and/or trade prices. There is also ambiguity about the expected direction of the 'variability effect' on the volumes of both exports and imports (De Grauwe, 1998). The purpose of this chapter is to contribute to that debate by seeking to establish whether a statistically significant link exists between exchange rate variability and UK export volumes and prices: in particular, whether there is any evidence of an empirical influence of exchange rate variability on UK aggregate exports (volumes and prices) to its eight main trading partners. The sample period is 1973Q2 to 1990Q3, a recent period during which sterling exchange rates have been floating. Three different measures of exchange variability are employed, each of which has been widely used in the literature. The empirical model is a two equation structural system of export supply and demand (see for example, Holly, 1995), where the two equations are derived as export price and export volume equations.

The framework derived by Holly *loc. cit* was used to establish whether a statistically significant relationship was present between exchange rate variability and UK export volumes and prices, over the sample period 1974Q1 to 1992Q4. To proxy exchange rate variability, a GARCH (1,1) process of a martingale model of the effective exchange rate was used. ADF tests on the measure of exchange rate variability established that the variable is stationary; and a single cointegrating vector was found when the Johansen (1988) procedure was applied to each structural equation separately. The variability measure was eliminated from the long-run model, leaving inferences regarding the effect of exchange rate variability to be derived from estimated short-run error correction equations. Holly's two main findings were: (i) that the GARCH measure of exchange rate variability had a positive, though insignificant, influence on the short-run movements in UK aggregate manufactured export volumes; and (ii) that there was evidence of a significant positive 'variability effect' on the short-run movements in UK aggregate prices. Given the assumed nature of the structural system, the economic interpretation of these empirical findings is that exchange rate variability has a negative influence on the short-run movements in the supply of UK exports, though no significant influence on the short-run movements in export demand. For example, an increase in exchange rate variability would contract the supply of exports in the short-run causing a rise in export prices. Assuming a relatively price-inelastic demand curve, the increase in exchange rate variability would cause no significant reduction in the short-run demand for and hence the volume of exports.

There are two limitations of Holly's approach however, from the perspective of more recent literature. Firstly, elimination of the stationary variable (exchange rate variability) from the cointegrating vectors denies it long-run impact on either export volumes or export prices. Recent literature has suggested that stationary variables should be included in cointegrating vectors, especially if economic theory indicates they play an important role in defining the long-run equilibrium relationship (Harris, 1995). Wickens (1996) has also argued:

> *'In practice the structural model will often contain I(0) variables too; it is possible for I(0) variables to be present in the long-run solutions of economic models as well as in the short-run dynamics. These should be included in the VECM from the outset because, although they do not affect the CVs, which will remain superconsistent if the I(0) variables are excluded, the small sample properties of the estimates of the CVs are likely to be impaired'.*
>
> (Wickens, 1996, p. 257).

Including relevant stationary variables increases the cointegrating rank of the long-run coefficient matrix from the VECM and defines individual long-run relations for each of the stationary variables included in the system. The recent ARDL approach to cointegration (Pesaran, Shin and Smith, 1996 and Pesaran and Shin, 1997) is one procedure which permits the estimation of long-run structural relationships, irrespective of knowing whether the order of integration is I(0) or I(1). The ARDL approach allows the interpretation of a single estimated structural equation encompassing both I(1) and I(0) variables simultaneously. By comparison, the Johansen (1988) generates individual cointegrating vectors for each stationary variable included in the VECM, in addition to those cointegrating vectors found for each linear combination of I(1) variables. However, developments in the ARDL literature have only allowed for the estimation of single equations. Estimation of a structural system also requires a test for identification.

The second issue concerns the structural identification of the cointegrating vectors. The Johansen (1988) procedure is based on a reduced form representation of a VECM, which includes all the variables from the structural system of equations. As demonstrated in section 5.3, Wickens (1996) has shown that in the case of systems of equations, only by imposing *a priori* restrictions can structural (economic) inferences be acquired from the estimation of cointegrating vectors. In the case of a single structural equation a unique cointegrating vector is expected. The only identifying restriction required here can be viewed as a 'normalizing' restriction, which is usually imposed on the coefficient of the 'dependent' variable from the structural equation. Estimation of a single structural equation also requires separation of the variables in the system into one endogenous variable and a vector of weakly exogenous variables. In the case of a structural system it is expected that at least one equation will contain more than one endogenous variable. Consequently, the number of cointegrating vectors will be defined by the number of underlying structural equations. By applying the Johansen method to each structural equation separately, Holly implicitly assumed that each of the regressors in the volume and price equations is weakly exogenous. Thus each equation was estimated as though it was a single structural equation; and the estimation of the export volume equation is separate to the estimation of the export price equation. This requires the assumption that the supply of exports schedule is infinitely elastic. However, given the possibility that export prices and volumes may be determined simultaneously, this assumption could be usefully tested.

Recent developments in long-run structural modelling by Pesaran and Shin (1997b) have provided a framework by which identifying restrictions can be tested to establish whether the structural assumptions made by economic theory are data-consistent. This involves, firstly, imposing restrictions on the number of cointegrating vectors to be coincident with the number of structural equations. Exclusion restrictions for each cointegrating vector are then tested in order to derive a structural representation from a reduced form VECM. Pesaran and Shin (1997b) derive the appropriate conditions for system identification. Firstly, exact- or just-identifying restrictions are imposed; Pesaran and Shin *op. cit* show that exact-identification requires that the number of restrictions, k is equal to r^2 (where r is the number of cointegrating vectors) of which r restrictions will be 'normalizing restrictions'. Thus, r restrictions are imposed on each of the r cointegrating vectors. These restrictions are sufficient for 'statistical' identification of the coefficients of the cointegrating vectors when using the Johansen (1988) procedure. However, the coefficients from the system subject to the exactly-identifying restrictions cannot be given an economic interpretation, since they are not unique or derived from economic theory. To derive a data-consistent structural representation consistent with economic theory requires additional restrictions to be imposed on the system. Exclusion restrictions are imposed on every cointegrating vector, for each variable which is not included in the structural equation but included in the reduced form VECM. The total number of restrictions then becomes $k=m+r^2$, where m is the number of over-identifying restrictions, which are derived from the restrictions suggested by economic theory, in order to derive the structural representation.

Section 6.2 presents the empirical analysis which is separated into five parts: (i) specification of the empirical model and the data set; (ii) the measures of exchange rate variability used; (iii) unit root tests are calculated to establish the order of integration of each variable in the system; (iv) structural estimates are acquired from the ARDL approach; and this is followed by a test for identification in section (v). The empirical analysis is presented for UK aggregate exports to its eight main trading partners[62] over the sample period 1973 Q2 to 1990 Q3.[63] Section 6.3 provides concluding comments.

6.2 Empirical Analysis

6.2.1 The Model and Data

In order to investigate the empirical influence of exchange rate variability on the demand and supply for exports, we specify the following structural system of export volumes and prices (Holly, 1995):

$$p_t = \delta_0 + \delta_1 c_t + \delta_2 (k/x)_t + \delta_3 \sigma^e_t \qquad ..6.2.1$$

$$x_t = \beta_0 + \beta_1 p^x_t + \beta_2 p^*_t + \beta_3 y^*_t + \beta_4 \sigma^e_t \qquad ..6.2.2$$

(all variables measured in natural logs)[64]

62. The trading partners are France; West Germany; the Netherlands; Belgium; Italy; USA; Canada; and Japan.

63. The sample period was selected since it represents a regime when the UK pound was floating against the currencies of the eight main trading partners. Over the period 1987 to 1988, the pound did shadow the Deutschemark however, this did not represent a formal policy regime of fixed exchange rates by the UK government. Ending the sample period at 1986 Q4 would have lowered the number of available observations and consequently reduced the degrees of freedom.

64. The notation σ^e will be used to represent the natural log of the measure of exchange rate variability throughout the empirical analysis in chapters 6 and 7.

where p_t is the logarithm of the price of exports in domestic currency terms; c_t is the log of unit costs of production; $(k/x)_t$ is the log of the ratio of fixed capital stock to aggregate export volumes; σ^e_t is the chosen measure of exchange rate variability. In 6.2.2, x_t is the log of the volume of UK aggregate exports to its eight main trading partners; p^x_t is the log of the price of exports in foreign currency terms;[65] p^*_t is the log of the price of foreign substitutes and y^*_t is the log of foreign income, both denominated in foreign currency terms. A full description of the data set and the sources used in the empirical analysis can be found in appendix C.

6.2.1 is assumed to represent the supply of exports and 6.2.2 represents the demand for exports. Export prices in domestic currency terms are assumed to be positively related to unit costs and the ratio of capital stock to export volumes, thus $\delta_1>0$ and $\delta_2>0$. If export contracts are denominated in foreign currency, then the uncertainty resulting from exchange rate variability will be faced by exporters. This causes a fall in the supply of exports, leading to a rise in export prices, hence δ_3 will be positive. By contrast, if export contracts are denominated in domestic currency then exchange rate uncertainty will be faced by importers, causing a fall in the demand for exports and a fall in export prices, thus $\delta_3<0$.

Export demand is assumed to have a negative relationship with export prices in foreign currency terms, so $\beta_1<0$ and a positive relationship with foreign prices and

65. $p^X_t = (p_t/e_t)$, where e is the exchange rate, which is defined as the price of foreign currency per unit of domestic currency. The export price in exporter's currency is assumed to be constant over the contract period, so that uncertainty about the domestic currency price only occurs because of fluctuations in the exchange rate.

foreign income, so $\beta_2>0$ and $\beta_3>0$. We assume that exchange rate variability acts as a deterrent to international trade, causing a fall in export demand, so that $\beta_4<0$.

6.2.2 The Measurement of Exchange Rate Variability

As we noted in chapter 3, the empirical literature has suggested a large number of exchange rate variability measures, although no consensus has emerged about the most appropriate proxy and under what circumstances a particular measure should be used in preference to another. In this section three measures are taken from the literature, in order to examine the sensitivity of the empirical relationship between exports and exchange rate variability to the chosen proxy. The measures used are: (i) the standard deviation for a given quarter of the percentage changes in the monthly observations of the effective exchange rate, calculated from the sterling exchange rates with respect to the UK's eight main trading partners; (ii) a four quarter moving average standard deviation of the percentage changes in the effective exchange rate; (iii) the average absolute difference between the current spot rate index and the lagged 3 month forward rate index using monthly observations for a given quarter.

These measures were selected because the literature suggests that they have distinct economic and statistical properties. The standard deviation and 'moving average' measures tend to measure the degree of *ex-post* exchange rate variability, while the 'absolute difference' measure more closely reflects exchange rate uncertainty, since the dispersion of the actual exchange rate from its assumed expected value (i.e. the lagged forward rate index) is calculated.

Figure 6.2.1 shows a plot of the standard deviation measure. In 85 Q1 there is a very large increase: this outlier could possibly be explained by the changes in UK monetary policy that occurred during this quarter. At the start of 1985 short-term lending rates for the London clearing banks were 9½-9¾%, compared to 12% in July 1984 (Britton, 1991). The changing stance of UK monetary policy arose from concerns about the vlaue of the sterling relative to major currencies, in particular the US dollar. On January 14th 1985 sterling had fallen to £1=$1.1105 and reached a low of £1=$1.05 on March 7th (Britton, *loc. cit*). Also during this period co-ordinated foreign exchange market intervention took place to prevent the large rise in the price of US dollars, resulting in further exchange rate volatility. After 86Q2 the standard deviation measure appears to become more stable. During this period the UK government was reported to have followed an unofficial policy of 'Shadowing the Deutschemark' during the period 1987 to 1988. This stability in exchange rate volatility is reflected up to the end of the sample period at 1990 Q3, when sterling entered the European Exchange Rate Mechanism on 9th October, 1990.

Comparing figure 6.2.1 with 6.2.2, it is evident that the four quarter moving average produces a far smoother series than the standard deviation. In 85 Q1 there is a large increase in the standard deviation compared to the rest of the sample period. This peak is smoothed from the moving average measure. Since the moving average measure takes account of lags in the standard deviation, any large increase in exchange rate variability is prolonged for the next four time periods. In figure 6.2.1, the large increase in exchange rate variability is followed by an immediate reduction in the following quarter which is not represented by the moving average measure.

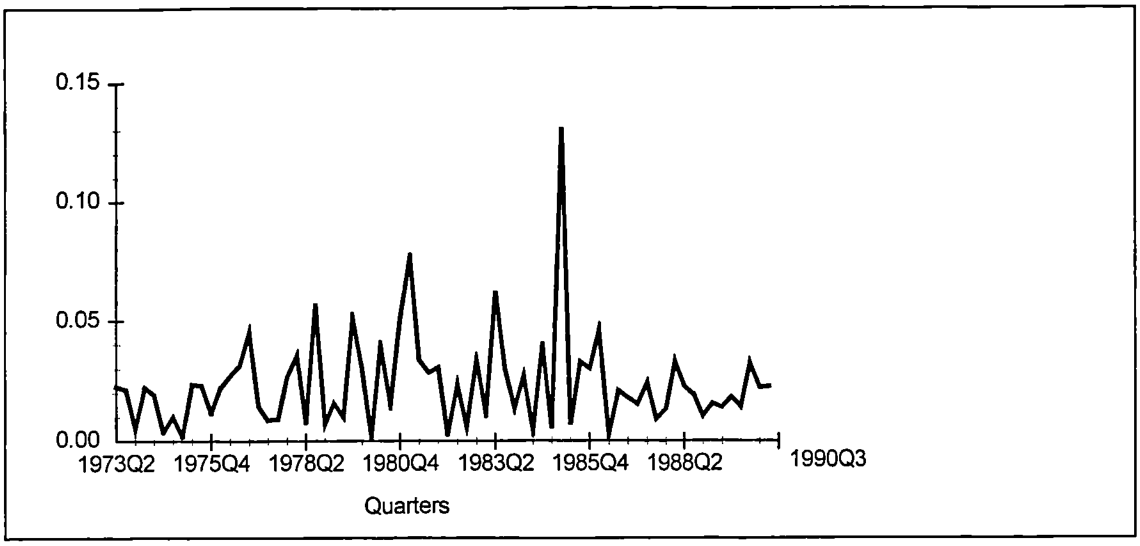


Figure 6.2.1 Plot of standard deviation of monthly percentage changes in the effective exchange rate, 1973 Q2 to 1990 Q3.

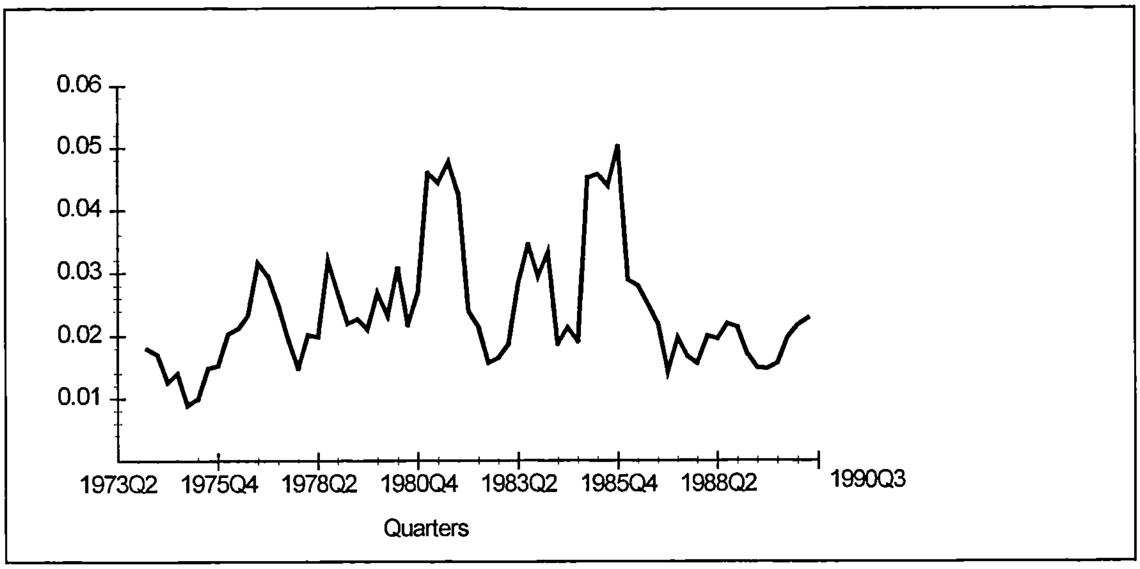


Figure 6.2.2 Plot of four quarter moving average standard deviation of monthly percentage changes in the effective exchange rate, 1973 Q2 to 1990 Q3.

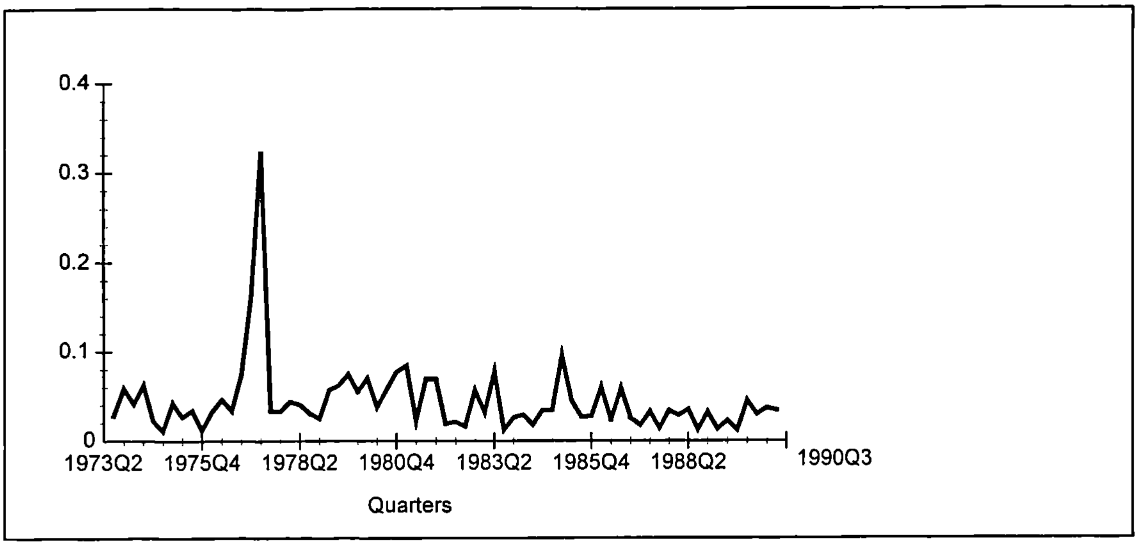


Figure 6.2.3 Plot of average absolute difference between the current spot rate and the lagged forward exchange rate, 1973 Q2 to 1990 Q3.

Figure 6.2.3 shows the average absolute difference between the current spot rate index and the lagged forward rate index for each quarter. The pattern depicted in this graph appears to be distorted by the very large increase in this measure at 1977 Q2. This outlier is explained by a significant fall in the price of sterling on the forward market relative to some of the currencies considered in the assumed exchange rate index, most notably the US dollar. In March 1977, the Bank of England's minimum lending rate was 9½% compared to 15% in the last quarter of 1976 Q4 (Britton, *op. cit*). Monetary policy was relaxed to prevent an influx of capital resulting from higher UK interest rates. The fall in the price of forward sterling may reflect market expectations of a further decline in future sterling spot exchange rates, following the relaxation of UK monetary policy and could possibly explain the large disparity in spot and forward rates.

The spot and forward effective exchange rate indices are calculated by adapting a batch program suggested by M. H. Pesaran and B. Pesaran (1997)[66] together with monthly sterling bi-lateral exchange rates and trade expenditure weights for the UK's eight main trading partners.[67] The effective exchange rate index is computed as follows:

$$E_t = \sum_{j=1}^{8} w_{jt} \left[\frac{E_{jt} \times 100}{E_{j,90}} \right] \quad ..6.2.3$$

where w_{jt} is the share of UK exports to the jth country, so that $\sum_{j=1}^{8} w_{jt} = 1$ and E_{jt} is the sterling rate of exchange with respect to the jth currency, calculated from US dollar cross exchange rates as follows:

$$E_{jt} = \left[\frac{\text{jth country national currency}}{\text{US dollar}} \right] \times \left[\frac{\text{US dollar}}{\text{UK pound}} \right] \quad ..6.2.4$$

$E_{j,90}$ is the average of E_{jt} over the months in 1990, so that E_{90} = 100. This procedure is applied to both spot and forward exchange rates so that each of the measures of exchange rate variability could be calculated.

6.2.3 Unit Root Tests

Before proceeding with the cointegration analysis, it is necessary to establish the order of integration of each variable in the system. While the ARDL approach allows us to test for the presence of a long-run equilibrium relationship with a class of variables which are either I(0) or I(1), it is still necessary to test for higher orders of integration

66. The batch program is available from the author on request.

67. The trade expenditure weights were calculated from the proportion of export expenditure accounted for by country j of the aggregate export expenditure for the eight main trading partners.

than I(1), so that the required level of differencing of each variable can be determined before they are incorporated into the long-run model.

With this in mind, augmented Dickey-Fuller (ADF) tests (Dickey and Fuller, 1979) were computed by using the following regression equation:[68]

$$\Delta x_t = \alpha_0 + (\rho-1)\, x_{t-1} + \alpha_1 t + \sum_{i=1}^{p-1} \beta_i \Delta x_{t-i} + \varepsilon_t \qquad ..6.2.5$$

6.2.5 tests the null hypothesis of a unit root (H_0: ρ=1) against the alternative of stationarity (H_1: $|\rho|$<1). α_0 and t are included to allow for the presence of significant drift and/or trend components. If x_t follows an AR(p) process, then a number of lagged dependent variables need to be included to ensure ε_t is 'white noise' and thus possibly alleviating potential bias in the estimation of ρ. The test is completed by deriving an OLS estimate of γ = (ρ-1) and comparing the calculated 't' statistic with the adjusted critical values.

The estimated ADF test statistics presented in table 6.2.1 suggest that two of the variability measures are stationary and the remaining variables in the system are I(1). The level of each variable can be included in our long-run model.

Visual observation of the data set suggested that some of the variables might be subject to structural breaks in the time series. Perron (1989) has shown that if structural breaks are not accounted for then the standard ADF test will have low power.

Perron *loc. cit* has suggested a testing procedure which allows for the presence of structural breaks at period t=k+1.[69] The general form of this test allows for a one-time

68. Alternative methods for calculating unit root tests include the Cointegration Regression Durbin - Watson (CRDW) test (Sargan and Bhargava, 1983) and the non-parametric adjustment to the Dickey-Fuller regression of Phillips and Perron (Phillips, 1987; Perron, 1988; and Phillips and Perron, 1988).

69 Alternative procedures for unit root testing in the presence of structural breaks include Zivot and Andrews (1992); Lumsdaine and Papell (1997); and Nunes *et al* (1997).

change in both the level and drift components of the series. The null and alternative hypothesis are given as follows:

$$H_0: x_t = \alpha_0 + x_{t-1} + \mu_1 D_p + \mu_2 D_L + \varepsilon_t \qquad \textbf{..6.2.6}$$

$$H_1: x_t = \alpha_0 + \alpha_2 t + \mu_2 D_p + \mu_3 D_T + \varepsilon_t \qquad \textbf{..6.2.7}$$

D_p is a pulse dummy variable, where D_p=1 if t=k+1 and D_p=0 otherwise; D_L is a level dummy variable, so that D_L=1 if t>k and D_L=0 otherwise and D_T is a trend dummy variable where D_T=t-k for t>k and D_T=0 otherwise.

Under the null hypothesis x_t is a unit root process with a one-period jump in the level (due to D_p) and drift (due to D_L) of the time series at period t=k+1. Under the alternative x_t is a trend-stationary process with structural breaks in the drift (due to D_p) and the trend term (due to D_T). Under the null hypothesis, the series is given as $x_t=\alpha_0+x_{t-1}+\varepsilon_t$ up to period k, then becoming $x_t=(\alpha_0+\mu_2)+\mu_1+x_{t-1}+\varepsilon_t$ at period t=k+1 and $x_t=(\alpha_0+\mu_2)+x_{t-1}+\varepsilon_t$ thereafter.

Under the alternative hypothesis the trend-stationary process is influenced by a change in the coefficients for both the drift and trend components, when t>k. D_T=t-k and D_T=0 otherwise. For t<k $x_t=\alpha_0+\alpha_2 t+\varepsilon_t$ and then evolves as $x_t=(\alpha_0+\mu_2)+(\alpha_2+\mu_3)t+\varepsilon_t$ thereafter.

Table 6.2.1: Augmented Dickey - Fuller Tests

Variable	ADF Test (Levels)	Lag Length of ADF	ADF Test (First Differences)	Lag Length of ADF
x	-3.0957* (-3.4790)	4	-4.7854 (-2.9062)	3
y^*	-1.9386* (-3.4759)	1	-5.8097 (-2.9042)	0
p	-0.4625† (-4.18)	1	-6.0537† (-4.18)	0
p^x	-1.2418† (-4.18)	1	-6.8812† (-4.18)	0
p^*	-2.4125 (-2.9042)	1	-3.7124 (-2.9042)	0
c	-2.9243* (-3.4769)	2	-3.1295 (-2.9077)	5
k/x	-2.8232 (-3.4779)	3	-7.6941 (-2.9055)	2
σ^e (Standard Deviation)	10.2911‡ (-3.85)	0	-	-
σ^e (Moving Average SD)	-3.545§ (-3.80)	4	-5.086 (-3.80)	-
σ^e (Absolute Difference)	-7.9041‡ (-3.85)	0	-	-

note: the alternative hypothesis in each case is that the variable in question is I(0); the 95% critical values are presented in parentheses. * denotes a significant time trend. The critical values vary since the number of observations used to estimate the ADF tests changes with the size of the lag length used.† denotes the export price variables (in domestic and foreign currency terms) were subject to a structural break between 85Q1 and 86Q3, which influenced the drift term of the process. Adjusted critical values devised by Perron(1989) were used for λ=0.7. ‡ denotes a pulse shock in the exchange rate variability measure at 85Q1 and § denotes a pulse shock for the same variable from 77Q1 to 77Q2. Adjusted critical values also used for the relevant time period of the break.

The general form of the Perron test is given as:

$$x_t = \alpha_0 + \mu_1 D_p + \mu_2 D_L + \alpha_2 t + \gamma x_{t-1} + \sum_{i=1}^{p} \beta_i \Delta x_{t-i} + \varepsilon_t \qquad ..6.2.8$$

From 6.2.8 the 't'-statistic can be used to test the null of a unit root i.e. γ=1, while at the same time being general enough to test for structural breaks to the level and drift terms. This statistic is then compared to the relevant critical values computed by Perron (1989). These critical values are calculated for a structural break at a number of time periods, calculated as a percentage of the total number of observations T, (λ=k/T). The values of λ increase in increments of 0.1. When λ=0 or λ=1, clearly there are no structural breaks and the Perron critical values are equivalent to those calculated by Dickey and Fuller (1976). If $0<\lambda<1$ then the adjusted critical values should be used.

For most of the measured export price variables, the null hypothesis of a unit root was accepted in favour of the alternative. Hypothesis testing also suggested that the structural break between 85Q1 and 86Q3 had a significant influence on the level and drift of the process. The variability measures were also subject to breaks at either 77Q1-77Q2 or 85Q1. In two cases, the null hypothesis was rejected in favour of the alternative of stationarity. However, the coefficients for the trend and trend dummy variables were found to be insignificant, so that only the pulse dummy was included in 6.2.8. Alternative adjusted critical values were used.

6.2.4 ARDL Estimates

This section uses the ARDL approach to cointegration (Pesaran, Shin and Smith 1996; Pesaran and Shin, 1997a) in order to investigate the empirical influence of exchange rate variability on UK export volumes and prices. Three measures are used to proxy exchange rate variability in order to investigate whether any significant measured variability effect is unique to any one proxy. The estimation procedure is separated into two parts: firstly, the critical bounds test is used to examine whether a long-run equilibrium relationship is present. Thus for the structural system specified in 6.2.1 and 6.2.2 the following error correction models are estimated (see 5.4.6):

$$\Delta x_t = \alpha_{10} + \alpha_{11}\, t + \sum_{i=1}^{n-1} \psi_{1i}\, \Delta x_{t-i} + \sum_{i=1}^{k-1} \varphi_{1i}\, \Delta p^{x}_{t-i} + \sum_{i=1}^{p-1} \beta_{1i}\, \Delta p^{*}_{t-i} + \sum_{i=1}^{q-1} \theta_{1i}\, \Delta y^{*}_{t-i}$$

$$+ \sum_{i=1}^{s-1} \xi_{1i}\, \Delta \sigma^{e}_{t-i} + \phi_1\, x_{t-1} + \delta_{11}\, p^{x}_{t-1} + \delta_{12}\, p^{*}_{t-1} + \delta_{13}\, y^{*}_{t-1} + \delta_{14}\, \sigma^{e}_{t-1} + \varepsilon_{1t} \quad ..6.2.9$$

$$\Delta p_t = \alpha_{20} + \alpha_{21}\, t + \sum_{i=1}^{n-1} \psi_{2i}\, \Delta p_{t-i} + \sum_{i=1}^{k-1} \varphi_{2i}\, \Delta c_{t-i} + \sum_{i=1}^{p-1} \beta_{2i}\, \Delta(k/x)_{t-i}$$

$$+ \sum_{i=1}^{s-1} \xi_{2i}\, \Delta \sigma^{e}_{t-i} + \phi_2\, p_{t-1} + \delta_{21}\, c_{t-1} + \delta_{22}\, (k/x)_{t-1} + \delta_{23}\, \sigma^{e}_{t-1} + \varepsilon_{2t} \quad ..6.2.10$$

The null hypotheses which would deny the presence of a long-run relationship in both volume and price equations are:

$$H_0\!: \phi_1 = \delta_{11} = \delta_{12} = \delta_{13} = \delta_{14} = 0 \quad ..6.2.11$$

and

$$H_0\!: \phi_2 = \delta_{21} = \delta_{22} = \delta_{23} = 0 \quad ..6.2.12$$

The alternative in each case is that at least one of the regressors in the error correction equation is statistically significant. The null hypothesis is tested by estimating 6.2.9 and 6.2.10 via OLS and using the F or Wald Statistic to test the joint zero restrictions on the ϕ and δ coefficients. If the estimated test statistic exceeds both critical values (computed for either all I(0) or all I(1) regressors) then we can reject the null hypothesis and conclude a long-run equilibrium relationship exists, irrespective of establishing whether the order of integration is I(1) or I(0).[70] The critical values are calculated for 1% to 10% significance levels and three cases: (i) either a zero drift term

70. If the F-statistic falls within both critical values then conclusive inferences cannot be made without establishing the order of integration of each variable. In this instance the results derived from the ARDL approach may need to be supported from estimation of cointegrating vectors using alternative procedures, such as the Engle and Granger (1987) two-step method or the Johansen (1988) procedure.

(i.e. $\alpha_{i0} = 0$ and $\alpha_{i1} = 0$ for i=1, 2); (ii) non-zero drift (i.e. $\alpha_{i0} \neq 0$ and $\alpha_{i1} = 0$) or (iii) significant drift and trend components ($\alpha_{i0} \neq 0$ and $\alpha_{i1} \neq 0$).

The second step involves choosing for the lag lengths the short-run dynamics, using either the Akaike information criterion (AIC) or Schwarz Bayesian criterion (SBC). The long-run parameter estimates from 6.2.9 and 6.2.10 can be derived as follows:

$$x_t = \Theta_{10} + \Theta_{11}\, t + \Theta_{12}\, p^x_t + \Theta_{13}\, p^*_t + \Theta_{14}\, y^*_t + \Theta_{14}\, \sigma^e_t \qquad \textbf{..6.2.13}$$

$$p_t = \Theta_{20} + \Theta_{21}\, t + \Theta_{22}\, c_t + \Theta_{23}\, (k/x)_t + \Theta_{24}\, \sigma^e_t \qquad \textbf{..6.2.14}$$

where:

$\Theta_{10} = -\alpha_{10}/\phi_1$; $\Theta_{11} = -\alpha_{11}/\phi_1$; $\Theta_{12} = -\delta_{11}/\phi_1$; $\Theta_{13} = -\delta_{12}/\phi_1$; $\Theta_{14} = -\delta_{13}/\phi_1$; $\Theta_{15} = -\delta_{14}/\phi_1$;

$\Theta_{20} = -\alpha_{20}/\phi_2$; $\Theta_{21} = -\alpha_{21}/\phi_2$; $\Theta_{22} = -\delta_{21}/\phi_2$; $\Theta_{23} = -\delta_{22}/\phi_2$; $\Theta_{24} = -\delta_{23}/\phi_2$.

6.2.9 and 6.2.10 were estimated by OLS using a general to specific approach to determine the optimal lag length for the short-run dynamics. In their original empirical application, Pesaran *et al* (1996) impose the same lag length on each of the short-run regressors. However, we found using this approach over-parameterised the error correction model and consequently lowered the power of the critical bounds test. Consequently, different lag lengths for each independent variable were allowed. The OLS estimates and diagnostic tests[71] using the standard deviation measure to represent σ^e are as follows:

71. The diagnostic test include the Durbin-Watson (DW) test for first-order serial correlation (Durbin and Watson, 1950 and 1951); the Lagrange Multiplier test for serial correlation (see for example Godfrey, 1978); the Ramsey RESET Test for functional form misspecification (Ramsey, 1969); the Jarque-Bera normality test (Bera and Jarque, 1981); and the Koenker test for heteroscedasticity (Koenker, 1981).

$$\Delta x_t = -0.15463\ \Delta x_{t-1} + 0.00517\ \Delta x_{t-2} - 0.0582\ \Delta x_{t-3} + 0.42409\ \Delta x_{t-4}$$
$$(-1.3582)\quad (0.0518)\quad (-0.59943)\quad (4.8125)$$

$$+ 3.5837\ \Delta y^{*}_{t} - 0.000021\ \Delta p^{x}_{t} + 0.000013\ \Delta p^{x}_{t-1} + 0.000022\ \Delta p^{x}_{t-2}$$
$$(5.4826)\quad (-1.0638)\quad (0.6293)\quad (1.1001)$$

$$+ 0.000016\ \Delta p^{x}_{t-3} - 0.00068\ \Delta p^{x}_{t-4} + 0.1479\ \Delta p^{*}_{t} + 1.5336\ \Delta p^{*}_{t-1}$$
$$(0.7297)\quad (-3.5519)\quad (0.2330)\quad (2.4007)$$

$$-1.5664\ \Delta p^{*}_{t-2} + 0.96225\ \Delta p^{*}_{t-3} - 0.01272\ \Delta \sigma^{e}_{t}$$
$$(-2.7028)\quad (1.6536)\quad (-1.8586)$$

$$-0.3957\ x^{e}_{t-1} - 0.2733\ p^{x}_{t-1} + 0.6804\ p^{*}_{t-1} + 0.2103\ y^{*}_{t-1} + 0.0062\ \sigma^{e}_{t-1}$$
$$(-3.2573)\quad (-2.5817)\quad (3.2796)\quad (1.8327)\quad (0.5455)$$

$\bar{R}^2 = 0.7937$ DW = 1.7278 Serial Correlation (LM): $\chi^2(4) = 2.7411$

Functional Form: $\chi^2(1) = 0.0331$ Normality: $\chi^2(2) = 0.5264$

Heteroscedasticity: $\chi^2(1) = 0.18788$

Variable Deletion Test: $F(5, 45) = 3.7736$
(95% Critical Values I(0) = 2.157; I(1) = 3.334) [see appendix D] **..6.2.15**

$$\Delta p_t = 0.21278\ \Delta p_{t-1} - 0.03131\ \Delta(k/x)_{t} - 0.0880\ \Delta(k/x)_{t-1} + 0.0648\ \Delta c_{t}$$
$$(2.1098)\quad (-1.0145)\quad (-2.9234)\quad (0.6395)$$

$$-0.1534\ \Delta c_{t-1} - 0.1594\ \Delta c_{t-2} - 0.2809\ \Delta c_{t-3} - 0.0920\ p_{t-1}$$
$$(-1.5303)\quad (-1.6433)\quad (-2.8437)\quad (-2.8437)$$

$$+0.0372\ (k/x)_{t-1} + 0.0685\ c_{t-1} + 0.00152\ \sigma^{e}_{t-1} - 0.0648\ DUM_t$$
$$(2.4356)\quad (2.1928)\quad (2.1276)\quad (-4.2142)$$

$\bar{R}^2 = 0.6615$ DW = 1.9831 Serial Correlation (LM): $\chi^2(4) = 5.5174$
Functional Form: $\chi^2(1) = 0.6915$ Normality: $\chi^2(2) = 0.0676$
Heteroscedasticity: $\chi^2(1) = 0.1395$

Variable Deletion Test: $F(4, 54) = 7.2312$
(95% Critical Values I(0) = 2.2812; I(1) = 3.474) [see appendix D] **..6.2.16**

Both price and volume equations had insignificant drift and trend components. To test for the presence of a long-run relationship the critical values from Case I of appendix D are used. In both cases the estimated F-statistic exceeds the 95% upper critical value, so that we can reject the null hypothesis of no long-run relationship (see 6.2.11 and 6.2.12).

A similar conclusion was found when two alternative measures of exchange rate variability were used. For the 'absolute difference' measure the estimated F-statistic for the volume equation was 3.3415, which just exceeds the 95% upper critical value. For the price equation the F-statistic was 9.9479. Using the moving average standard deviation in the estimation of the volume and price equations produced estimated F-statistics of 5.8261 and 7.8806 respectively.

Establishing the presence of a long-run relationship means that the error correction model can be used to estimate the long-run elasticities from 6.2.13 and 6.2.14. The Akaike Information (AIC) and Schwarz Bayesian (SBC) criteria can be used to determine the optimal lag length for the short-run dynamics.

Table 6.2.2: Long-Run ARDL Estimates (Volume Equation)

Standard deviation used as exchange rate variability measure		
Long-Run Coefficients	**Model Selection Criteria**	
	ARDL-SBC (5, 0, 0, 1, 1)	**ARDL-AIC (5, 5, 4, 1, 1)**
p^x	-0.6977 (-7.7949)†	-0.7134 (-7.1726)†
p^*	1.6386 (14.7729)†	1.6922 (11.9572)†
y^*	0.5740 (4.4670)†	0.6030 (4.5855)†
σ^e	-0.0017 (-0.0721)	0.0099 (0.38345)
Absolute difference used as exchange rate variability measure		
	ARDL-SBC (5, 0, 0, 1, 0)	**ARDL-AIC (5, 0, 3, 6, 5)**
p^x	-0.7061 (-7.7220)†	-0.6480 (-6.7388)†
p^*	1.6913 (13.4661)†	1.5965 (11.4774)†
y^*	0.5761 (4.5323)†	0.5596 (5.0718)†
σ^e	0.0135 (0.6165)	-0.0344 (-0.9549)
Moving average standard deviation used as exchange rate variability measure		
	ARDL-SBC (5, 0, 0, 1, 0)	**ARDL-AIC (5, 4, 5, 5, 6)**
p^x	-0.6914 (-7.3392)†	-0.8032 (-14.6525)†
p^*	1.6649 (14.4003)†	1.6245 (25.6105)†
y^*	0.5759 (3.5081)†	0.9424 (8.4657)†
σ^e	0.0015 (0.0376)	0.1039 (2.9032)
Estimation results excluding variability measure		
	ARDL-SBC (5, 0, 0, 1)	**ARDL-AIC (5, 0, 3, 1)**
p^x	-0.69242 (-7.8061)	-0.7270 (-6.9032)
p^*	1.6483 (14.7977)	1.7277 (10.9012)
y^*	0.5935 (4.8389)	0.5842 (4.2249)

note: † denotes significance at the 95% level. Asymptotic 't' ratios in parentheses. The lag structure for each variable in the export volume equation are also shown in parentheses.

The estimation results for the export volume equation are shown in table 6.2.2. Varying lag lengths are found according to which lag selection criteria is used. The AIC criterion tends to select a higher order ARDL than the SBC, as well being less consistent in producing similar lag structures according to which measure of exchange rate variability is used. The long-run parameter estimates for the export price, foreign price and income variables appear to be consistent across the variability measures used and the lag selection criteria, though the ARDL-SBC model tends to produce more consistent estimates. The estimated elasticities for the export price variable range from -0.69 to -0.70 (using the ARDL-SBC model) and between -0.65 and -0.80 (using the ARDL-AIC model). Similarly, the estimates for the foreign price variable range from 1.64 to 1.69 (ARDL-SBC model) and from 1.60 to 1.70 (ARDL-AIC). Overall the results suggest that the demand for UK exports is own-price inelastic and foreign price elastic. A positive relationship between export demand and foreign income is found with the estimates ranging from 0.56 to 0.94.

Before proceeding to analyse the variability effect, it is interesting to compare the estimation results for these variables with a few recent empirical studies. It is difficult to make a direct comparison of the export price and foreign price elasticities, since many researchers have used the ratio of export to foreign prices. We shall therefore only compare the income elasticities. Chowdhury (1993) found an income elasticity of 0.270 for a study of UK aggregate export volumes over the period 1973 Q1 to 1990 Q4, while Arize (1997b) found an income elasticity of 1.59 over the period 1973 Q2 to 1992 Q4. Both studies use the Johansen (1988) multivariate cointegration procedure and a proxy for world economic activity,[72] as opposed to a trade weighted income index. The difference in the magnitudes of the estimated elasticities found from this study is most likely to be accounted for by the definition of foreign income used and the fact that the aggregate export variable is restricted to a sample of eight countries.

Regarding the variability effect, the empirical evidence strongly suggests that each of the proxies has an insignificant influence on the demand for UK aggregate exports to its eight main trading partners. The majority of coefficients have very small magnitudes and in all but one case are statistically insignificant. The moving average standard deviation measure suggests that exchange rate variability has a significant positive influence on export demand from the ARDL-AIC model. In this case, the 't' statistics are larger when estimating the model by the AIC, given the order of the ARDL is larger. This result however, is not supported by the estimation results from the ARDL-SBC model. The sign of the variability elasticity varies according to which lag selection criteria is used. There is also some evidence to suggest that the magnitude of the variability elasticity varies according to which lag selection criteria or variability measure is adopted. The fact that the variability elasticity is statistically insignificant for all three measures, leads us to conclude that exchange rate variability has no influence on UK export demand. This conclusion is also supported by the fact that when the export demand equation is re-estimated excluding exchange rate variability, the sign and magnitude of the parameter estimates for the remaining variables do not change significantly from those found when the variability measures are included. Thus, including the measures of exchange rate variability does not improve the explanatory

72. Chowdhury (1993) uses quarterly GDP figures for the G7 countries and Arize (1997b) uses a weighted index of industrial production from a sample of sixteen countries.

power of the export demand equation. Moreover, the fact that the remaining elasticities from the export volume equation have very consistent signs and magnitudes across variability measures and lag selection criteria also provides supporting evidence that the measures of exchange rate variability have no statistically significant impact on the volume of UK aggregate exports.

These findings somewhat contradict the conclusions from recent empirical studies. Chowdhury (1993) found a statistically significant variability elasticity of -0.68, from a model of UK aggregate export volumes, estimated over the period 1973 Q1 to 1990 Q4. Arize (1997b) also found a statistically significant variability elasticity of -0.12 for UK aggregate export volumes, over the period 1973 Q2 to 1992 Q4.

The estimation results for the export price equation are shown in table 6.2.3. Again the ARDL-SBC model produces more consistent lag selections than the ARDL-AIC model. The unit cost and capital to export volume variables have signs which are consistent with economic theory. The magnitude of the elasticities for the unit cost variable range from 0.64 to 0.75. Holly (1995), by contrast found an elasticity of 1.07, when estimating the long-run export supply equation over the period 1974 Q1 to 1992 Q4. The estimates for the (k/x) variable range from 0.31 to 0.53, which are broadly consistent with the estimate derived by Holly *loc. cit* of 0.31. Overall, the estimates for the capital-aggregate export ratio and unit cost variables appear to be statistically significant.

The estimated elasticities for exchange rate variability are also statistically insignificant for each measure. Thus the empirical evidence leads us to conclude that exchange rate variability has no significant influence on the supply of UK exports. Furthermore, when exchange rate variability is excluded from the export price equation, the estimated coefficients for the remaining variables do not change significantly from the sample of estimates derived when the variability measures are included. It is difficult to compare the estimation results for the variability effect on export prices with the Holly (1995) study, since the GARCH measure used was excluded from the export price cointegrating vector. Moreover, to this author's knowledge, no other studies have modelled the long-run impact of exchange rate variability on export prices using cointegration analysis. Holly *loc. cit* found a significant positive effect of the GARCH measure of exchange rate variability on the short-run movements in UK export prices of manufactured goods.

Table 6.2.3: Long-Run ARDL Estimates (Price Equation)

Standard deviation used as exchange rate variability measure		
Long-Run Coefficients	Model Selection Criteria	
	ARDL-SBC (2, 0, 0, 0)	ARDL-AIC (3, 2, 4, 2)
(k/x)	0.4917 (1.4894)	0.5269 (2.8939)†
c	0.6558 (2.2122)†	0.6613 (4.4117)†
σ^e	-0.00072 (-0.0137)	0.0479 (0.8316)
Absolute difference used as exchange rate variability measure		
	ARDL-SBC (2, 0, 0, 0)	ARDL-AIC (3, 2, 4, 2)
(k/x)	0.4607 (1.5022)	0.5037 (2.5941)†
c	0.6827 (2.4910)†	0.6426 (3.7667)†
σ^e	0.0162 (0.2244)	-0.1001 (-0.1751)
Moving average standard deviation used as exchange rate variability measure		
Long-Run Coefficients	Model Selection Criteria	
	ARDL-SBC (2, 0, 0, 0)	ARDL-AIC (2, 2, 4, 1)
(k/x)	0.4147 (1.3749)	0.3554 (4.0800)†
c	0.6694 (1.9680)†	0.7504 (7.8491)†
σ^e	-0.0562 (-0.3521)	-0.0233 (-0.4318)
Estimation results excluding exchange rate variability measures		
(k/x)	0.4060 (1.6507)	0.3065 (3.7327)
c	0.7247 (3.1565)	0.7652 (8.4136)

note: † denotes significance at the 95% level. Asymptotic 't' ratios in parentheses. The lag structure for each variable in the export price equation is also shown in parentheses. The first two estimated equations also included a dummy variable to account for a pulse shock to the exchange rate variability measure used.

6.2.5 Structural Identification

The main advantage of the ARDL approach is that it allows the estimation of long-run relationships when the regressors are either I(0) or I(1). However, this approach assumes only one long-run relation exists so that the ARDL model is characterized by a single structural equation. As Pesaran and Shin (1997a) conclude:

> '[Focussing] *exclusively on single equation estimation techniques....*[means that] *the important issue of system estimation is not addressed.....Such an analysis inevitably involves the problem of identification of short-run and long-run relations and demands a structural approach to the analysis of econometric models.....An alternative procedure, which takes us back to the Cowles Commission approach, would be to extend the ARDL model methodology..... to systems of equations subject to short-run and/or long-run identifying restrictions.....thus establishing a closer link between the recent cointegration analysis and the traditional simultaneous equations econometric methodology'.*
>
> (Pesaran and Shin, 1997a, p. 24).

At the time of writing this thesis these econometric advances are still being developed. However, to establish whether each long-run structural equation is identified, a restricted VECM is estimated using an approach to long-run structural modelling advocated by Pesaran and Shin (1997b).[73]

73. See also Garratt *et al* (1998); Pesaran and Smith (1998); Pesaran, Shin and Smith (1997).

The first step involves estimation of an unrestricted VECM in order to establish the cointegrating rank. The optimal lag length for the short-run dynamics can be determined from estimating an unrestricted VAR and using lag selection criteria. The VAR includes all of the variables from the structural system, as well as dummy variables to account for structural shocks to some of the variables identified from the ADF tests. The dummy variables are included as exogenous variables.[74] The lag selection criteria, using the standard deviation measure of exchange rate variability, are shown in table 6.2.4.

Table 6.2.4: Lag selection criteria derived from estimation of an unrestricted VAR (using standard deviation measure).

VAR Order	Akaike Information Criterion	Schwarz Bayesian Criterion	Adjusted L-R Test
3	1115.2	925.9	-
2	1162.7	1004.0	$\chi^2(64) = 69.14$
1	1163.2	1075.0	$\chi^2(128) = 146.94$
0	271.7	254.0	$\chi^2(192) = 1316.3$

note: the estimation period was 1974Q1 to 1990Q3, thus a total of 67 observations are used. The maximum VAR lag length was set at 3 periods. The L-R test adjusts the maximised log-likelihood of a restricted VAR to account for the number of parameters estimated. The VAR includes dummy variables for breaks in the export price and exchange rate variability series for the periods 85 Q1 to 86 Q3 and 85Q1 respectively. Exclusion restrictions on the exogenous variables are rejected using L-R tests.

The Akaike Information (AIC) and Schwarz Bayesian (SBC) criteria, as well as an adjusted likelihood ratio test, all suggest the optimal VAR lag length is one period. The same procedure was followed using the moving average standard deviation and 'absolute difference' measures and the test statistics are presented in tables E1 and E2 of appendix E. In these cases, the AIC criterion suggests a VAR lag length of three

74. Likelihood ratio tests were computed to establish the statistical significance of the exogenous variables.

periods, while the SBC criterion suggests a first order VAR. The adjusted L-R test indicates a second order VAR. To avoid over-parameterization, in all cases a first order VAR was selected for estimation of the VECM.[75]

Definition of the cointegrating rank was achieved by estimating an unrestricted VECM incorporating unrestricted intercepts and restricted trends. The ADF tests presented in table 6.2.1 suggest that a number of variables in the system are trended. If the VECM contains linear trends, then quadratic trends will be present in the level of the variables when the model contains unit roots. Without restrictions on the trend coefficients the nature of the trend for the variables in the system varies with the chosen number of cointegrating vectors.[76] Thus the following VECM is estimated:

$$\Delta z_t = \delta_0 + \sum_{i=1}^{k-1} \Gamma_i \, \Delta z_{t-i} + \pi(z_{t-k} - \gamma t) + \varepsilon_t \qquad ..6.2.17$$

where $z = (x, p^x, p^*, y^*, p, (k/x), c, \sigma^e)'$; δ_0 is an intercept term; t is a time trend; $\pi=\alpha\beta'$; γ is an arbitrary vector of fixed constants; and the deterministic trend coefficients are estimated in the cointegrating vector(s).

The AIC and SBC model selection criteria, the trace and maximum-eignvalue tests, together with the asymptotic and finite sample critical values[77] are presented in table 6.2.5 for the system including the standard deviation measure. The same procedure

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75. Hall (1991) and Pesaran and Smith (1998) have illustrated how the Johansen L-R testing procedure is sensitive to identifying different numbers of cointegrating vectors according to the lag length of the VAR; the number of available observations; the degrees of freedom; as well as whether or not the drift and / or trend components are restricted.

76. For a proof of why this result occurs see Pesaran and Shin (1997b); Pesaran, Shin and Smith (1997); and Pesaran and Smith (1998).

77. The finite sample critical values are calculated using a scaling factor suggested by Cheung and Lai (1993). $CR_F = CR_\infty \times (T/(T\text{-}nk))$ where CR_F is the finite sample critical value; CR_∞ is the asymptotic critical value (Johansen and Juselius, 1990; Osterwald-Lenum, 1992); T is the number of observations; n is the number of variables in the system; and k is the number of parameters estimated in the VECM.

was followed using the other measures of exchange rate variability and the results are presented in tables E3 and E4 of appendix E.

For all cases the null hypothesis of 'no cointegration' (i.e. r=0) is rejected. However, the various likelihood ratio tests suggest different number of cointegrating vectors. Using the standard deviation measure, the maximum eigenvalue test suggests four cointegrating vectors, while the trace test indicates at most five cointegrating vectors. The model chosen by the AIC also suggests the presence of five cointegrating vectors, while the SBC indicates four cointegrating vectors. For the moving average standard deviation measure each test except the AIC criterion suggests the presence of two cointegrating vectors. When the 'absolute difference' measure is used all tests indicate four cointegrating vectors.

The structural system implied by economic theory suggests that there should be two cointegrating vectors from the two endogenous variables. However, the likelihood ratio testing procedure rejects this null hypothesis in each case and could explained by the presence of more than two structural equations.[78] It would therefore be advantageous to test for structural identification. Following Engle, Hendry and Richard (1983) weak exogenity implies that for example, the joint distribution ϕ_t[79] is independent of the marginal distribution of φ_t. In other words the parameters of interest i.e. β are a function only of the parameters in the conditional model i.e. η_t/φ_t. This implies that there should be no cross-equation restrictions between the conditional and marginal models. If it is found that there are $r \leq n-1$ cointegrating vectors in β, then the last n-r columns of α will

78. This result should not lead us to reject the implications of the relevant economic theory, since it could still be possible to identify the structural price and volume equations as part of a larger cointegrating space.

79. $\phi_t = [\eta_t, \varphi_t]'$, where η_t is a vector of endogenous variables and φ_t is a vector of exogenous variables.

equal zero. Thus establishing the exogenity of variables can be achieved by identifying the number of non-zero α columns in the long-run matrix $\pi = \alpha\beta'$. Each of the zero columns in α indicate the cointegrating vectors which do not enter the short-run equations. The presence of weakly exogenous variables implies no loss of information for the parameters of interest in the VECM from not modelling the short-run dynamics. The testing procedure can be completed by imposing zero restrictions on the relevant cointegrating α coefficients from the VECM and using a likelihood ratio testing procedure involving the restricted and unrestricted models. PcFIML 8.0 (Hendry and Doornik, 1995) allows this estimation procedure to be completed. Unfortunately, this software was not available at the time of writing this thesis.

A further explanation for the larger cointegrating space is that the stationary variable (exchange rate variability) has defined its own long-run relation (see section 5.1), with only one significant coefficient appearing in the cointegrating vector. However, to implement the structural identification procedure we shall restrict the size of the cointegrating space, so that r=2.

The unrestricted cointegrating vectors are not presented at this stage[80], since we now proceed to test for structural identification of the system implied by economic theory in 6.2.1 and 6.2.2. Furthermore, as we noted in section 5.3 Wickens (1996) has demonstrated that it is difficult to provide an economic interpretation to cointegrating vectors derived from the estimation of unrestricted VECMs, unless *a priori* restrictions are imposed on the reduced form system. The cointegrating vectors reflect the long-run

80. The estimation results are available from the author upon request

relations from a reduced form representation of an underlying structural system of equations.

Table 6.2.5: Unrestricted VECM (using standard deviation measure); sample period: 1973Q3 - 1990Q3; VAR=1; exogenous dummy variables included in the VAR; unrestricted intercepts and restricted trends.

Maximum Eigenvalue Test

Rank	r=0	r=1	r=2	r=3	r=4	r=5
Statistic	108.56	92.81	64.03	47.18	31.17	22.75
Asymptotic Critical Value (95%)	55.14	49.32	43.61	37.86	31.79	25.42
Asymptotic Critical Value (90%)	52.08	46.54	40.76	35.04	29.13	23.10
Finite Sample Critical Value (95%)	63.41	56.72	50.15	43.54	36.56	29.23
Finite Sample Critical Value (90%)	59.89	53.52	46.87	40.29	33.50	26.57

Trace Test

Rank	r=0	r≤1	r≤2	r≤3	r≤4	r≤5
Statistic	381.53	272.97	180.17	116.14	68.95	37.18
Asymptotic Critical Value (95%)	182.99	147.27	115.85	87.17	63.00	42.34
Asymptotic Critical Value (90%)	176.92	141.82	110.60	82.88	59.16	39.34
Finite Sample Critical Value (95%)	210.44	169.36	133.23	100.25	72.45	48.96
Finite Sample Critical Value (90%)	203.46	163.09	127.19	95.31	68.03	45.24

Maximized Log-likelihood and Model Selection Criteria

Rank	r=0	r=1	r=2	r=3	r=4	r=5
Maximized log-Likelihood	1100.7	1155.0	1201.4	1233.4	1257.0	1272.9
Akaike Information Criterion	1076.7	1115.0	1147.4	1167.4	1181.0	1188.9
Schwarz Bayesian Criterion	1049.9	1070.3	1087.1	1093.7	1096.1	1095.0

Using the long-run structural modelling approach of Pesaran and Shin (1997b) involves imposing identifying restrictions on the cointegrating vectors. Exactly-identifying restrictions are imposed on the system for the purpose of 'statistical identification'. These restrictions are 'statistical' in the sense that they are independent of economic theory and are not unique. Pesaran and Shin *loc. cit* prove that exact-identification requires that the number of restrictions, k should be equal to r^2, of which r will be 'normalizing' restrictions and the remainder are exclusion restrictions. Over-identification requires additional exclusion restrictions to be imposed on the system from economic theory. Thus the total number of restrictions becomes $k= m+ r^2$, where m is the number of over-identifying restrictions, which are consistent with the structural system implied by economic theory.

The β matrix from the two cointegrating vectors used to represent the structural system implied by economic theory are given as follows:

$$\beta = \begin{pmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} & \beta_{16} & \beta_{17} & \beta_{18} & \beta_{19} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} & \beta_{25} & \beta_{26} & \beta_{27} & \beta_{28} & \beta_{29} \end{pmatrix} \qquad \text{..6.2.18}$$

based on the structural system:

$$-\beta_{11} x_t = \beta_{12} p_t^x + \beta_{13} p_t^* + \beta_{14} y_t^* + \beta_{18} \sigma_t^e + \beta_{19} \text{ trend} \qquad \text{..6.2.19}$$

$$-\beta_{25} p_t = \beta_{26} (k/x)_t + \beta_{27} c_t + \beta_{28} \sigma_t^e + \beta_{29} \text{ trend} \qquad \text{..6.2.20}$$

where: $\beta_{15} = \beta_{16} = \beta_{17} = 0$ and $\beta_{21} = \beta_{22} = \beta_{23} = \beta_{24} = 0$

where β_{ij} represents the long-run coefficients for variable i (for i=1...9) and cointegrating vector j, for j=1,2. One set of exactly-identifying restrictions is given as follows:

$$H_E: \begin{Bmatrix} \beta_{11} = -1 & \beta_{21} = 0 \\ \beta_{15} = 0 & \beta_{25} = -1 \end{Bmatrix} \qquad \text{..6.2.21}$$

The first cointegrating vector is assumed to represent the export volume equation, while the second cointegrating vector represents the export price equation. Thus a minus unity restriction is imposed on the β_{11} and for the cointegrating vector representing the export price equation $\beta_{25} = -1$.

The relevant economic theory also suggests a number of exclusion restrictions should be imposed on the VECM to test for over-identification. In particular, the p, (k/x) and c variables should not appear in the cointegrating vector for the export volume equation and x, p^x, p^* and y^* should not be included in the cointegrating vector for the export price equation. Thus the null hypothesis for the particular over-identification of the proposed structure is:

$$H_0: \begin{pmatrix} -1 & \beta_{12} & \beta_{13} & \beta_{14} & 0 & 0 & 0 & \beta_{18} & \beta_{19} \\ 0 & 0 & 0 & 0 & -1 & \beta_{26} & \beta_{27} & \beta_{28} & \beta_{19} \end{pmatrix} \quad ..6.2.22$$

The null hypothesis is tested by using the following L-R test:

$$\text{L-R} = 2\,(LR_E - LR_O) \sim \chi^2_r\,(k-r^2) \quad ..6.2.23$$

where LR_E is the maximized value of the log-likelihood function under the $k=r^2$ exactly-identifying restrictions and LR_O is the maximized value of the log-likelihood function under the exactly- and over-identifying restrictions. The test statistic has an asymptotic chi-squared distribution with $m=k-r^2$ degrees of freedom. If the estimated test statistic is less than the critical value then we can conclude the over-identifying restrictions are supported by the data.

The reduced form system was estimated subject to the four exactly-identifying restrictions specified in 6.2.21 and the restriction that r=2. The values of the maximized log-likelihood, using the standard deviation, 'absolute difference', and moving average standard deviation measures are 1201.4, 1218.2, and 1277.6 respectively. In each case, these values are identical to the maximized log-likelihood from estimation of the unrestricted VECM when r=2 (see tables 6.2.5, D3 and D4). Thus we can conclude that the exactly-identifying restrictions are not rejected.

We can now proceed to test the additional over-identifying restrictions from economic theory. The log-likelihood function is maximized using the Newton-Raphson algorithm until convergence occurs. Initial conditions are specified from the system estimates derived under the exactly-identifying restrictions.

Given that the ARDL estimates implied that the measures of exchange rate variability had no statistically significant influence on either the demand for or supply of exports, we firstly imposed an exclusion restriction on the variability coefficient of each cointegrating vector. The estimated likelihood ratio test for the two over-identifying restrictions are 50.12, 30.67 and 56.28 for the system including the standard deviation; absolute difference and moving average standard deviation measures respectively. The estimated likelihood ratio tests exceed the 95% chi-squared critical value of 5.99 in each case. Thus the hypothesis testing procedure indicates that the measures of exchange rate variability play a significant role in defining the long-run relationships represented by the cointegrating vectors. This result somewhat contradicts the conclusions made from the ARDL procedure, which suggested that each of the variability elasticities were statistically insignificant. Furthermore, we later show that many of the variability elasticities from the estimated restricted VECMs are statistically insignificant and for both cointegrating vectors. However, in light of the above evidence each measure of exchange rate variability will remain in the VECM, and we will now proceed to test the five over-identifying restrictions implied by economic theory. The estimates are presented in table 6.2.6.

Table 6.2.6: Maximum likelihood estimates of cointegrating vectors subject to exactly- and over-identifying restrictions.

	Standard Deviation		Absolute Difference		Moving Average Standard Deviation	
	CV1	**CV2**	**CV1**	**CV2**	**CV1**	**CV2**
x	-1	0	-1	0	-1	0
p^x	4.1357 (3.0415)	0	-2.3040 (1.5740)	0	0.6062 (0.5841)	0
p^*	-8.8504 (6.3330)	0	5.2439 (3.6142)	0	-1.3242 (1.3757)	0
y^*	-1.3781 (2.2085)	0	-3.0071 (1.6764)	0	0.5139 (0.5242)	0
p	0	-1	0	-1	0	-1
(k/x)	0	-1.2500 (0.1978)	0	-2.4287 (none)	0	-0.7433 (0.3424)
c	0	1.3290 (0.0390)	0	-0.4962 (1.5116)	0	0.3631 (none)
σ^e	-0.029 (none)	0.0087 (none)	0.2433 (0.1588)	-0.6734 (none)	0.0039 (0.0534)	-0.0255 (0.1239)
Trend	0.0079 (0.0526)	-0.0185 (0.0027)	0.0126 (0.0197)	-0.0412 (0.0113)	0.0196 (0.0127)	-0.0099 (0.0076)
LL - exactly-identifying restrictions	1201.4		1218.2		1277.6	
LL - over-identifying restrictions	1140.6		1177.9		1238.9	
LR Test of Restrictions $\chi^2(5)$	**121.68**		**80.59**		**77.40**	

note: asymptotic standard errors in parentheses.

The estimated likelihood ratio test for the over-identifying restrictions exceeds the 95% chi-squared critical value of 11.07 in each case. Thus the structural restrictions implied by economic theory are not supported by the data. There are two possibilities to interpreting this result. Firstly, the system is defined by a greater number of structural equations than implied by the economic theory. The likelihood ratio testing procedure from the restricted VECM indicated that the number of cointegrating vectors was greater than two in each case. Thus it may still be possible to interpret the export volume and price cointegrating vectors as export demand and supply equations, as a component of a larger cointegrating space. A test for weak exogenity is one way forward to identify the number of endogenous variables in the system. It would then be possible to extend the original model to encompass a wider system of equations.[81]

Secondly, that the restrictions imposed on the cointegrating vectors by economic theory are not supported by the data. The implied cointegrating vectors could then not be considered to represent export demand and supply equations. In this instance the regressors from the export supply equation would play a significant role in defining the long-run relationship of the export demand equation and vice versa. Consequently, the cointegrating vectors could only be interpreted as representing the reduced form solution of export volumes and prices.

Economic interpretation is also made difficult by the fact that in some cases the normalised coefficients are incorrectly signed. For example, with the system including the standard deviation measure, the coefficients are incorrectly signed for the p^x, p^* and y^* variables in cointegrating vector one and the coefficient for the (k/x) variable is incorrectly signed in cointegrating vector two. The magnitude of the coefficients are also larger than we may expect, in particular compared to those estimates derived from the ARDL approach. For example, the ARDL estimate for the elasticity of the p^x variable, using the standard deviation measure, is -0.70 compared to 4.14 derived from the first cointegrating vector of the restricted VECM. Similarly, the ARDL estimate of the p^* elasticity is 1.64 compared to -8.85. More concerning is the fact that many of the

81. As mentioned earlier the software required to undertake the test for weak exogenity was not available at the time of writing this thesis.

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estimates appear to have large standard errors, indicating that the coefficients are statistically insignificant. The ARDL estimates indicate that all of the variables except the measures of exchange rate variability are statistically significant. In some instances, the values produced by the maximum likelihood procedure are so large that values are not produced by the software program. The values for the estimated likelihood ratio test are also very large.

A further problem is that the likelihood ratio test is founded on an asymptotic chi-squared distribution which may be subject to finite sample bias. The testing procedure is likely to be sensitive to the sample size of the data set; the order of the VAR; the number of parameters; the number of restrictions; and the size of the cointegrating space. Garratt *et al* (1998) have developed a bootstrapping procedure to generate finite sample critical values which takes account of the dimensions of the system and the sample size of data set. At the time of writing this thesis, full details of the bootstrapping procedure were not available. It is intended to use this procedure in the future to interpret more fully the conclusions made from the estimated likelihood ratio test.

6.3 Conclusions

The purpose of this chapter was to investigate whether exchange rate variability had any significant influence on UK aggregate exports to its eight main trading partners, over the period 1973 Q2 to 1990 Q3. A structural system of export volumes and prices was used in order to model the factors influencing export demand and supply.

The ARDL approach to cointegration (Pesaran, Shin and Smith, 1996) allowed the estimation of long-run relationships incorporating both I(1) and I(0) variables simultaneously. The estimation results suggest that exchange rate variability had no significant influence on either the demand for or supply of exports, over the sample period considered. As we mentioned in chapter 3, the plethora of exchange rate variability measures from the literature have a variety of economic and statistical properties. It is essential therefore to test the robustness of our conclusions across a range of proxies. We find no significant 'variability effect' on export volumes or prices across the three measures of exchange rate variability employed. Estimation of the long-run structural equations excluding exchange rate variability leaves the remaining parameters unchanged, suggesting that the measures do not enhance the explanatory power of the export demand and supply equations at all.

However, the ARDL procedure only allows us to focus on the estimation of single equations. In order to interpret the structural system as representing a model of export demand and supply, we need to test whether the restrictions implied by economic theory are data admissible. The long-run structural modelling approach of Pesaran and Shin (1997b) has provided a framework in order to test structural restrictions on the cointegrating vectors. The estimation results from this procedure strongly reject the restrictions implied by economic theory. In the light of this evidence it is difficult to interpret the restricted cointegrating vectors as representing structural export demand and supply equations. They could be viewed as the reduced form solution of export volumes and prices. Alternatively, the system may be defined by a larger structural system than just the export demand and supply equations given in 6.2.1 and 6.2.2. Further research could usefully employ a test for weak exogenity. These results also raise questions regarding the estimation results from the ARDL approach; developments to date in this literature have assumed that each cointegrating vector is defined by a single structural equation.

However, while there are difficulties associated with identifying the structural system, the evidence from the ARDL approach leads us to suggest that the measures of exchange rate variability used have no significant influence of the prices or volumes of UK exports to its eight main trading partners.

In the next chapter we re-estimate our model of export demand and supply in order to consider whether the relationship between UK exports and exchange rate variability is sensitive to the country of destination. Thus, estimation is undertaken for each of the bi-lateral trade flows between the UK and its eight main trading partners.

Chapter Seven

Exchange Rate Variability and UK Export Volumes and Prices - Further Empirical Evidence.

Abstract

In this chapter we examine whether the relationship between UK exports and exchange rate variability is sensitive to the country of destination. The model adopted in the previous chapter is estimated for bi-lateral exports to each of the UK's eight main trading partners. The ARDL approach to cointegration is again used to derive the long-run estimates of the structural system. A restricted VECM is estimated to test for identification.

7.1 Introduction

From the previous chapter we were able to conclude from an initial analysis that none of the three measures of exchange rate variability had a statistically significant influence on either the prices or volumes of UK aggregate exports to its eight main trading partners. One problem with using aggregate trade data is that exchange rate variability may have different impacts on trade volumes and prices across countries and even sectors of a particular economy. The potential negative influence on exports may depend on the degree of exchange rate variability and could be greater for countries with larger unanticipated fluctuations compared to those countries whose exchange rates are relatively stable and more predictable. The influence on export volumes may also vary across bi-lateral export flows depending upon the price elasticity of demand.

Unpredictable fluctuations in the exchange rate create uncertainty regarding the price of exports received by exporters in domestic currency terms. The negative influence of exchange rate uncertainty may vary depending upon the price elasticity of demand for each foreign market. Exporters may also have varying degrees of market power in different markets which can affect their ability to pass on any costs of exchange rate variability in the form of higher prices. The hedging facilities available may also vary across importing countries.

In this chapter we estimate the model adopted in chapter six for each bi-lateral export flow between the UK and its eight main trading partners. The purpose of this investigation is to examine to what extent the influence of exchange rate variability on the demand for and supply of UK exports varies across countries of destination. This research will also hopefully clarify some of the ambiguities discovered in chapter six regarding the exchange rate variability effect and the identification of the structural equations from the reduced form system. We select one of the measures of exchange rate variability used in the previous chapter: the standard deviation in the monthly observations of the sterling effective exchange rate with respect to country j (for j = 1,...8). This measure was selected since from the aggregate export study we found that the moving average standard deviation produced a smoothed series, which may lead to an understatement of the 'true' degree of exchange rate uncertainty (Pagan and Ullah, 1986). Furthermore, the absolute difference measure had a very large outlier in the series compared to the other values, which could distort the empirical analysis. The econometric methodology is the same as in the previous chapter. The ARDL approach is used to derive structural estimates for each trade flow and the restricted VECM approach adopted to test for identification. Thus we aim to establish whether the sign and magnitude of the structural elasticities are economically sensible and whether they vary across trade flows; also whether structural identification from a restricted VECM is dependent upon the country of destination.

Section 7.2 briefly reviews the model and data used for each trade flow. Section 7.2 presents the empirical analysis which is separated into three parts: (i) unit root tests are calculated to test the order of integration of each variable; (ii) structural estimates are provided by the ARDL approach, in order to examine the influence of exchange rate variability on UK bi-lateral export flows; (iii) a restricted VECM is estimated in order to examine whether the restrictions imposed on the structural system by economic theory are supported by the data. Section 7.3 provides concluding comments.

7.2 Empirical Analysis

7.2.1 The Model and Data

We adopt the basic model used in chapter six to examine the influence of the standard deviation measure on UK export volumes and prices to country j, over the period 1973 Q2 to 1990 Q3:

$$\beta_{11j}\, x_{jt} = \beta_{12j}\, p^{x}_{jt} + \beta_{13j}\, p^{*}_{jt} + \beta_{14j}\, y^{*}_{jt} + \beta_{18j}\, \sigma^{e}_{jt} \qquad ..7.2.1$$

$$\beta_{25j}\, p_t = \beta_{26j}\, (k/x)_t + \beta_{27j}\, c_t + \beta_{28j}\, \sigma^{e}_{jt} \qquad ..7.2.2$$

(all variables in natural log form)

The c_t and $(k/x)_t$ variables are common for each trade flow, since they represent the exporter's unit cost and capital to aggregate export ratio, which are assumed to be the same irrespective of the country of destination for exports. Disaggregated export price data according to country of destination, is not available for the UK, so we assume that the same sterling price of exports, p_t is faced by all importers. However, the price of exports in foreign currency terms, p^x_{jt} varies across countries since p_t is deflated by the relevant bi-lateral sterling exchange rate i.e. $p^x_{jt} = p_t/e_{jt}$, where e_{jt} is the price of foreign currency for the jth country in terms of sterling. The p^*_{jt} and y^*_{jt} variables are the wholesale price index and measure of output for country j respectively, x_{jt} is the volume of UK exports to country j. Finally, σ^e_{jt} is the standard deviation for a given quarter of the percentage changes in the monthly observations of the sterling exchange rate with respect to country j.

7.2.2 Unit root tests

To establish the order of integration of each variable except p_t, c_t and $(k/x)_t$, augmented Dickey-Fuller tests were calculated for every trade flow. The estimation results are presented in appendix F. In general, each variable except the standard deviation appears to be integrated of order one. The only exception is the wholesale price index for Italy which is I(0). The variability measure was found to be I(0) for each sterling bi-lateral exchange rate. From section 6.3 (part iii) we noted that the export price variable, p_t appears to be subject to a structural break between 85Q1 and 86Q3. Also the exchange rate variability measure appeared to be subject to a pulse shock either at 85Q1 or 77Q1-77Q3. In order to avoid potential bias in the calculation of the unit root tests due to breaks in the series, a modified version of the ADF test was calculated due to Perron (1989). The results confirm that each export price variable was I(1).

7.2.3 ARDL estimates

The first step in implementing the ARDL approach to cointegration involves establishing whether a long-run equilibrium relationship exists for both the volume and price equations of our structural system. The following autoregressive distributed lag error correction model is estimated for each UK export flow and the critical bounds test used to test the null hypothesis of no long-run relationship:

$$\Delta x_{jt} = \alpha_{10j} + \alpha_{11j}\, t + \sum_{i=1}^{n-1} \psi_{1ij}\, \Delta x_{t-i} + \sum_{i=1}^{k-1} \varphi_{1ij}\, \Delta p^{x}_{jt-i} + \sum_{i=1}^{p-1} \beta_{1ij}\, \Delta p^{*}_{jt-i}$$

$$+ \sum_{i=1}^{q-1} \theta_{1ij}\, \Delta y^{*}_{jt-i} + \sum_{i=1}^{s-1} \xi_{1ij}\, \Delta \sigma^{e}_{jt-i} + \phi_{1j}\, x_{jt-1} + \delta_{11j}\, p^{x}_{jt-1} + \delta_{12j}\, p^{*}_{jt-1}$$

$$+ \delta_{13j}\, y^{*}_{jt-1} + \delta_{14j}\, \sigma^{e}_{jt-1} + \varepsilon_{1jt} \qquad ..7.2.3$$

$$\Delta p_t = \alpha_{20j} + \alpha_{21j}\, t + \sum_{i=1}^{n-1} \psi_{2ij}\, \Delta p_{t-i} + \sum_{i=1}^{k-1} \varphi_{2ij}\, \Delta c_{t-i} + \sum_{j=1}^{p-1} \beta_{2ij}\, \Delta(k/x)_{t-i}$$

$$+ \sum_{i=1}^{s-1} \xi_{2ij}\, \Delta \sigma^{e}_{jt-i} + \phi_{2j}\, p_{t-1} + \delta_{21j}\, c_{t-1} + \delta_{22j}\, (k/x)_{t-1} + \delta_{23j}\, \sigma^{e}_{jt-1} + \varepsilon_{2jt} \qquad ..7.2.4$$

for j=1,....,8

The null hypothesis of no long-run relationship for the export volume equation is $\phi_{1j}=\delta_{11j}=\delta_{12j}=\delta_{13j}=\delta_{14j}=0$ and $\phi_{2j}=\delta_{21j}=\delta_{22j}=\delta_{23j}=0$ for the export price equation. If the computed F-statistic exceeds the critical value bounds then the null hypothesis can be rejected.

For each trade flow an ARDL error correction model was estimated by OLS, using a general-to-specific approach to determine the optimal lag length of the short-run dynamics of each variable. Exclusion restrictions were then imposed on the lagged levels of the variables and the F-statistic computed to test the statistical significance of the restrictions. The estimated F-statistics are presented in table 7.2.1. In all but one case the null hypothesis of no long-run relationship is rejected using the 95% critical values. For the case of UK export volumes to Canada the estimated F-statistic is below both critical values, even at the 90% level.

Table 7.2.1: Test results for the existence of a long-run relationship

Volume Equation	
Importing Country	**F - statistic**
France	6.2782
West Germany†	7.6831
Belgium†	4.7800
Netherlands†	6.7607
Italy†	4.9335
USA†	8.8360
Canada§	1.6291
Japan§	5.3005
95% Critical Values	**Case 1:** I(0) = 2.157; I(1) = 3.334; **Case 2:** I(0) = 2.649; I(1) = 3.805. [see appendix D]
Price Equation	
Importing Country	**F - statistic**
France	4.5600
West Germany	6.2492
Belgium†§	7.3915
Netherlands§	7.3088
Italy§	8.6889
USA	5.6212
Canada	4.1544
Japan§	7.6401
95% Critical Values	**Case 1:** I(0) = 2.2812; I(1) = 3.474); **Case 2:** I(0) = 2.850; I(1) = 4.049. [see appendix D]

note: † denotes that the regression equation included an intercept term; § denotes dummy variables were included in the regression equation to allow for structural breaks in the drift processes of some of the series. The critical values for case 1 are computed under the assumption of zero drift and trend components, while the critical values for case 2 assume a significant drift and zero trend.

The long-run structural estimates for the export volume and price equations are derived from applying the solutions in 6.2.13 and 6.2.14 to each trade flow. The estimates were computed for all trade flows except UK export volumes to Canada, since the critical bounds test suggested there was no long-run relationship for the export volume equation.

The results for the export volume equation are shown in table 7.2.2. The SBC and AIC are again used to determine the optimal lag structure for the short-run dynamics. In most cases the AIC selects a higher order ARDL than the SBC, though the lag structure tends to vary across trade flows using both criteria. Concentrating first on the elasticities for the p^x, p^* and y^* variables, there is some evidence to suggest that the sign and magnitude of the estimated coefficients are not consistent with economic theory. For example, in four cases the ARDL-SBC model indicates that the p^x elasticity is incorrectly signed and insignificant and in one is negatively signed and significant. The ARDL-SBC specification also suggests that the p^* elasticity is incorrectly signed and insignificant in three cases and positively signed but insignificant in one case. Both the AIC and SBC indicate that the y^* elasticity is incorrectly signed and insignificant in two cases and positive and insignificant in one case using the AIC. Comparing these results with the aggregate export study, we found that the elasticity for the p^x, p^* and y^* variables were all correctly signed and significant using both lag selection criteria.

Among those coefficients which are correctly signed and significant there is also significant variation in the magnitude of the price and income elasticities. For example, the elasticity for the p^x variable varies from -0.75 to -1.44 (using the AIC) and from -0.62 to -0.94 (using the SBC). By contrast, the p^x elasticity obtained from the aggregate export model varied from -0.69 to -0.70 (using the SBC) and between -0.65 and -0.80 (using the AIC). The elasticity for the p^* variable ranges from 1.29 to 2.65 (using the AIC) and from 1.28 to 5.02 (using the SBC). The range of magnitudes from the aggregate export equations was between 1.64 and 1.69 (ARDL-SBC model) and from

1.60 to 1.69 (ARDL-AIC model). Finally, the y^* elasticity ranges from 1.17 to 3.75 using both lag selection criteria, compared to a range of 0.56 to 0.94 from the estimated aggregate export equations.

Overall, the evidence suggests that the standard deviation measure of exchange rate variability has no significant influence on export volumes over the sample period. A significant variability elasticity is found in three cases; however, these results are not consistent across the lag selection criteria. For example, the ARDL-AIC model indicates that the standard deviation has a significant negative influence on UK export volumes to Italy and Japan. However, these results are not supported by the ARDL-SBC model. The SBC also indicates a statistically significant positive relationship between UK export volumes to Belgium and the standard deviation measure but the ARDL-AIC model also does not support this conclusion.

The conclusion of no significant variability effect is also supported by the fact that when the volume equation is re-estimated for each bi-lateral export flow excluding exchange rate variability (see table 7.2.3 for estimation results) the sign, magnitude and statistical significance of the remaining elasticites remain unchanged in the majority of cases. However, some of the elasticities are still incorrectly signed and statistically insignificant, a conclusion which is inconsistent with economic theory. Thus it appears that including the measure of exchange rate variability does not improve the explanatory power of the export volume equation. Furthermore, the small variation in the sign and magnitude of the remaining elasticities across variability measures and lag selection criteria also lead to supporting the conclusion of an insignificant variability effect.

Table 7.2.3: Long-run structural estimates for export volume equation (excluding exchange rate variability measure).

	ARDL-SBC			SRDL-AIC		
Importing Country	p^x	p^*	y^*	p^x	p^*	y^*
France (SBC-6,1,0,0; AIC-6,1,5,0)	-0.9442 (-8.1843)	1.8849 (15.2336)	-0.0255 (-0.3452)	-1.1483 (-6.8665)	2.1952 (10.1048)	-0.0335 (-0.4785)
West Germany (SBC-1,0,1,0; AIC-1,0,1,0)	-1.8201 (-2.2226)	2.9200 (3.2655)	0.0119 (0.0188)	-1.8201 (-2.2226)	2.9200 (3.2655)	0.0119 (0.0188)
Belgium†§ (SBC-5,0,0,0; AIC-5,0,4,3)	-0.6141 (-2.2290)	-0.0089 (-0.0268)	2.0353 (6.4517)	-0.3582 (-1.9809)	-0.1926 (-0.8608)	1.7407 (6.4640)
Netherlands† (SBC-1,0,0,0; AIC-1,2,5,1)	-0.3787 (-0.6581)	2.6339 (2.3869)	-0.5288 (-0.6883)	-1.5593 (-2.2735)	5.2868 (3.5840)	-1.3003 (-1.7292)
Italy† (SBC-5,4,0,0; AIC-5,4,0,4)	-0.1997 (-1.2120)	-0.0773 (-0.6542)	3.7069 (10.6651)	-0.0794 (-0.3699)	-0.1584 (-1.0768)	3.7504 (10.4990)
Japan (SBC-1,0,1,0; AIC-1,6,0,2)	-0.1913 (-1.2783)	-1.6544 (-4.1329)	2.1159 (17.0379)	-0.2825 (-1.8792)	-1.4587 (-3.5816)	2.1522 (17.6977)
USA† (SBC-0,1,0,0; AIC-4,1,0,0)	-0.8485 (-5.4149)	1.3393 (6.3152)	1.2475 (4.2919)	-0.9339 (-6.4794)	1.4720 (7.2891)	1.1439 (4.4241)

note: † denotes that the regression equation included an intercept term; § denotes dummy variables were included in the regression equation to allow for structural breaks in the drift processes of some of the series. The lag structure for each variable in the equation is shown in parentheses.

The estimation results for the export price equation are presented in table 7.2.4. The SBC produces a lower order ARDL than the AIC and the lag structure is more consistent across the trade flows. The elasticities for the c_t and $(k/x)_t$ variables have signs which are consistent with economic theory in each case. The magnitudes are also broadly consistent, which is not surprising given both variables are common for each trade flow. The elasticity for the c_t variable is significant and positive in six cases from the ARDL-SBC model and in all cases using the ARDL-AIC specification. The $(k/x)_t$ variable has significant and positive elasticities in four cases from the ARDL-SBC model and the elasticities are significant and positive in all cases using the ARDL-AIC model. The sign and magnitude of the elasticities for these variables are also consistent with those obtained from the price equation for aggregate exports and the estimation results when exchange rate variability is excluded (see table 6.2.3)

The sign of the variability elasticity varies across trade flows: the ARDL-SBC model suggests that the variability elasticity is negative in five cases and positive in two cases. Using the AIC three negative elasticities and four positive elasticities are found. In only one case, UK exports to the Netherlands, using the AIC is the variability elasticity significant and in this case it has a negative sign. However, this conclusion is not supported by the ARDL-SBC model where the estimated 't' ratio is smaller given the much lower ARDL selected by the SBC. Overall there is no conclusive evidence of a statistically significant relationship between export prices and the standard deviation measure of exchange rate variability.

Table 7.2.4: Long-run structural estimates from ARDL Approach - export price equation

	ARDL-SBC			SRDL-AIC		
Importing Country	(k/x)	c	σ^e	c	(k/x)	σ^e
France (SBC-2,0,0,0; AIC-2,4,2,4)	0.7008 (2.4177)	0.4571 (1.3439)	0.02447 (0.4063)	0.7725 (9.1095)	0.34284 (3.0512)	-0.0095 (-0.1821)
West Germany (SBC-2,0,0,0; AIC-2,2,4,0)	0.4044 (1.6232)	0.7242 (3.1241)	-0.00228 (-0.07679)	0.3764 (3.7956)	0.7742 (8.9379)	0.02627 (1.0786)
Belgium§ (SBC-2,0,0,0; AIC-2,2,4,0)	0.3797 (1.6695)	0.7214 (3.1985)	-0.0302 (-0.6311)	0.3709 (3.7061)	0.7693 (8.5961)	0.0151 (0.6194)
Netherlands§ (SBC-2,0,0,0; AIC-3,2,4,2)	0.5329 (1.3873)	0.6517 (2.0471)	0.0344 (0.5107)	0.5118 (2.5945)	0.6540 (4.1346)	-1.0627 (-1.8888)
Italy§ (SBC-2,0,0,0; AIC-3,2,4,2)	0.4623 (1.5176)	0.6647 (2.3641)	-0.0209 (-0.4017)	0.5598 (2.4481)	0.6280 (3.4472)	0.0475 (0.8282)
USA (SBC-2,0,0,0; AIC-2,2,4,0)	0.3490 (1.7024)	0.7421 (3.6846)	-0.0402 (-0.7875)	0.3629 (3.5879)	0.7619 (8.3865)	-0.00014 (-0.0059)
Canada (SBC-2,0,0,0; AIC-2,4,0,0)	0.3749 (1.5033)	0.7103 (2.7692)	-0.0509 (-0.7414)	0.3549 (2.4987)	0.7528 (5.4658)	-0.0044 (-0.1155)
Japan§ (SBC-2,0,0,0; AIC-2,2,4,0)	0.2652 (1.5903)	0.8586 (5.2812)	-0.0348 (-0.6250)	0.3137 (3.5148)	0.8219 (9.7403)	0.00073 (0.0316)

note: § denotes dummy variables were included in the regression equation to allow for structural breaks in the drift processes of some of the series. The lag structure for each variable in the equation is shown in parentheses.

Thus the empirical results obtained from estimating the system of export volume and export price equations for each trade flow does not tend to provide supporting evidence for the economic theory in two respects. Firstly, we can unambiguously conclude that the standard deviation measure of exchange rate variability (calculated for each sterling bi-lateral exchange rate) has no statistically significant influence on either bi-lateral export volumes or aggregate export prices. These findings are robust across all of the trade flows examined and are consistent with the results from the aggregate export study. Secondly, the sign of some of the remaining elasticities in the export volume equation are inconsistent with our prior expectations from theory and in some cases are also statistically insignificant, which we did not find when estimating the aggregate export volume equation.

7.2.4 Structural Identification

Economic theory indicates that the export volume and price equations should be interpreted as demand and supply equations. It is useful to test whether the restrictions imposed on the structural system are data consistent. This requires estimation of a restricted VECM.

Firstly, we estimate an unrestricted VECM in order to define the cointegrating rank. The optimal lag length for the short-run dynamics is determined from lag selection derived from estimation of an unrestricted VAR. The test results are presented in tables G1 to G7 of appendix G. For all of the trade flows, the SBC selects a lag length for the VAR of one period. This conclusion is supported in only two cases by the AIC, whereas in three cases a second order VAR is indicated and in two cases a third order VAR is considered to be the optimal VAR lag length. The adjusted L-R test suggests a first order VAR in only one case; a second order VAR in three cases; and a third order VAR also in three cases. Given the SBC provided the most consistent VAR selection across the trade flows and to avoid over-parameterization a first order VAR was chosen for estimation of the unrestricted VECM in each case.

Estimation of the cointegrating VAR was undertaken incorporating unrestricted intercepts and restricted trends. The ADF tests presented in appendix F indicate that a number of the variables in the system contain deterministic trends.[82] Restrictions are imposed on the trend coefficients to avoid the possibility of quadratic trends in the levels of the variables when the model contains unit roots (Pesaran and Smith, 1998).

The estimation results for the unrestricted VECM are shown in tables G8 to G10. The maximum eigenvalue and trace tests are presented as well as the asymptotic and finite sample critical values. The AIC and SBC model selection criteria are also used to identify the number of cointegrating vectors. The null of no cointegration (r=0) is rejected in each case. A summary of the number of cointegrating vectors identified by each L-R test is shown in table 7.2.5. There is some variation in the size of the cointegrating rank across the trade flows. However, the maximum eigenvalue and trace tests, as well as the SBC identify the same number of cointegrating vectors in all but two cases. The AIC tends to suggest the presence of far more long-run relations than the other tests in every case. The hypothesis testing procedure suggests the presence of more cointegrating vectors than implied by economic theory. This finding may lead us to reject the economic theory in the sense that there could be more than two endogenous

82. While the ADF tests suggest none of the variables were trended in the cases of UK exports to the Netherlands and Italy, the cointegrating VAR was estimated incorporating unrestricted intercepts and restricted trends. Exclusion restrictions were then imposed on the trend coefficients. L-R testing suggested these exclusion restrictions are not supported by the data.

variables, and hence more than two structural equations. Therefore, the size of the data-consistent structural system could be larger than that implied by economic theory. Alternatively, one of the additional cointegrating vectors could be accounted for by the stationary variability measure, which defines its own long-run relation. However, in an attempt to implement the structural identification procedure we restrict the number of cointegrating vectors to equal two.

Table 7.2.5 A summary of the number of cointegrating vectors identified by the likelihood ratio tests.

Importing Country	Number of cointegrating vectors			
	Maximum Eigenvalue Test	Trace Test	Schwarz Bayesian Criterion	Akaike Information Criterion
France	3	3	3	6
West Germany	4	4	4	6
Belgium	3	3	3	7
Netherlands	3	3	3	8
Italy	3	3	4	5
USA	5	3	5	8
Japan	3	5	4	7

We define the restricted VECM as follows:

$$\Delta z_{jt} = \alpha_{0j} + \sum_{i=1}^{k-1} \Gamma_{ij}\, \Delta z_{jt-i} + \pi(z_{jt-k} - \gamma_j t) + \varepsilon_{jt} \qquad ..7.2.5$$

where: $z_j = (x_j,\ p_j^x,\ p_j^*,\ y_j^*, p, (k/x), c,\ \sigma_j^e)'$,

γ = a n×1 vector of unknown fixed constants,

$$\beta = \begin{pmatrix} \beta_{11j} & \beta_{12j} & \beta_{13j} & \beta_{14j} & \beta_{15j} & \beta_{16j} & \beta_{17j} & \beta_{18j} & \beta_{19j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} & \beta_{24j} & \beta_{25j} & \beta_{26j} & \beta_{27j} & \beta_{28j} & \beta_{29j} \end{pmatrix} \qquad \text{for } j=1,....,7$$

One null hypothesis for exact-identification, incorporating two 'normalizing' restrictions and two exclusion restrictions is given as follows:

$$H_E: \begin{Bmatrix} \beta_{11j} = -1 & \beta_{21j} = 0 \\ \beta_{15j} = 0 & \beta_{25j} = -1 \end{Bmatrix} \qquad ..7.2.6$$

where the first cointegrating vector, β_{1j} is assumed to represent the UK export volume equation with respect to country j and the second cointegrating vector, β_{2j} represents the UK export price equation for country j. The VECM was estimated subject to the four exactly-identifying restrictions. The values of the maximized log-likelihood are shown in tables 7.2.6 together with the values of the maximized log-likelihood from the unrestricted VECM, taken from table G10 when r=2. From these estimation results we can conclude the exactly-identifying restrictions cannot be rejected.

Table 7.2.6: Values of the maximized log-likelihood for the cointegrating vectors subject to exactly-identifying restrictions, assuming r=2.

Importing Country	Value of the maximized log-likelihood (exactly-identifying restrictions)	Value of the maximized log-likelihood (unrestricted VECM)
France	1050.6	1050.6
West Germany	1030.0	1030.0
Belgium	892.6	892.6
Netherlands	913.7	913.7
Italy	899.4	899.4
USA	995.95	995.95
Japan	994.27	994.27

The null hypothesis for over-identification of the cointegrating vectors implied by economic theory is:

$$H_O: \begin{pmatrix} -1 & \beta_{12j} & \beta_{13j} & \beta_{14j} & 0 & 0 & 0 & \beta_{18j} & \beta_{19j} \\ 0 & 0 & 0 & 0 & -1 & \beta_{26j} & \beta_{27j} & \beta_{28j} & \beta_{19j} \end{pmatrix} \qquad ..7.2.7$$

Before proceeding with the test for the five over-identifying restrictions, we firstly conducted a test for exclusion restrictions imposed on the variability coefficients. The results from the ARDL approach suggested that exchange rate variability had no statistically significant influence on either the prices or volumes of UK exports. Thus the VECM was estimated subject to the two over-identifying restrictions. The likelihood ratio tests presented in table 7.2.7 exceed the 95% chi-squared critical value of 5.99 in each case, leading us to reject the null hypothesis that the variability coefficients are equal to zero in each case. This conclusion directly contradicts the findings from the ARDL approach. We therefore estimate the restricted VECM without exclusion restrictions on the variability coefficients.

Table 7.2.7: Likelihood ratio tests for exclusion restrictions imposed on the variability coefficients in both cointegrating vectors.

Importing Country	Likelihood Ratio Test Statistic - $\chi^2(2)$
France	13.87
West Germany	11.87
Belgium	72.85
Netherlands	81.92
Italy	18.65
Japan	17.18
USA	99.74

The test statistics for the five over-identifying restrictions suggested by economic theory are shown in table 7.2.8. In three out of seven cases the likelihood ratio test exceeds the 95% chi-squared critical value of 11.07. In the remaining four cases we cannot reject the null hypothesis. In a number of cases the estimated elasticities have signs which are inconsistent with economic theory. For example, the y^* elasticity is incorrectly signed for UK exports to France, the Netherlands, USA and Japan and the elasticity for the (k/x) variable is incorrectly signed for all trade flows. The magnitude of the coefficients are also larger than we may expect and there is considerable variation across the trade flows. For example, the y^* elasticity varies from -5.90 (UK exports to Japan) to 2.22 (UK exports to Belgium), while the p^* elasticity ranges from -0.57 (UK exports to Belgium) to 11.83 (UK exports to the Netherlands). A significant proportion of the estimated elasticities also have large estimated standard errors, implying that some of the coefficients are statistically insignificant.

The variability coefficient is significant at the 95% level in five cases: UK exports to West Germany (CV2); UK exports to Belgium (CV2); UK exports to Italy (CV2) and UK exports to Japan (CV1 and CV2). In three cases (UK exports to Belgium, Italy and Japan) the structural restrictions cannot be rejected. In the case of UK exports to Japan both of the variability coefficients are negatively signed indicating that exchange rate variability has a negative influence on the demand and supply of exports. However, it is difficult to provide an economic interpretation of this result, since we typically assume that either exporters or importers face the foreign exchange risk associated with fluctuations in the exchange rate. The negative variability coefficient in CV1 suggests that the exchange rate variability faced by Japanese importers depresses the demand for UK exports. However, because our economic theory assumes an infinitely elastic export supply schedule, export prices should remain unaffected and only export volumes should fall. If UK exporters face the foreign exchange risk then the supply of exports should contract, causing a rise in export prices, not a fall as implied by the estimated elasticity. In the other two cases where the structural representation is data consistent, the variability coefficient is negatively signed in CV2 and insignificant for

CV1. This result implies that the measure of exchange rate variability has no significant influence on the demand for exports. However, if the supply of exports is expected to contract in the face of foreign exchange risk then the price of exports should rise not fall as implied by the estimated elasticities.

Table 7.2.8: Maximum likelihood estimates of cointegrating vectors subject to exactly- and over-identifying restrictions.

	Importing Country													
	France		West Germany		Belgium		Netherlands		Italy		USA		Japan	
	CV1	CV2	CV1	CV2	CV1	CV2	CV1	CV2	CV1	CV2	CV1	CV2	CV1	CV2
x	-1	0	-1	0	-1	0	-1	0	-1	0	-1	0	-1	0
p^x	-0.4296 (0.332)	0	-0.1277 (0.122)	0	-0.4434 (0.163)	0	-3.864 (2.855)	0	0.0605 (0.409)	0	-2.4851 (0.852)	0	-0.0462 (0.425)	0
p^*	1.2936 (0.638)	0	0.7078 (0.374)	0	-0.5722 (0.331)	0	11.825 (7.981)	0	0.0192 (0.159)	0	3.2046 (1.671)	0	-0.2427 (0.818)	0
y^*	-0.4438 (0.818)	0	3.4255 (1.055)	0	2.2193 (0.441)	0	-4.4122 (3.355)	0	-1.3730 (1.941)	0	-2.6778 (3.727)	0	-5.8988 (3.783)	0
p	0	-1	0	-1	0	-1	0	-1	0	-1	0	-1	0	-1
(k/x)	0	-0.9989 (0.178)	0	-1.0346 (0.183)	0	-0.7910 (0.165)	0	-1.4201 (0.202)	0	-1.1797 (0.217)	0	-1.5884 (0.401)	0	-1.8911 (0.364)
c	0	1.3016 (0.121)	0	1.2288 (0.088)	0	1.0568 (0.089)	0	1.3335 (0.087)	0	1.4858 (0.173)	0	1.1729 (0.151)	0	2.0712 (0.374)
σ^e	-0.0662 (0.041)	-0.0630 (0.195)	0.0339 (none)	-0.0751 (0.032)	-0.2166 (0.166)	-0.1449 (0.078)	-1.0759 (0.801)	0.046 (none)	-0.0754 (0.127)	-0.1116 (0.048)	0.1167 (none)	0.1524 (0.017)	-0.1657 (0.099)	-0.1544 (0.069)
trend	0.0085 (0.009)	0.0157 (0.004)	-0.0069 (0.009)	-0.0180 (0.003)	-0.0100 (0.006)	-0.0165 (0.003)	0.0087 (0.039)	-0.0206 (0.003)	0.0394 (0.013)	-0.0195 (0.003)	0.0357 (0.029)	-0.0196 (0.005)	0.079 (0.041)	-0.0407 (0.011)
LL-exactly-identifying restrictions	1050.6		1030.0		892.56		913.7		899.4		996.0		994.3	
LL-over-identifying restrictions	1049.2		984.56		887.99		894.5		896.5		978.0		993.1	
LR Test: $\chi^2(5)$	2.88		90.79		9.13		38.37		5.65		35.97		2.41	

note: asymptotic standard errors in parentheses. The likelihood ratio test is calculted as L-R= $2(LR_E - LR_O)$ where LR_E is the value of the maximized log-likeliood subject to the four exactly-identifying restrictions and LR_E is the value of the maximized log-likeliood subject to the twelve over-identifying restrictions defined by economic theory and the ARDL estimates imposed on the system. The L-R test has an asymptotic chi-squared distribution with $(k-r^2)$ degrees of freedom.

7.3 Conclusions

The purpose of this chapter was to investigate the relationship between bi-lateral export volumes and prices and the standard deviation measure of exchange rate variability. The ARDL approach was used for estimation of each trade flow between the UK and its eight main trading partners.

The results from the ARDL approach indicate that the variability measure had no significant empirical influence on either UK export volumes or prices, over the sample period 1973Q1 to 1990Q3. These results are robust across all of the trade flows examined and support the findings from the previous chapter using aggregate trade data. While the variability coefficients are statistically insignificant, it is apparent that the sign and magnitude of the remaining elasticities are sensitive to the particular trade flow, especially in the case of the export volume equation. This suggests that the price and income effects on the volume of exports vary according to which country is importing UK goods. In some cases the price and income elasticities were found to be incorrectly signed and/or statistically insignificant. Using the aggregate trade data we found that all of the price and income elasticities were correctly signed and statistically significant.

Since the ARDL approach only allows for the estimation of single equations, it is useful to examine whether the restrictions imposed on the system to derive a structural representation consistent with economic theory are data consistent. By estimating a restricted VECM we found that in four out of the seven cases investigated the null hypothesis for over-identification could not be rejected at conventional significance levels. However, even when a data consistent structural representation was obtained, it was difficult to provide an economic interpretation for many of the estimated coefficients. Surprisingly, when exclusion restrictions were imposed on the variability coefficients the null hypothesis was rejected in each case, implying that the variability measure played a statistically significant role in defining the long-run relations derived from each cointegrating vector. However, when the variability measure was included in the VECM many of the estimates had very large standard errors, implying the coefficients were statistically insignificant. It was also difficult to provide an economic interpretation for many of the significant variability coefficients, as well as the remaining coefficients which were either incorrectly signed and /or statistically insignificant. The fact that the restricted VECM results are neither robust nor lend themselves to economic interpretation could possibly be explained by the fact that the system is defined by a larger number of structural equations than suggested by economic theory. The hypothesis testing procedure from estimation of the unrestricted VECM led us to conclude in each case that the number of cointegrating vectors was greater than the two long-run relations implied by economic theory. A test for weak exogenity could usefully identify the number of endogenous variables and therefore provide direction for further modelling of the structural system.

Chapter Eight

Summary and Conclusions

The main purpose of this thesis was to investigate whether exchange rate variability has any empirical influence on international trade volumes and prices. The evidence presented in chapter two indicates that for those countries which switched to a floating rate regime in 1973 their exchange rates became more volatile. At the same time, many industrialised and developing countries experienced a reduction in the growth of trade volumes and increased volatility in trade prices. Early contributions to economic theory (Clark, 1973; Ethier, 1973) predicted that uncertainty about exchange rate movements has an adverse effect on foreign trade, assuming economic agents are risk averse. Unpredictable fluctuations in the exchange rate, which cannot be covered through hedging techniques, can create uncertainty about the prices exporters and importers will receive or pay, in domestic currency terms, at a date in the future. However, De Grauwe (1988) has shown that the direction of the exchange rate variability effect depends upon the degree of risk aversion, rather than economic agents being risk averse *per se*. In the long term, persistent exchange rate variability may also create a *'political economy effect'* (De Grauwe, 1988) which leads to increased protectionism by governments whose balance of payments are adversely influenced by volatile exchange rates. Furthermore, exchange rate uncertainty can hinder long term planning by firms, thus deterring domestic and foreign investment.

The voluminous empirical literature has yet to provide clear conclusions as to whether exchange rate volatility has a statistically significant influence on trade volumes and prices. Ambiguity also remains as to the direction of the 'variability effect'. The survey of the empirical literature presented in chapter three indicates that nearly as many studies find no empirical influence of exchange rate variability on international trade as the number of studies which find statistically significant variability coefficients. This is despite research being undertaken for numerous countries, sample periods and across aggregate, bi-lateral and product-specific trade flows. We find that one of the main reasons for this ambiguous conclusion is that the literature has yet to suggest what is the most appropriate and reliable proxy of exchange rate variability and under what circumstances one proxy is more appropriate than another. Given that the various measures have their own distinct characteristics the 'variability effect' may change according to the particular proxy used.

In chapter four we provided a formal definition of risk as opposed to uncertainty, following the seminal work of Knight (1921). Knight argues that risk refers to events when the probability of an outcome occurring could be calculated, while uncertainty refers to events when it is not possible to calculate probabilities. A later interpretation of the Knightian risk-uncertainty distinction was provided by LeRoy and Singell (1987). They argue that under conditions of risk, probabilities can be calculated from a range of possible outcomes and insurance markets will exist to provide opportunities to avoid risk. Under conditions of uncertainty, statistical probabilities cannot be calculated so insurance markets fail to exist. Given that much of the literature is concerned with that component of foreign trade transactions which cannot be covered through forward markets or hedging techniques, proxies have been generated to measure exchange rate uncertainty.

In attempting to measure exchange rate uncertainty directly it is necessary to use a proxy for the expected future exchange rate, so that the dispersion of the actual exchange rate from its expected value is calculated. Given the difficulties in deriving an 'accurate' proxy for the expected exchange rate many researchers have relied on proxies for exchange rate variability to indirectly measure exchange rate uncertainty. However, if for example exchange rate movements are highly volatile but relatively predictable then measures of exchange rate variability may overstate the 'true' degree of exchange rate uncertainty (Akhtar and Hilton, 1984).

We then proceeded to discuss the measures of exchange rate variability and uncertainty that have been utilized in the literature. This survey was completed by means of discussing the factors which applied researchers should consider when selecting an appropriate proxy. In particular, the measurement of exchange rate variability (uncertainty) could be sensitive to the sample frequency of the exchange rate data; the length of period over which the proxy is measured; the distribution of the exchange rate; whether nominal or real exchange rates are used; and the influence of exchange rate policy regimes on the distribution of the exchange rate. Each of the variability/uncertainty measures could estimate different influences on international trade, according to the particular proxy used. For example, some authors (Bini-Smaghi, 1991; Pagan and Ullah, 1986) have argued that because moving averages of the standard deviation produce a smoothed series, this may lead to an understatement of the measured effect of exchange rate variability on international trade. This problem becomes particularly acute when the sign and magnitude of exchange rate movements are highly unpredictable. GARCH processes for models of the exchange rate can also suffer from the problem of smoothing of the variability series.

The empirical research presented in the thesis attempted to investigate whether the measured 'variability effect' was sensitive to the particular proxy chosen. An econometric model previously estimated by Holly (1995), was estimated for UK export volumes and prices, which represents the export demand and supply equations, assuming the supply of exports schedule is infinitely price-elastic. Recent developments in econometrics suggest an appropriate way to estimate the model which is outlined in chapter five. There are two distinct elements of the approach adopted. Firstly, unit root tests established that the order of integration of each variable was I(1), except the variability measures which were I(0). Using the ARDL approach to cointegration (Pesaran, Shin and Smith, 1996; Pesaran and Shin, 1997a) allowed the estimation of long-run structural relationships encompassing both I(1) and I(0) variables simultaneously. This approach thus represents an advance over the Johansen (1988) procedure where individual cointegrating vectors may be found for each stationary variable included in the long-run structural equation.

However, current developments in the ARDL literature only allow for the estimation of single structural equations. It is necessary to test for identification of the export demand and supply equations by discovering whether the restrictions imposed on the system by economic theory are data-consistent. System identification was tested by estimating a restricted VECM following an approach to long-run structural modelling advocated by Pesaran and Shin (1997b).

The empirical analysis presented in chapters six and seven tested the influence of exchange rate variability on both aggregate and bi-lateral exports to the UK's eight main trading partners, over the sample period 1973Q2 to 1990Q3. In chapter six, three measures of exchange rate variability/uncertainty were taken from the literature to examine the sensitivity of sign, magnitude and statistical significance of each coefficient estimate to the selected proxy. It was apparent from the ARDL estimation results that none of the measures had any statistically significant influence on either export volumes or prices. Moreover, when exchange rate variability (uncertainty) was eliminated from the system, the sign, magnitude and statistical significance of the remaining coefficients remained unchanged, leading us to conclude that the measures of exchange rate variability did not enhance the explanatory power of the volume and price equations.

The estimation results from the restricted VECM also raised questions regarding the measured variability effect and predictions of economic theory regarding the nature of the structural system defined in equations 6.2.1 and 6.2.2. Firstly, the likelihood ratio hypothesis testing procedure indicated that the number of long-run relations was greater than the two cointegrating vectors implied by economic theory. These results can possibly be explained in two ways: (i) each of the stationary variability measures may have created their own unique long-run relation, in addition to the cointegrating vectors found for the I(1) variables; and (ii) there may be more than two endogenous variables and hence more than the two structural equations suggested by economic theory. A test for weak exogenity could be usefully employed to identify the number of endogenous variables and therefore allow for further structural modelling.

Secondly, the null hypothesis for over-identification was rejected in each case, implying that the restrictions imposed on the system from economic theory were not data-consistent. As the estimation results currently stand, it is difficult for us to interpret the export volume and price equations as a structural model of export demand and supply. Another point of concern was that the estimates derived from the restricted VECM had signs which were not consistent with economic theory, as well as having larger magnitudes than expected. Moreover, as well as the measures of exchange rate variability, many of the remaining elasticities were statistically significant, a finding which directly contradicts the estimation results from the ARDL approach.

Chapter seven considered the relationship between UK bi-lateral exports and the standard deviation measure of exchange rate variability, in the hope of producing further evidence on the estimated 'variability effect' on UK export volumes and whether the identification of the structural equations varied according to the final destination country for UK exported goods. Again the ARDL estimation results indicated that the measure of exchange rate variability had no significant empirical influence on either export volumes or prices to each of the UK's eight main trading partners. However, the sign and magnitude of the remaining elasticities in the export volume equation varied across the trade flows, suggesting that the price and income effects on the volume of exports change according to which country is importing UK goods.

Estimation of an unrestricted VECM for each case also indicated that the cointegrating rank was inconsistent with that implied by economic theory i.e. $r=2$. The results from the restricted VECM suggested that in four out of the seven cases investigated the null hypothesis for over-identification suggested by economic theory could not be rejected. However, it was difficult to provide an economic interpretation to many of the structural coefficients in these cases, due to signs being inconsistent with economic theory; larger than anticipated coefficient magnitudes; and many of the estimates having large standard errors.

In light of the above summary we can highlight the significant contributions of this thesis as follows: It was identified that the measurement of exchange rate variability can be sensitive to a variety of factors, which not only influences the observed nature of each variability measure but also the relationship between each proxy and trade volumes and prices. Given this finding the empirical research undertaken encompassed a variety of variability measures, to examine whether the relationship between UK export volumes and/or prices was sensitive to the chosen proxy. Robustness of the empirical work was also considered to examine whether the measured variability effect on UK exports was sensitive to the particular country UK goods were exported to.

The use of the ARDL approach allowed the estimation of structural relationships encompassing I(1) and I(0) variables simultaneously. Previous research by Holly (1995) denied the presence of a long-run impact of exchange rate variability on export volumes and prices, through its elimination from the cointegration vectors, since the variability measure was tested to be I(0). The ARDL procedure also generates a single estimated structural equation, whereas the Johansen (1988) procedure produces individual cointegrating vectors for each stationary variable, in addition to those derived from each linear combination of I(1) variables. The presence of multiple cointegrating vectors can raise interpretation difficulties when economic theory indicates the presence of a single structural equation.

Much of the international trade literature has not modelled a system of trade price and volume equations using cointegration analysis. The attempt made by Holly

(1995) to empirically estimate such a system did not consider the issue of structural idenitication of the long-run price and volume relationships. Estimation of a restricted VECM provides a useful framework to test for structural identification of the underlying system of equations consistent with the number of cointegrating vectors.

While the empirical research presented in this thesis presents many advances over previous studies, there are several ways in which the results could be extended to provide an agenda for future research. The most obvious extension would be to test whether these results are robust across a range of countries and different trade flows. It would also be interesting to use the data set from previous studies and discover whether the use of these new econometric procedures yields significantly different results from those produced with earlier estimation methods. Much of the literature using cointegration analysis has tended to only estimate export volume equations, ignoring the long-run modelling of export prices. Further research could usefully be undertaken on long-run structural modelling of system of equations, to encompass a richer theoretical framework.

The ARDL approach assumes that the long-run model being estimated is represented by a single structural equation. Pesaran and Shin (1997a) note that future developments in the ARDL procedure could encompass structural identification and system estimation. When these developments are available it would be interesting to replicate the estimation of our structural system, to establish (i) if the null hypothesis for over-identification suggested by economic theory is rejected as the results from the restricted VECM suggest; (ii) whether the long-run estimates are significantly different in sign, magnitude and statistical significance from those produced by the current ARDL procedure.

Estimation results from the restricted VECM indicate that additional structural relationships need to be modelled in the system, relative to the two equations implied by economic theory. A test for weak exogenity could be usefully employed to identify the number of endogenous variables. Revised estimates from the ARDL approach could then be produced to allow for the inclusion of I(1) and I(0) variables simultaneously into the structural equations. It would also be of interest to compare the revised ARDL estimation results with the results from the restricted VECM.

While we have attempted to measure whether the relationship between export volumes (prices) and exchange rate variability is sensitive to the chosen proxy, research on the robustness of these measures has yet to be completed and to what extent the characteristics of the same proxy change using different exchange rate data series. For example, does the nature of the variability measure change using daily exchange rate data compared to say a monthly series and if so how does this influence the relationship between exchange rate variability and international trade? Similarly, is the measured 'variability effect' sensitive to whether real or nominal exchange rates are used with different sample frequencies of exchange rate data?

Finally, a further avenue for future research would be to examine whether the structural coefficients for the export volume and price equations vary over time. We may find that the sign and magnitude of the estimated variability coefficient changes from periods of high exchange rate variability compared to lower exchange rate variability. Kalman filter estimation techniques could be used in this case.

Appendix A

Table A1: A Summary of Empirical Literature on the Relationship between Exchange Rate Variability and International Trade Volume and Prices

Author	Sample Period	Countries	Measure(s) of Variability	Estimation Technique	Dependent Variable	Result
Makin (1976)	1960Q1-1973Q4	US, Germany, Japan and Canada.	Standard deviation of the spot and forward exchange rates.	OLS	Aggregate real imports	No significant influence on trade volumes.
Hooper and Kohlhagen (1978)	1965Q1-1975Q4.	West Germany; France; Japan; UK; US and Canada.	Average absolute deviation between current spot rate and the lagged forward rate, using 13 weekly observations for a given quarter..	OLS	Bi-lateral trade volumes and prices for US and West Germany.	Price Equation: significant negative influence in 6 cases, significant positive influence in 2 cases. Volume Equation: significant positive influence in 1 case.
Abrams (1980)	1973Q1-1976Q4.	Austria; Australia; Belgium; Japan; Canada; Finland France; West Germany; Iceland; Ireland; Italy; the Netherlands; Norway; Portugal; Sweden.	Variability of bi-lateral nominal spot rate; variance of bi-lateral spot rare from estimated trend.	OLS	Pooled time series cross-section data for the countries in the sample.	Significant negative effect on trade for both variability measures.
Kenen (1980)	1974-1976 (Annual Data)	33 developing and developed countries.	Mean and Standard Deviation of absolute monthly percentage changes in nominal and real spot exchange rates.	OLS	Movements in aggregate real exports and fixed capital formation for pooled time series cross-section data.	No significant influence on trade volumes.
Thursby (1980)	1953Q1-1977Q4	Canada	Percentage difference between an assumed 'fixed' exchange rate and the actual rate in each quarter	OLS	Aggregate real exports	No significant influence on trade volumes.
Coes (1981)	1957-1974 (Annual Data)	Brazil	Integral difference in cumulative distribution of monthly real exchange rate and a "certain" exchange rate.	OLS with Cochrane-Orcutt Iterative Technique where appropriate.	Exports as a fraction of Production for 22 products†.	Significant effect on trade volumes for 18 out of 22 cases.
Clark & Haulk (1982)	1952Q1-1962Q4	Canada	Standard deviation of forward exchange rate over previous four quarters.	OLS	Aggregate real imports and exports	No significant influence on trade volumes.

† The products analysed include non-metallic mineral products; metals; machinery; electrical and communications equipment; transportation equipment; paper and paper products; rubber products; leather and leather goods; textiles; clothing and footwear; food processing; beverages; tobacco products; beef; fish; seafood; cashews; wool; rice; corn; peanuts; soybeans.

Author	Sample Period	Countries	Measure(s) of Variability	Estimation Technique	Dependent Variable	Result
Thursby (1981)	1972Q1-1979Q4	Austria, Belgium, Denmark, France, Germany, Italy, Japan, The Netherlands, Norway, Sweden, Switzerland, UK, US, Brazil, Finland, Greece, Ireland, Spain, Turkey.	Variance of the nominal and real effective exchange rates.	OLS	Aggregate Export-GNP ratio.	No significant influence on trade volumes.
Cushman (1983)	1965Q1-1977Q4.	UK; US; France; West Germany; Canada and Japan.	Four Quarter moving average standard deviation of the percentage changes in the real exchange rate	OLS	Bi-lateral trade volumes and prices.	6 out of 16 cases show evidence of a negative relationship between real exchange rate variability and trade volumes. 2 out of 16 cases show a significant effect on trade prices.
Justice (1983)	1973Q1-1981Q4.	UK	Index of world currency variation; forward rate measures; standard deviation of nominal exchange rate changes.	Polynomial distributed lag model	Manufactured export volumes and prices.	Trade volume equations show an insignificant result. Results for price equation are inconclusive.
Akhtar and Hilton (1984)	1974Q1-1978Q4 and 1974Q1-1982Q4.	West Germany and US.	Standard Deviation of daily observations of the Effective Exchange Rate for a give quarter/.	OLS	Aggregate exports and imports; prices of aggregate imports and exports.	Significant negative effect except for US imports. No significant effect on export prices. Extended sample period presents some evidence of a significant negative effect.
International Monetary Fund (1984)	1959Q1-1982Q4. Sub-periods: 1962Q1-1982Q4; 1967Q1-1987Q4; 1959Q1-1991Q4; 1974Q1-1987Q4.	Canada; France; Italy; West Germany; Japan; UK and US.	Standard deviation of a seven country trade weighted average of quarterly real effective exchange rate.	OLS	World Trade Index and 42 Bilateral trade flows of imports and exports between countries	Insignificant results and positively signed for world trade. 2 out of 42 bi-lateral trade flows significant and negatively signed.
Chan and Wong (1985)	1977Q1-1984Q4	Hong Kong, US, UK and West Germany.	4 Quarter Moving Average Standard Deviation of percentage changes in the real bi-lateral exchange rate.	OLS with correction for serial correlation where appropriate.	Bi-lateral Exports of Hong Kong to US, UK and West Germany.	No significant effect on export volumes for any of the countries analysed.
Gotur (1985)	1975Q1-1983Q4.	US; West Germany; France; Japan and UK.	Standard deviation of the Effective Exchange Rate Index weighted from the IMF Multilateral Exchange Rate Model (MERM). Daily observations used to calculate quarterly measure.	OLS and Cochrane-Orcutt correction procedure where appropriate.	Aggregate import and export volumes and prices.	1 out of 10 trade volume equations have significant variability elasticities which are negatively signed. 4 out of 10 price equations have significant variability elasticities..

Author	Sample Period	Countries	Measure(s) of Variability	Estimation Technique	Dependent Variable	Result
Bailey, Tavlas and Ulan (1986)	1973 Q1-1983Q4	Canada, France, West Germany, Italy, Japan, UK and US.	Absolute value of quarter to quarter changes in the nominal effective exchange rate	Second Order Polynomial Distributed Lag.	Aggregate Trade Flows.	No significant effect for any of the countries analysed.
Cushman (1986)	1965Q1-1977Q4 and 1973Q1-1983Q4	USA, UK, the Netherlands, France, Germany, Canada and Japan.	Moving Average Standard Deviation of the real exchange rate; third country exchange risk.	OLS	Bi-lateral Trade Flows from and to the USA.	1965-1977: 4 out of 6 cases negatively signed and significant; 3 out of 6 cases negatively signed and significant (with Third Country Risk). 1973-1983: 3 out of 6 cases negatively signed and significant; 2 out of 6 cases negatively signed and significant (with Third Country Risk).
Kenen and Rodrik (1986)	1975Q1-1984Q2.	US; Canada; Belgium; France; Germany; Italy; the Netherlands; Sweden; Switzerland and the UK.	Standard deviation of percentage changes in the real exchange rate over 12 and 24 month periods; standard deviation (error) of real exchange rate from estimated log-linear trend equation; standard deviation (error) of the real exchange rate from first order auto-regressive equation.	OLS	Volume of aggregate manufactured imports.	4 out of 11 cases are negatively signed and significant.
Maskus (1986)	1974Q1-1984Q4	US sectoral exports to Japan, UK, West Germany and Canada	3-month spread between spot and forward exchange rates, adjusted for a measure of expected inflation	OLS	Bi-lateral real exports for agriculture; erude materials; chemicals; machinery; transport equipment; and miscellaneous manufactures	56 out of 64 equations estimated had a negative variability coefficient, 26 statistically significant.
Bailey, Tavlas and Ulan (1987)	1962Q2-1974Q4 and 1975Q1-1985Q3	Canada, France, Germany, Italy, Japan, UK, US, Australia, the Netherlands and Switzerland.	The absolute quarterly percentage change in the effective exchange rate (nominal and real forms); eight quarter moving average standard deviation of the effective exchange rate (nominal and real forms).	Polynomial distributed lag model	Volume of Aggregate Exports.	Overall significant effect but not very strong. Direction of the variability effect inconclusive.

Author	Sample Period	Countries	Measure(s) of Variability	Estimation Technique	Dependent Variable	Result
Gosling (1987)	1977Q2-1988Q2	UK	Quarterly standard deviation of the daily nominal effective exchange rate.	Polynomial distributed lag model	Aggregate manufactured exports for seven products: Manufactures; Chemicals; Clothing & Footwear; Scientific instruments; Textiles; Machinery; Road Vehicles.	Volume Equation: 5 out of 7 cases significant and negative; 1 case significant and positive. Price Equation: 2 out of 7 cases significant and positive; 4 cases significant and negative.
Thursby and Thursby (1987)	1974-1982 (Annual Data).	Austria; Japan; Belgium; Canada; Denmark; Finland; France; West Germany; Greece; Italy; the Netherlands; Norway; South Africa; Sweden; Switzerland; UK and US.	The variance of the spot rate around its estimated trend.	OLS	Bi-lateral trade volumes and prices in real terms	Significant negative effect on international trade for 7 out of 17 cases.
Brada and Méndez (1988)	1973-1977 (Annual Data)	30 Developing and Developed Countries.	Month to Month percentage changes in various trade weighted effective exchange rates (nominal / real form)	OLS	Bi-lateral trade volumes. Pooled Cross-Section data across sample period	Significant negative result overall.
Cushman (1988b)	1974Q1-1983Q4.	US; UK; the Netherlands; France; West Germany; Canada and Japan.	Four quarter moving standard deviation of recent changes in bi-lateral real exchange rates; forward exchange rate measures; forward risk premium measures.	OLS	US bi-lateral trade flows.	5 out of 6 cases have significant negative risk coefficients for imports. 2 out of 6 cases have a significant risk coefficient for exports.
De Grauwe (1988)	1960Q1-1969Q4 and 1973Q1-1984Q4	Belgium; Canada; France; West Germany; Italy and Japan; the Netherlands; Switzerland; UK and US.	Variability of the yearly percentage changes in the bi-lateral nominal and real exchange rates.	Zellner's Seemingly Unrelated Regression Estimator	Average yearly movements rates of bi-lateral exports between chosen countries.	Insignificant result during fixed rate period and significant effect during floating period for real exchange rate variability. Nominal exchange rate variability has an insignificant effect.
Anderson and Garcia (1989)	1975Q1-1985Q4	US, Japan, Spain and France.	Absolute percentage changes in quarter to quarter movements in the spot rate; Absolute percentage difference between the current spot and the lagged forward rate.	Polynomial Distributed Lag Model	US Exports of Soybeans to Japan, France and Spain.	All cases show a significant negative relationship with trade in Soybeans.

Author	Sample Period	Countries	Measure(s) of Variability	Estimation Technique	Dependent Variable	Result
Caballero and Corbo (1989)	Not presented in the paper.	Chile; Colombia; Peru; Philippines; Thailand and Turkey.	Quarterly standard deviation of the real exchange rate.	OLS and Instrumental Variable Estimation.	Aggregate Export values in real terms.	Strong negative effect of risk variable on exports.
Koray and Lastrapes (1989)	1959M1-1985M12.	US; UK; Germany; France; Japan and Canada.	12th Order Moving Average Standard Deviation	Vector Autoregressive (VAR) technique.	Bilateral US imports.	Weak relationship between variability and trade volume overall. Stronger relationship following the move to floating exchange rates.
Mann (1989)	1977Q1-1987Q1	Japan, Germany and US.	3 or 6 month back Moving Average Standard Deviation of the month to month percentage changes in the nominal effective exchange rate.	OLS	Aggregate and Industry Specific Exports.	Overall insignificant effect.
Perée and Steinherr (1989)	1966-1985 (Annual Data).	US; UK; Belgium; Japan and West Germany.	Disequilibrium measures incorporating short-run volatility and long-run misalignments of the exchange rate.	OLS	Aggregate Export Volumes.	Insignificant result overall.
Lastrapes and Koray (1990)	1973M3-1987M12.	US	Moving Sample Standard Deviation of the movements of the real exchange rate.	Vector Autoregressive (VAR) technique.	Real multilateral US imports and exports.	Significant but weak effect on trade. Effect of variability on trade is small compared to other determinants specified in the model e.g. income.
Medhora (1990)	1976-1982 (Annual Data)	Benin; Burkina Faso; Côte d'Iodire; Niger; Senegal; Togo.	Standard deviation of the nominal effective exchange rate, using weekly, monthly and quarterly data.	OLS	Aggregate imports pooled for six countries, 42 observations.	Insignificant result from all measures.
Klein (1990)	1978M2-1986M6.	US; UK; West Germany; France; Italy; Japan; the Netherlands and Canada.	Standard deviation of monthly percentage changes in bi-lateral exchange rates over 12 monthly periods.	OLS corrected for serial correlation and heteroscedasticity if required	US exports of Food and Animal Products; Beverages and Tobacco; Crude Materials; Fuels and Lubricants; Oils and Fats; Chemicals; Manufactured goods; Machinery and Transport and Miscellaneous goods. Cross section data pooled to generate series.	10 out of 54 bi-lateral trade flows significant. Only 3 out of 10 cases negatively signed and significant.

Author	Sample Period	Countries	Measure(s) of Variability	Estimation Technique	Dependent Variable	Result
Asseery and Peel (1991)	1972Q1-1987Q4	Australia, Japan, UK, US and West Germany.	Squared residuals from ARIMA process fitted to the real effective exchange rate.	Engle and Granger Cointegration Methodology	Aggregate Trade Flows	Significant negative effect from Short-run Error Correction Model for all countries except the UK.
Bahmani-Oskooee (1991)	1973Q1-1980Q4	Brazil, Greece, South Korea, Pakistan, Philippines, Thailand and Turkey.	Standard deviation of the percentage changes in the real effective exchange rate over the previous eight quarters.	OLS technique with correction for serial correlation in some cases.	Aggregate volume index of exports and imports.	Significant negative elasticities for Greece and Turkey. Significant positive elasticity for Brazil and Korea.
Bini-Smaghi (1991)	1976Q1-1984Q4.	Italy; France and West Germany.	Standard deviation of the rate of change of the nominal exchange rate.	OLS	Aggregate trade volumes and prices for manufacture exports.	Overall significant negative influence on export volumes. For Germany volatility has a positive influence on export prices, for France and Italy a negative influence on export prices.
Feenstra and Kendall (1991)	1975Q1-1988Q1.	UK; Japan and West Germany.	GARCH-M (1,1) process of the exchange rate.	Maximum Likelihood Estimation	International Trade Prices, determined by spot exchange rate.	Significant negative effect for UK and Germany.
Kumar and Dhawan (1991)	1975-1985 (Annual Data)	Pakistan, West Germany, Japan, US and UK.	Standard Deviation of the nominal exchange rate (nominal and real form); moving average standard Deviation (nominal and real form); the coefficient of variation (nominal and real form); Gini's mean difference coefficient (nominal and real form); third country risk.	OLS	Bi-lateral exports.	Generally exchange rate variability has a small influence on international trade volumes. Inclusion of third country risk proxy significantly improves the econometric performance of the regression model.
Bahmani-Oskooee & Ltaifa (1992)	1973-1980 (Annual Data)	19 Developed and 67 Developing Countries.	Standard Deviation of the percentage changes in the real effective exchange rate.	OLS	Aggregate Export Volumes. Pooled Cross Section Data.	Variability exerts a negative influence on exports for all countries considered in the sample. The influence of variability is stronger on developing countries compared to developed countries.
Savvides (1992)	1973-1986 (Annual Data)	62 developed and developing countries.	Unanticipated standard deviation of the changes in the real effective exchange rate. Proxy obtained from residuals of regression of standard deviation of real effective exchange rate on a series of fundamental determinants.	OLS	Cross Section data obtained across 62 countries.	Significant negative effect on trade volumes. Unanticipated exchange rate variability has a significant negative effect, whilst anticipated exchange rate variability has an insignificant effect.

Author	Sample Period	Countries	Measure(s) of Variability	Estimation Technique	Dependent Variable	Result
Pozo (1992)	1900-1940	Exports of Britain to US.	Standard deviation of percentage changes in real exchange rate for one year period; GARCH measure of percentage changes in real exchange rate.	OLS	Bi-lateral trade flows.	Significant negative result for both measures employed.
Bahmani-Oskooee and Payesteh (1993)	1973Q1-1990Q4	Greece; Korea; Pakistan; S. Africa; Singapore; Phillippines.	Standard deviation of the Quarterly Percentage Changes in the Real Effective Exchange Rate.	OLS; Almon Polynomial Lag and Engle - Granger Cointegration Procedure.	Real Aggregate Import and Export Volumes.	Significant negative effect on import volumes for 3 out of 6 cases. Significant negative effect on export volumes for 3 out of 6 cases.
Chowdhury (1993)	1973Q1-1990Q4	Canada; France; West Germany; Italy; Japan; UK and US.	Moving sample monthly standard deviation of the movements of the real exchange rate.	Johansen Cointegration Procedure and Error Correction Model	Volume of aggregate real exports.	Strong, significant negative effect.
Kroner and Lastrapes (1993)	1973M1-1990M12	US; UK; West Germany; Japan and France.	GARCH-M(1,1) process of percentage changes in the nominal exchange rate.	Maximum Likelihood Estimation	Aggregate export volumes.	Statistically significant effect for all trade volume equations. 1 out of 5 cases significant for price equation.
Caparole and Doroodian (1994)	1974M1-1992M10	US and Canada.	GARCH (1,1) process. Real exchange rate uncertainty.	Maximum Likelihood Estimation	Aggregate US imports from Canada.	Significant negative effect.
Qian and Varangis (1994)	1974M1-1990M12	Canada; Australia; Japan; UK; the Netherlands and Sweden.	ARCH-M Process of percentage changes in the nominal exchange rate.	Maximum Likelihood Estimation	Aggregate Export Volumes and Prices.	1 out of 9 significant trade volume / risk relationship. 2 out of 9 significant trade price / risk relationship.
Arize (1995a)	1973Q2-1991Q3	US	First Order ARCH process of AR process of first differences of the nominal effective exchange rate; five quarter moving average of variance of effective exchange rate.	Johansen Cointegration Procedure and Error Correction Model	Aggregate Export Volumes	Significant negative effect for all measures of variability.
Arize (1995b)	1973Q2-1992Q4	Denmark; the Netherlands; Sweden and Switzerland.	8th Order Moving Average Standard Deviation of the changes in the real effective exchange rate.	Johansen Cointegration Procedure and Error Correction Model	Aggregate Real Export Volumes,	Unique cointegrating vector found in each case and negative variability elasticity found in each case. Each variability elasticity is significant in all cases at 5% level.

Author	Sample Period	Countries	Measure(s) of Variability	Estimation Technique	Dependent Variable	Result
Holly (1995)	1974Q1-1992Q4	UK	GARCH (1, 1) process of percentage changes in the nominal exchange rate.	Johansen Cointegration Procedure and Error Correction Model	Aggregate Manufactured Export Volumes and Prices	Significant positive short-run influence on export prices from Error Correction Model. Insignificant influence on export volumes.
Stokman (1995)	1980Q1-1990Q4	Italy, France, West Germany, Belgium and the Netherlands.	Standard deviation of the percentage changes in weekly trade weighted nominal effective exchange rate	Zellner's SURE Technique	Aggregate exports to EU for Food; Raw Materials; Chemicals; Manufactures; Machinery.	Significant negative influence on export volumes for all countries analysed. The direction of the exchange rate variability effect varies across sectors and countries.
Arize (1996)	1973Q2-1992Q4	Belgium; Denmark; Finland; France; Greece; the Netherlands; Spain and Sweden.	8th Order Moving Average Sample Standard Deviation of the changes in the real effective exchange rate.	Johansen Cointegration Procedure and Short-run Error Correction Model.	Aggregate Real Export Volumes.	Unique cointegrating vector found in each case and negative variability elasticity found in each case. Each variability elasticity is significant in all but one case at 5% level; 10% significance for the remaining elasticity. Significant short-run variability elasticity at 5% level in most cases.
Bahmani-Oskooee (1996)	1973Q1-1990Q4	Greece; Korea; Pakistan; S. Africa; Singapore; Phillippines.	Standard deviation of the Quarterly Percentage Changes in the Real Effective Exchange Rate.	Johansen Cointegration Procedure	Real Aggregate Import and Export Volumes.	3 out of 6 import volume cases have significant elasticities. All export cases have significant coefficient. *In both cases the sign of the* normalised elasticities change according to *which cointegrating vector is examined.*
Arize (1997a)	1973Q2-1992Q4	Denmark, Germany, Italy, Japan, Switzerland, UK, US	ARCH process of the changes in the exchange rate; Moving Average Standard Deviation of percentage changes in the real effective exchange rate.	Johansen Cointegration Procedure and Error Correction Model	Aggregate Real Export Volumes	Significant negative influence on export volumes for all countries analysed. The short-run variability effect is significant and negative, though the lag structure varies across countries.
Arize (1997b)	1973Q2-1992Q4	Canada; France; Germany; Italy; Japan; UK; US.	8th Order Moving Average Sample Standard Deviation of the changes in the Real Effective Exchange Rate.	Johansen Cointegration Procedure and Short-run Error Correction Model	Aggregate Real Export Volumes.	Unique cointegrating vector found in each case and negative variability elasticity found in each case. Each variability elasticity is significant in all but one case at 5% level; 10% significance for the remaining elasticities. Significant SR variability elasticity at 5% level in most cases.

Author	Sample Period	Countries	Measure(s) of Variability	Estimation Technique	Dependent Variable	Result
Arize and Shwiff (1998)	1973Q2-1995Q1	USA, UK, Japan, Italy, Germany, France, Canada.	8th Order Moving Average Standard Deviation of the real effective exchange rate from its predicted value. Predicted value calculated from four quarter moving average of the real effective exchange rate.	Multivariate Cointegration Procedures.	Aggregate real import volumes.	Significant long-run variability elasticity in 6 out of 7 cases. Variability elasticity negative in all cases.
Daly (1998)	1978Q1-1992Q2	Japan, Australia, Canada, France, Germany, Italy, UK and USA	Absolute value of the four quarter moving average standard deviation	Autoregressive Distributed Lag Model will variables included in first difference form	Japanese bi-lateral export and import volumes	Statistically significant variability coefficients in 7 out of 14 cases. Significant variability coefficient for 2 export volume cases and 5 import volume cases. Negative variability coefficients in 6 cases.
Fountas and Bredin (1998)	1979Q2-1993Q3	Ireland, UK	8th Order Moving Average Standard Deviation of the Real Exchange Rate.	Johansen Cointegration Procedure and Short-run Error Correction Model	Aggreagte real export volumes to the UK.	Long-run variability elasticity has a positive sign but is statistically insignificant. Variability coefficient negative and significant in short run error correction model.
Hassan and Tufte (1998)	1977M7-1992M1	Bangladesh	8th Order Moving Average Sample Standard Deviation of the changes in the Real Exchange Rate.	Johansen Cointegration Procedure	Aggregate Real Export Volumes.	Two cointegration vectors found. One normalised elasticity suggests a positive variability effect, the other a negative effect. A restricted VECM provides two negative long-run variability elasticities.
Pugh, Tyrall, Rodecki and Tarnawa (1998)	1980-1992	Austria, Belgium, Canada, Finland, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, UK and USA	Moving Average Standard Deviation based on real effective exchange rate	Panel Data Estimation Technique	Percentage changes in aggregate real import volumes	Significant variability coefficients in all cases.

Appendix B - Table B1: The Characteristics of the Main Measures of Exchange Rate Variability.

	Characteristics	
Measure	**Advantages**	**Disadvantages**
Standard Deviation or Variance	1. Computationally easy to calculate. 2. Measures short term volatility of exchange rate rather than long run misalignments.	1. This measure requires the exchange rate to have a normal distribution. Empirical evidence suggests that the distribution of many exchange rates are leptokurtic ('fat tails'). 2. Measures variability of the exchange rate rather than risk/uncertainty. Changes in the exchange rate maybe anticipated. Unpredictable nature of the exchange rate not taken account of. Uncertainty / risk should measure deviation from expected value.
Forward Rate Measures	1. Provide a measure of the unanticipated exchange rate. Shows deviation of spot rate from its expected value. 2. Information set encompasses expectations of the spot rate, set at beginning of contract sample period, rather than information over the whole sample period like the standard deviation.	1. Use of forward rate derived from Efficient Markets Hypothesis (EMH). Empirical evidence suggests forward rate is not a wholly accurate proxy of the expected future spot rate. EMH rejected from most evidence. 2. Over a given sample period, forward rate changes. Unable to measure deviations of the exchange rate from trend over a given contract (sample) period. 3. Forward rate errors are assumed to reflect risk and net cost to trade. However the effects of trade maybe ambiguous, if a net loss of trade on one side is balanced by a gain on the other side of trade.
Variance of Trade Weighted Index / Effective Exchange Rate	1. Takes account of the total risk facing importers/exporters who transact a wide variety of currencies. Thus allows for the fact that importers can diversify away their bilateral risk by holding a wide variety of currencies. 2. Useful for aggregate import studies.	1. A wide variety of weights have been suggested by the literature e.g. Currency weights, IMF MERM weights, trade weights etc.. It is not entirely clear what criteria should be used for using one type of weight relative to another.
Conditional Variance	1. Takes account of the time series properties of standard deviation (variance). 2. Particularly useful for use with daily/ weekly exchange rate data, which has a high degree of noise. 3. This measure can take account of the problem of leptokurtosis.	1. The fact that the variance of the spot rate is autoregressive, may reflect some degree of predictability in the variance. GARCH estimates may therefore not be useful as a measure of uncertainty / risk. 2. GARCH models assume errors from original model are stationary but the conditional variance is non-stationary, despite zero mean assumption.
Real Exchange Rate Variability Measures	1. Takes account of movements in relative prices offsetting movements in the nominal exchange rate.	1. Current evidence questions whether PPP is a useful proxy for the LR equilibrium exchange rate. 2. During the floating period most changes in real exchange rate occur due to changes in the nominal exchange rate, rather then changes in relative prices. 3. No criteria is provided for choosing appropriate price indices.
Moving Average Measures	1. Smooths out variability series	1. Smoothing may lead to an understating of the 'true' degree of exchange rate variability.
Variance of Spot rate around 9estimated trend	1. LR misalignments of the exchange rate could be taken account of. 2. Traders take expectations of future exchange rate movements on past trends so that the divergence of current exchange rate movements from their underlying path provides an indication of risk.	1. Usually assume a linear time trend is observed by agents and used as a proxy for the expected future spot rate. 2. Measure calculated ex-post rather than as ex-ante forecast error.
Non-parametric measures.	1. Non-parametric measures give more weight to observations in the tails. The measure is thus useful for taking account of the problem of leptokurtosis.	1. Some parametric measures (e.g. interfractile range) ignore extreme observations, which may be important in characterising risk. 2. Measures are calculated *ex-post* rather than as *ex-ante* forecast error. Measures estimate variability rather than risk / uncertainty.

Appendix C: Data and Sources - Sample period: 1973 Q2 - 1990 Q3

Estimation involves converting all the variables below into a natural log form. Therefore, the regression results are presented in lower case letters.

X = Quarterly volume of UK exports to its eight main trading partners (Belgium, France, West Germany, the Netherlands, Italy, Canada, USA and Japan). The reason for selecting this data series is that these trading partners have played an increasingly important role in influencing the UK's export performance. In 1973 these countries accounted for 19.83% of UK exports, yet by 1990 they represented 71.16% of the UK's export trade (*OECD Statistics of Foreign Trade*, various issues, OECD).

Data on the value of UK bi-lateral exports (not seasonally adjusted) to its eight main trading partners in US dollar terms, was obtained from the *OECD Statistics of Foreign Trade, Series A*, various issues. The data was then converted to sterling by dividing the values in US dollars by $/£ spot exchange rate (obtained from the *OECD Main Economic Indicators*, various issues), and then deflated by the UK price (unit value) index of exports to convert the series into volume form. The price index data was obtained from the *NSO Economic Trends Annual Supplement*, 1997.

Y^* = a trade weighted measure of foreign output:

$$Y_t^* = \sum_{j=1}^{8} w_{jt} Y_{jt}^* \qquad ..C1$$

where Y_{jt}^* is the level of GDP for the jth country and w_{jt} is the quarterly trade weight, as above. Quarterly GDP at constant prices (1990=100) for France, Italy, Canada, and USA was obtained from the *Microfit 4.0* Tutorial Files (Pesaran and Pesaran, 1997). For Japan and West Germany, GNP at constant prices (1990=100) was used. GNP / GDP data is seasonally adjusted The source of this data is the *IMF International Financial*

Statistics, various issues. For Belgium and the Netherlands, data on quarterly GNP / GDP was not available, over the sample period. Consequently, a quarterly, seasonally adjusted index of industrial production (1990=100) was obtained from the *OECD Main Economic Indicators*, various issues. For the bi-lateral trade study GDP/GNP/industrial production data was used for country j.

P = Quarterly aggregate UK exports price (unit value) index data in sterling. Data obtained from the *NSO Economic Trends Annual Supplement*, 1997.

P^* = a trade weighted foreign price index for the eight main trading partners:

$$P_t^* = \sum_{j=1}^{8} w_{jt} P_{jt}^* \qquad \textbf{..C2}$$

where P_{jt}^* is the wholesale price index of the jth country and w_{jt} is the quarterly weight (based on export expenditure) for UK exports to the jth country as a proportion of the total exports to the eight countries. Quarterly wholesale price indices (1990=100) were obtained for each of the main trading partners. This data was obtained from the *Microfit 4.0* Tutorial Files (Pesaran and Pesaran, 1997). For the bi-lateral trade study wholesale price index data was used for country j.

σ^e = (i) standard deviation of the log percentage changes in a UK nominal effective exchange rate index (1990=100). Monthly Sterling bi-lateral rates were obtained by converting US dollar bi-lateral rates, obtained from the *OECD Main Economic Indicators*, various issues. A batch program suggested by Pesaran and Pesaran (1997) was then adapted to calculate a trade weighted effective exchange rate index. (ii) A four quarter moving average standard deviation of the percentage changes in the effective exchange rate. (iii) The average absolute difference between the current spot rate and the lagged forward rate for the monthly observations of a given quarter. A trade weighted effective exchange rate index was also calculated using the forward exchange rates. For the bi-lateral trade study sterling bi-lateral exchange rates were used.

P^x = aggregate UK export (to the world) price index data in sterling divided by the effective exchange rate index, defined previously.

K = An index of UK capital stock. Official publications only produce annual data on capital stock. A quarterly measure was derived by using an initial estimate of the UK gross capital stock in 1970 taken from OECD (1996), *Flows and Stocks of Fixed Capital*, OECD, Paris and then using the quarterly movements in UK Gross Domestic Fixed Capital Formation (taken from *NSO Economic Annual Trends Annual Supplement*, 1997) to determine a quarterly measure.

C = (0.7*W+0.3*(M/OUTEMP)), where W is an index of UK wages and salaries for the manufacturing sector per unit of output (1990=100); M is an index of materials and fuel purchased by manufacturing industry (1990=100) and OUTEMP is an index of output per person employed for manufacturing industry (1990=100). The weighting for the calculation of C was suggested by Holly (1995). All data obtained from the *NSO Economic Trends Annual Supplement*, 1997.

Appendix D: Table D1 -Critical value bounds of the F statistic for testing for a long-run equilibrium relationship using the ARDL approach.

Case I: no intercept and no trend								
	90%		95%		97.5%		99%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0	3.016	3.016	4.136	4.136	5.347	5.347	7.381	7.381
1	2.458	3.342	3.145	4.153	3.893	4.927	5.020	6.006
2	2.180	3.211	2.695	3.837	3.258	4.458	3.939	5.341
3	2.022	3.112	2.459	3.625	2.901	4.161	3.372	4.797
4	1.919	3.016	2.282	3.474	2.618	3.924	3.061	4.486
5	1.825	2.943	2.157	3.340	2.481	3.722	2.903	4.261
6	1.760	2.862	2.082	3.247	2.367	3.626	2.744	4.124
7	1.718	2.827	2.003	3.199	2.288	3.536	2.595	3.909
8	1.678	2.789	1.938	3.133	2.198	3.445	2.481	3.826
9	1.640	2.774	1.873	3.072	2.122	3.351	2.396	3.725
10	1.606	2.738	1.849	3.026	2.076	3.291	2.319	3.610
Case II: intercept and no trend								
	90%		95%		97.5%		99%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0	6.597	6.597	8.199	8.199	9.679	9.679	11.94	11.94
1	4.042	4.788	4.934	5.764	5.776	6.732	7.057	7.815
2	3.182	4.126	3.793	4.855	4.404	5.524	5.288	6.309
3	2.711	3.800	3.219	4.378	3.727	4.898	4.385	5.615
4	2.425	3.574	2.850	4.049	3.292	4.518	3.817	5.122
5	2.262	3.367	2.649	3.805	3.056	4.267	3.516	4.781
6	2.141	3.250	2.476	3.646	2.823	4.069	3.267	4.540
7	2.035	3.153	2.365	3.533	2.665	3.871	3.027	4.296
8	1.956	3.085	2.272	3.447	2.533	3.753	2.848	4.126
9	1.899	3.047	2.163	3.349	2.437	3.657	2.716	3.989
10	1.840	2.964	2.099	3.270	2.331	3.569	2.607	3.888
Case III: intercept and trend								
	90%		95%		97.5%		99%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0	9.830	9.830	11.72	11.72	13.50	13.50	16.13	16.13
1	5.649	6.335	6.606	7.423	7.643	8.451	9.063	9.786
2	4.205	5.109	4.903	5.872	5.672	6.554	6.520	7.584
3	3.484	4.458	4.066	5.119	4.606	5.747	5.315	6.414
4	3.063	4.084	3.539	4.667	4.004	5.172	4.617	5.786
5	2.782	3.827	3.189	4.329	3.573	4.782	4.011	5.331
6	2.578	3.646	2.945	4.088	3.277	4.492	3.668	4.978
7	2.410	3.492	2.752	3.883	3.044	4.248	3.418	4.694
8	2.290	3.383	2.604	3.746	2.882	4.081	3.220	4.411
9	2.192	3.285	2.467	3.614	2.723	3.898	3.028	4.305
10	2.115	3.193	2.385	3.524	2.607	3.812	2.885	4.135

source: Pesaran and Pesaran (1997).

Appendix E: VAR Lag Selection Criteria and Unrestricted VECMs

Table E1: Lag selection criteria derived from estimation of an unrestricted VAR (using 'absolute difference' measure).

VAR Order	Akaike Information Criterion	Schwarz Bayesian Criterion	Adjusted L-R Test
3	1196.5	968.81	-
2	1193.0	1035.3	$\chi^2(64) = 81.90$
1	1169.7	1082.1	$\chi^2(128) = 187.72$
0	251.53	234.01	$\chi^2(192) = 1378.2$

note: the estimation period was 1974Q2 to 1990Q3, thus a total of 66 observations are used. The maximum VAR lag length was set at 3 periods. The VAR includes dummy variables for breaks in the exchange rate variability series for the periods 77 Q1 to 77 Q2 and 85Q1 respectively. Exclusion restrictions on the exogenous variables are rejected using L-R tests.

Table E2: Lag selection criteria derived from estimation of an unrestricted VAR (using moving average standard deviation measure).

VAR Order	Akaike Information Criterion	Schwarz Bayesian Criterion	Adjusted L-R Test
3	1219.0	1003.1	-
2	1210.3	1063.5	$\chi^2(64) = 88.53$
1	1204.8	1127.1	$\chi^2(128) = 173.28$
0	291.01	283.37	$\chi^2(192) = 1363.2$

note: the estimation period was 1974Q4 to 1990Q3, thus a total of 64 observations are used. The maximum VAR lag length was set at 3 periods. The VAR includes a dummy variable for a pulse shock to the exchange rate variability series at 85Q1 respectively. Exclusion restrictions on the exogenous variables are rejected using L-R tests.

Table E3: Unrestricted VECM (using 'absolute difference' measure); sample period: 1973Q3 - 1990Q3; VAR=1; exogenous dummy variables included in the VAR; unrestricted intercepts and restricted trends.

Maximum Eigenvalue Test

Rank	r=0	r=1	r=2	r=3	r=4	r=5
Statistic	128.16	74.91	68.19	46.16	30.28	23.23
Asymptotic Critical Value (95%)	55.14	49.32	43.61	37.86	31.79	25.42
Asymptotic Critical Value (90%)	52.08	46.54	40.76	35.04	29.13	23.10
Finite Sample Critical Value (95%)	63.41	56.72	50.15	43.54	36.56	29.23
Finite Sample Critical Value (90%)	59.89	53.52	46.87	40.29	33.50	26.57

Trace Test

Rank	r=0	r≤1	r≤2	r≤3	r≤4	r≤5
Statistic	385.72	257.55	182.64	114.51	68.35	38.06
Asymptotic Critical Value (95%)	182.99	147.27	115.85	87.17	63.00	42.34
Asymptotic Critical Value (90%)	176.92	141.82	110.60	82.88	59.16	39.34
Finite Sample Critical Value (95%)	210.44	169.36	133.23	100.25	72.45	48.96
Finite Sample Critical Value (90%)	203.46	163.09	127.19	95.31	68.03	45.24

Maximized Log-likelihood and Model Selection Criteria

Rank	r=0	r=1	r=2	r=3	r=4	r=5
Maximized log-Likelihood	1116.6	1180.7	1218.2	1252.2	1275.3	1290.5
Akaike Information Criterion	1092.6	1140.7	1164.2	1186.2	1199.3	1206.3
Schwarz Bayesian Criterion	1066.0	1096.3	1104.2	1113.0	1115.0	1113.2

Table E4 Unrestricted VECM (Using moving average standard deviation measure); sample Period: 1973Q3 - 1990Q3; VAR=1; Exogenous dummy variables included in the VAR; unrestricted intercepts and restricted trends.

Maximum Eigenvalue Test

Rank	r=0	r=1	r=2	r=3	r=4	r=5
Statistic	120.56	69.82	45.87	31.36	22.19	17.17
Asymptotic Critical Value (95%)	55.14	49.32	43.61	37.86	31.79	25.42
Asymptotic Critical Value (90%)	52.08	46.54	40.76	35.04	29.13	23.10
Finite Sample Critical Value (95%)	63.41	56.72	50.15	43.54	36.56	29.23
Finite Sample Critical Value (90%)	59.89	53.52	46.87	40.29	33.50	26.57

Trace Test

Rank	r=0	r≤1	r≤2	r≤3	r≤4	r≤5
Statistic	322.63	201.98	132.16	86.29	54.92	32.73
Asymptotic Critical Value (95%)	182.99	147.27	115.85	87.17	63.00	42.34
Asymptotic Critical Value (90%)	176.92	141.82	110.60	82.88	59.16	39.34
Finite Sample Critical Value (95%)	210.44	169.36	133.23	100.25	72.45	48.96
Finite Sample Critical Value (90%)	203.46	163.09	127.19	95.31	68.03	45.24

Maximized Log and Model Selection Criteria

Rank	r=0	r=1	r=2	r=3	r=4	r=5
Maximized log-Likelihood	1182.4	1242.7	1277.6	1300.6	1316.2	1327.3
Akaike Information Criterion	1166.4	1210.7	1231.6	1242.6	1248.2	1251.3
Schwarz Bayesian Criterion	1148.9	1175.7	1181.3	1179.1	1173.8	1168.1

Variable	Importing Country							
	France	West Germany	Belgium	Netherlands	Italy	USA	Canada	Japan
x	-3.3292* (-3.4790)	-3.4076* (-3.4749)	-0.7620 (-2.9069)	-1.8943 (-2.9042)	1.0232 (-2.9084)	-3.1906* (-3.4779)	-1.3443* (-3.4779)	-1.1316* (-3.4759)
Lag Length of ADF	4	0	5	1	7	3	3	1
Δx	-4.5117 (-2.9062)	-12.0864 (-2.9042)	-4.3734 (-2.9069)	-9.4247 (-2.9042)	-5.4797 (-2.9084)	-8.0741* (-3.4779)	-7.3433 (-2.9048)	-10.4558 (-2.9042)
Lag Length of ADF	3	0	4	0	6	2	2	0
p^x	-0.9759† (-3.80)	-1.2292† (-3.80)	-2.0358† (-3.80)	-2.0200 (-2.9035)	-1.8700† (-3.80)	-1.9370 (-2.9035)	-2.3741 (-2.9035)	-2.6546 (-2.9042)
Lag Length of ADF	0	0	1	0	0	0	0	1
Δp^x	-7.3280† (-3.80)	-7.2200† (-3.80)	-6.4052† (-3.80)	-6.2515 (-2.9042)	-6.1500† (-3.80)	-6.6407 (-2.9035)	-6.1573 (-2.9042)	-4.1805 (-2.9048)
Lag Length of ADF	0	0	0	0	0	0	0	1
p^*	-2.0580 (-2.9062)	-2.6627 (-2.9048)	-1.2588 (-2.9042)	-2.1483 (-2.9092)	-3.1013 (-2.9077)	-2.2642 (-2.9042)	-2.5340 (-2.9048)	-2.1191 (-2.9062)
Lag Length of ADF	4	1	1	8	6	1	1	4
Δp^*	-2.9668 (-2.9042)	-3.4909 (-2.9042)	-5.2486 (-2.9042)	-5.2749 (-2.9042)	-	-5.5173 (-2.9042)	-3.5950 (-2.9042)	-3.5267 (-2.9042)
Lag Length of ADF	0	0	0	0	-	0	0	0
y^*	-0.16586 (-2.9048)	0.8372 (-2.9055)	-2.1241* (-3.4749)	-0.5078 (-2.9035)	-0.29723 (-2.9035)	-0.1231 (-2.9042)	-2.4348* (-3.4759)	-3.3787* (-3.4749)
Lag Length of ADF	2	3	0	0	0	1	1	0
Δy^*	-7.2007 (-2.9042)	-8.7498 (-2.9042)	-7.2920 (-2.9042)	-6.9786 (-2.9042)	-5.0950 (-2.9042)	-5.7880 (-2.9042)	-5.3085 (-2.9042)	-8.9629 (-2.9042)
Lag Length of ADF	2	0	0	0	0	0	0	0
σ^e	-8.4844‡ (-2.9035)	-10.5960 (-2.9035)	-9.2928 (-2.9035)	-10.3177 (-2.9035)	-8.0791 (-2.9035)	-9.2486‡ (-2.9035)	-6.8386 (-2.9035)	-7.7179 (-2.9035)
Lag Length of ADF	0	0	0	0	0	0	0	0

<u>note:</u> the 95% critical values are presented in parentheses. * denotes a significant time trend. † denotes a break in the export price variable between 85Q1 and 86Q3. Adjusted critical values devised by Perron(1989) are used. ‡ and ξ denote pulse shocks to the exchange rate variability measure at 85Q1 and 77Q1-77Q3 respectively.

Appendix G: Lag selection criteria derived from estimation of an unrestricted VAR

Table G1: UK Exports to France.

VAR Order	Akaike Information Criterion	Schwarz Bayesian Criterion	Adjusted L-R Test
3	992.44	763.16	-
2	983.19	824.46	$\chi^2(64) = 89.64$
1	983.23	895.04	$\chi^2(128) = 167.93$
0	167.34	149.71	$\chi^2(192) = 1244.8$

note: the estimation period was 1974Q1 to 1990Q3, thus a total of 67 observations are used. The maximum VAR lag length was set at 3 periods. The VAR includes dummy variables for breaks in the export price and exchange rate variability series for the periods 85 Q1 to 86 Q3 and 85Q1 respectively. Exclusions restrictions on the exogenous variables are rejected using L-R tests.

Table G2: UK Exports to West Germany.

VAR Order	Akaike Information Criterion	Schwarz Bayesian Criterion	Adjusted L-R Test
3	1007.7	796.02	-
2	999.97	858.87	$\chi^2(64) = 92.03$
1	997.98	927.44	$\chi^2(128) = 176.73$
0	101.66	101.66	$\chi^2(192) = 1409.4$

note: the estimation period was 1974Q1 to 1990Q3, thus a total of 67 observations are used. The maximum VAR lag length was set at 3 periods.

Table G3: UK Exports to Belgium.

VAR Order	Akaike Information Criterion	Schwarz Bayesian Criterion	Adjusted L-R Test
3	842.54	622.08	-
2	835.96	686.04	$\chi^2(64) = 88.49$
1	837.97	758.59	$\chi^2(128) = 166.22$
0	17.06	8.24	$\chi^2(192) = 1275.7$

note: the estimation period was 1974Q1 to 1990Q3, thus a total of 67 observations are used. The maximum VAR lag length was set at 3 periods. The VAR includes dummy variables for a break in the export price series for the periods 85 Q1 to 86 Q3. Exclusions restrictions on the exogenous variable are rejected using L-R tests.

Table G4: UK Exports to the Netherlands.

VAR Order	Akaike Information Criterion	Schwarz Bayesian Criterion	Adjusted L-R Test
3	850.32	638.67	-
2	854.15	713.05	$\chi^2(64) = 77.23$
1	857.16	786.61	$\chi^2(128) = 155.51$
0	36.81	36.80	$\chi^2(192) = 1290.7$

note: the estimation period was 1974Q1 to 1990Q3, thus a total of 67 observations are used. The maximum VAR lag length was set at 3 periods.

Table G5: UK Exports to Italy.

VAR Order	Akaike Information Criterion	Schwarz Bayesian Criterion	Adjusted L-R Test
3	855.14	634.67	-
2	860.97	711.05	$\chi^2(64) = 72.93$
1	840.24	760.87	$\chi^2(128) = 179.16$
0	24.52	15.70	$\chi^2(192) = 1282.1$

note: the estimation period was 1974Q1 to 1990Q3, thus a total of 67 observations are used. The maximum VAR lag-length was set at 3 periods. The VAR includes dummy variables for breaks in the export price series for the periods 85 Q1 to 86 Q3. Exclusions restrictions on the exogenous variable are rejected using L-R tests.

Table G6: UK Exports to USA.

VAR Order	Akaike Information Criterion	Schwarz Bayesian Criterion	Adjusted L-R Test
3	954.13	733.66	-
2	956.37	806.45	$\chi^2(64) = 77.44$
1	953.64	874.27	$\chi^2(128) = 161.09$
0	105.79	96.97	$\chi^2(192) = 1304.3$

note: the estimation period was 1974Q1 to 1990Q3, thus a total of 67 observations are used. The maximum VAR lag length was set at 3 periods. The VAR includes dummy variables for a break in the exchange rate variability series for the period 85Q1. Exclusions restrictions on the exogenous variable are rejected using L-R tests.

Table G7: UK Exports to Japan.

VAR Order	Akaike Information Criterion	Schwarz Bayesian Criterion	Adjusted L-R Test
3	944.36	715.07	-
2	959.39	800.65	$\chi^2(64) = 59.93$
1	933.47	845.29	$\chi^2(128) = 169.97$
0	133.79	116.15	$\chi^2(192) = 1227.0$

note: the estimation period was 1974Q1 to 1990Q3, thus a total of 67 observations are used. The maximum VAR lag length was set at 3 periods. The VAR includes dummy variables for a break in the export price series for the periods 85 Q1 to 86 Q3. Exclusions restrictions on the exogenous variable are rejected using L-R tests.

Unrestricted VECM; sample period: 1973Q3 - 1990Q3; VAR=1; exogenous dummy variables included in the VAR; unrestricted intercepts and restricted trends.

Table G8: Maximum Eigenvalue Test

Rank	**r=0**	**r=1**	**r=2**	**r=3**	**r=4**	**r=5**
Statistic - Importing Country						
France	83.95	68.57	55.42	40.92	29.59	14.04
West Germany	123.53	89.95	66.65	45.41	29.89	24.09
Belgium	110.52	84.18	61.58	41.38	27.49	18.34
Netherlands	101.42	76.16	66.42	29.94	25.73	19.67
Italy	105.53	89.29	64.84	43.32	29.69	10.58
USA	110.81	82.10	73.15	53.23	38.82	17.38
Japan	112.99	63.88	61.07	45.84	33.43	23.78
Asymptotic Critical Value (95%)	55.14	49.32	43.61	37.86	31.79	25.42
Asymptotic Critical Value (90%)	52.08	46.54	40.76	35.04	29.13	23.10
Finite Sample Critical Value (95%)	63.41	56.72	50.15	43.54	36.56	29.23
Finite Sample Critical Value (90%)	59.89	53.52	46.87	40.29	33.50	26.57

Table G9: Trace Test

Rank	**r=0**	**r≤1**	**r≤2**	**r≤3**	**r≤4**	**r≤5**
Statistic - Importing Country						
France	293.28	209.34	140.76	85.35	44.43	24.84
West Germany	391.17	267.64	177.69	111.04	65.63	35.73
Belgium	355.34	244.82	160.64	99.05	57.67	30.18
Netherlands	335.72	234.13	158.13	91.71	61.76	36.03
Italy	355.18	249.65	160.36	95.51	52.19	22.49
USA	393.42	282.61	200.51	127.36	74.13	35.31
Japan	358.66	245.67	181.78	120.71	74.88	41.45
Asymptotic Critical Value (95%)	182.99	147.27	115.85	87.17	63.00	42.34
Asymptotic Critical Value (90%)	176.92	141.82	110.60	82.88	59.16	39.34
Finite Sample Critical Value (95%)	210.44	169.36	133.23	100.25	72.45	48.96
Finite Sample Critical Value (90%)	203.46	163.09	127.19	95.31	68.03	45.24

Table G10: Maximized Log-likelihood and Model Selection Criteria

Importing Country - France								
Rank	r=0	r=1	r=2	r=3	r=4	r=5	r=6	r=7
Maximized log-Likelihood	974.34	1016.3	1050.6	1078.3	1098.8	1108.6	1115.6	1119.4
Akaike Information Criterion	950.35	976.32	996.61	1012.3	1022.8	1024.6	1025.6	1025.4
Schwarz Bayesian Criterion	923.54	931.64	936.29	938.59	937.88	930.74	825.05	920.39

Importing Country - West Germany								
Rank	r=0	r=1	r=2	r=3	r=4	r=5	r=6	r=7
Maximized log-Likelihood	939.59	1001.4	1046.3	1079.7	1102.4	1117.3	1129.4	1133.1
Akaike Information Criterion	923.59	969.35	1000.3	1021.7	1034.4	1041.3	1047.4	1047.1
Schwarz Bayesian Criterion	905.72	933.61	948.94	956.87	958.40	956.41	956.4	955.6

Importing Country - Belgium									
Rank	r=0	r=1	r=2	r=3	r=4	r=5	r=6	r=7	r=8
Maximized log-Likelihood	795.21	850.47	892.56	923.35	944.04	957.79	966.96	972.45	972.88
Akaike Information Criterion	779.21	818.47	846.56	865.35	876.04	881.79	884.95	886.45	884.88
Schwarz Bayesian Criterion	761.33	782.71	795.12	800.56	800.08	796.89	793.36	790.38	786.58

Importing Country - Netherlands									
Rank	r=0	r=1	r=2	r=3	r=4	r=5	r=6	r=7	r=8
Maximized log-Likelihood	824.87	875.58	913.66	946.87	961.84	974.71	984.54	989.62	992.73
Akaike Information Criterion	816.87	851.58	875.66	896.87	901.84	906.71	910.54	911.62	912.73
Schwarz Bayesian Criterion	807.93	824.77	833.21	841.02	834.82	930.75	827.88	824.49	823.36

Importing Country - Italy							
Rank	**r=0**	**r=1**	**r=2**	**r=3**	**r=4**	**r=5**	**r=6**
Maximized log-Likelihood	801.96	854.72	899.37	931.79	953.45	968.29	973.58
Akaike Information Criterion	785.96	822.72	853.37	873.79	885.45	892.29	891.59
Schwarz Bayesian Criterion	768.08	786.98	801.98	809.00	809.49	807.43	799.99

Importing Country - USA									
Rank	**r=0**	**r=1**	**r=2**	**r=3**	**r=4**	**r=5**	**r=6**	**r=7**	**r=8**
Maximized log-Likelihood	899.49	954.90	995.95	1032.5	1059.1	1078.6	1087.2	1092.8	1096.2
Akaike Information Criterion	883.49	922.90	949.95	974.53	991.14	1002.6	1005.2	1006.8	1008.2
Schwarz Bayesian Criterion	865.62	887.16	898.57	909.74	915.18	917.66	913.63	910.78	909.91

Importing Country - Japan									
Rank	**r=0**	**r=1**	**r=2**	**r=3**	**r=4**	**r=5**	**r=6**	**r=7**	**r=8**
Maximized log-Likelihood	905.84	962.33	994.27	1024.8	1047.7	1064.4	1076.3	1083.5	1085.2
Akaike Information Criterion	881.84	922.33	940.27	958.81	971.73	980.44	986.33	989.50	989.16
Schwarz Bayesian Criterion	855.03	877.65	879.95	885.08	886.83	886.61	885.79	884.50	881.93

Bibliography

Abrams, R. K. (1980), 'International Trade Flows Under Flexible Exchange Rates', *Federal Reserve Bank of Kansas Economic Review*, March, pp. 3-10.

Akaike, H. (1973), 'Information Theory and the Extension of the Maximum Likelihood Principle' in B. N. Petrov and C. F. Csaki (eds.), *Proceedings of the Second International Symposium Information Theory*, Budapest, pp. 207 - 251.

Akhtar, A. M. and Hilton, R. S. (1984), 'Effects of Exchange Rate Uncertainty on German and US trade', *Federal Reserve Bank of New York Quarterly Review*, Spring, pp. 7-16.

Aliber, R. Z. (1972), 'Uncertainty, Currency Areas and the Exchange Rate System', *Economica*, Vol. 39, pp. 432-441.

Allen, D. E., Carse, S. and Fujio, K. (1987), 'Trade Financing Procedures in Britain and Japan', *Applied Economics*, Vol. 19, No. 6, pp. 711-728.

Anderson, M. and Garcia, P. (1989), Exchange Rate Uncertainty and the Demand for US Soybeans', *American Journal of Agricultural Economics*, Vol. 71, No. 3, pp. 721-729.

Arize, A. C. (1995a), 'The Effects of Exchange Rate Volatility on United-States Exports - An Empirical Investigation', *Southern Economic Journal*, Vol. 62, No. 1, pp. 34-43.

Arize, A. C. (1995b), 'Trade Flows and Real Exchange - Rate Volatility: An Application of Cointegration and Error - Correction Modeling', *North American Journal of Economics and Finance*, Vol. 6, No. 1, pp. 37-51.

Arize, A. C. (1996), 'Real Exchange-Rate Volatility and Trade Flows: The Experience of Eight European Economies', *International Review of Economics and Finance*, Vol. 5, No. 2, pp. 187-205.

Arize, A. C. (1997a), 'Conditional Exchange-Rate Volatility and the Volume of Foreign Trade: Evidence from Seven Countries', *Southern Economic Journal*, Vol. 64, No. 1, pp. 235-354.

Arize, A. C. (1997b), 'Foreign Trade and Exchange - Rate Risk in the G-7 countries: Cointegration and Error - Correction Models', *Review of Financial Economics*, Vol. 6, No. 1, pp. 95-112.

Arize, A. C. and Shwiff, S. S. (1998), 'Does exchange-rate volatility affect import flows in G-7 countries? Evidence from cointegration models', *Applied Economics*, Vol. 30, pp. 1269-1276.

Arrow, K. J. (1965), *Aspects of the Theory of Risk-Bearing*, Yrjö Jahnsson Lectures, Helsinki, Finland.

Arrow, K. A. (1970), 'The Theory of Risk Aversion', in K. Arrow (ed.), *Essays in the Theory of Risk Bearing*, North-Holland, Amsterdam, the Netherlands.

Assane, D. and Konan, A. (1994), 'Exchange Rate Variability and Imports in WAMU Countries: Is this Relationship Relevant?', *World Development*, Vol. 22, No. 5, pp. 795-801.

Asseery, A. and Peel, D. A. (1991), 'The Effects of Exchange Rate Volatility on Exports: some new estimates', *Economics Letters*, Vol. 37, pp. 173-177.

Bagliano, F. C., Favero, C. A. and Muscatelli, V. A. (1991), 'Cointegrazione, simultaneità ed errata specificazione: un' applicazione alla domanda di moneta in Italia', *Ricerche applicate e modelli per la politica economica, Banca d'Italia Conference, Perugia.* See also Bagliano, F. C., Favero, C. A. and Muscatelli, V. A. (1991), 'Cointegration and Simultaneous Models: An Application to the Italian Money Demand', *Department of Political Economy, Discussion Papers in Economics, No. 9108.*

Bahmani-Oskooee, M. (1991), 'Exchange Rate Uncertainty and Trade Flows of Developing Countries', *The Journal of Developing Areas*, Vol. 25, pp. 497-508.

Bahmani-Oskooee, M. and Payesteh, H. S. (1993), 'Does Exchange Rate Volatility Deter Trade Volumes of LDCs?', *Journal of Economic Development*, Vol. 18, No. 2, pp. 189-205.

Bahmani-Oskooee, M. (1996), 'Exchange Rate Uncertainty and Trade Flows of LDCs: Evidence from Johansen's Cointegration Analysis', *Journal of Economic Development*, Vol. 21, No. 1, pp. 23-35.

Bahmani-Oskooee, M. and Ltaifa, N. (1992), 'Effects of Exchange Rate Risk on Exports: Cross - Country Analysis', *World Development*, Vol. 20, No. 8, pp. 1173-1181.

Bahmani-Oskooee, M. and Payesteh, S. (1993), 'Does Exchange Rate Volatility Deter Trade Volume of LDCs?', *Journal of Economic Development*, Vol. 18, No. 2, pp. 189-205.

Baillie, R. T. and McMahon, P. (1989), *The Foreign Exchange Market: Theory and Econometric Evidence*, Cambridge University Press, Cambridge, UK.

Baillie, R. T. and Bollerslev, T. (1989), 'The Message in Daily Exchange Rates: A Conditional - Variance Tale', *Journal of Business and Economic Statistics*, July, Vol. 7, No. 3, pp. 297-305.

Bailey, M. J., Tavlas, G. S. and Ulan, M. (1986), 'Exchange Rate Variability and Trade Performance: evidence for the Big Seven Industrial Countries', *Weltwirtshaftliches Archiv*, pp. 466-476.

Bailey, M. J., Tavlas, G. S. and Ulan, M. (1987), 'The Impact of Exchange Rate Variability on Export Growth: Some Theoretical Considerations and Empirical Results', *Journal of Policy Modeling*, Vol. 9, No. 1, pp. 225-243.

Ballasa, B. (1980), 'Flexible Exchange Rates and International Trade', in J. S. Chapman and C. P. Kindleberger (eds.), *Flexible Exchange Rates and the Balance of Payments: Essays in Memory of Egon Sohmen*, North - Holland, Amsterdam, Netherlands.

Banerjee, A., Hendry, D. F. and Smith, G. W. (1986), 'Exploring Equilibrium Relationships in Econometrics Through Static Models: some Monte Carlo evidence', *Oxford Bulletin of Economics and Statistics*, Vol. 52, pp. 95 -104.

Bank of England (1984), 'The Variability of Exchange Rates: measurement and effects', *Bank of England Quarterly Bulletin*, September.

Baron, D. P. (1976), 'Fluctuating Exchange Rates and the Pricing of Exports' *Economic Inquiry*, Vol. 14, pp. 425-438.

Bera, A. K. and Jarque, C. M. (1981) 'An efficient large-sample test for normality of observations and regression residuals', *Australian National University Working Papers in Econometrics*, No. 40, Canberra.

Bergsten, C. F. and Williamson, J. (1983), 'Exchange Rates and Trade Policy' in R. C. William (ed.), *Trade Policies in the 1980s*, Institute for International Economics, Washington, USA.

Bini-Smaghi, L. (1988), 'Exchange Rate Variability, Trade and Capital Mobility', *Phd Dissertation, University of Chicago, Department of Economics.*

Bini-Smaghi, L. (1991), 'Exchange Rate Variability and Trade: Why is it so difficult to find any empirical relationship?', *Applied Economics*, Vol. 23, pp. 927-936.

Brada, J. C. and Méndez, J. A. (1988), 'Exchange Rate Variability and the Volume of International Trade', *Kyklos*, Vol. 41, No. 2, pp. 263-280.

Britton, A. J. C. (1991), *Macroeconomic Policy In Britain 1974-1987*, Cambridge University Press, Cambridge, UK.

Brodsky, D. A. (1984), 'Fixed Versus Flexible Exchange Rates and the Measurement of Exchange Rate Instability', *Journal of International Economics*, Vol. 16, pp. 295-306.

Borch, K. H. (1968), *The Economics of Uncertainty*, Princeton, Princeton University Press, Princeton, New Jersey, USA.

Cabarello, R. J. and Corbo, V. (1989), 'The Effect of Real Exchange Rate Uncertainty on Exports: Empirical Evidence', *The World Bank Economic Review*, Vol. 3, No. 2, pp. 263-278.

Caporale, T. and Doroodian, K. (1994), 'Exchange Rate Variability and the Flow of International Trade', *Economics Letters*, Vol. 46, No. 1, pp. 49-54.

Chan, P. K. L. and Wong, J. H. Y. (1985), 'The Effect of Exchange Rate Variability on Hong Kong's Exports', *Hong Kong Economic Papers*, pp. 27-39.

Charemza, W. W. and Deadman, D. F. (1992), *New Directions in Econometric Practice: general to specific modelling, cointegration and vector autoregression*, Edward Elgar, Aldershot, UK.

Cheung, Y. and Lai, K. (1993), 'Finite - Sample Sizes of Johansen's Likelihood Ratio Tests for Cointegration', *Oxford Bulletin of Economics and Statistics*, Vol. 55, pp. 313-328.

Chowdhury, A. R. (1993), 'Does Exchange Rate Volatility Depress Trade Flows? Evidence from Error - Correction Models', *Review of Economics and Statistics*, Vol. 75, No. 4, pp. 700-706.

Clark, P. B. (1973), 'Uncertainty, Exchange Risk and the Level of International Trade', *Western Economic Journal*, Vol. 11, pp. 302-313.

Clark, P. B. and Haulk, C. J. (1972), 'Flexible Exchange Rates and the level of Trade: Preliminary Results of the Canadian Experience', *Federal Reserve Board*, unpublished.

Clifton, E. (1985), 'Real Exchange Rates, Import Penetration, and Protectionism in Industrial Countries'., *IMF Staff Papers*, Vol. 33, pp. 513-536.

Coes, D. V. (1981), 'The Crawling Peg and Exchange Rate Uncertainty' in J. Williamson (ed.), *Exchange Rate Rules: The Theory, Performance, and Prospect of the Crawling Peg*, St. Martin's Press, New York, USA.

Côté, A. (1994), 'Exchange Rate Volatility and Trade: A Survey', *Bank of Canada*, Working Paper, No. 5.

Cushman, D. O. (1983), 'The Effects of Real Exchange Rate risk on International Trade', *Journal of International Economics*, Vol. 15, pp. 45-63.

Cushman, D. O. (1986), 'Has Exchange Risk Depressed International Trade? The Impact of Third Country Exchange Risk', *Journal of International Money and Finance*, Vol. 5, pp. 361-379.

Cushman, D. O. (1988a), 'The Impact of Third Country Exchange Risk: A Correction', *Journal of International Money and Finance*, Vol. 7, pp. 359-360.

Cushman, D. O. (1988b), 'US Bi-lateral Trade Flows and Exchange Risk During the Floating Period', *Journal of International Economics*, Vol. 24, pp. 317-330.

Cushman, D. O. (1988c), 'Exchange Rate Uncertainty and Foreign Direct Investment in the United States', *Weltwirtschaftles Archiv*, Vol. 124, No. 2, pp. 322 - 336.

Cuthbertson, K., Hall, S. G. and Taylor, M. P. (1992), *Applied Econometric Techniques*, Philip Allan, Hertfordshire, UK.

Daly, K. (1998), 'Does exchange rate volatility impede the volume of Japan's bilateral trade?', *Japan and the World Economy*, Vol. 10, pp. 333-348.

Darnell, A. C. (1995), *A Dictionary of Econometrics*, Edward Elgar, Aldershot, UK.

Deaton, A. and Muellbauer, J. (1980), *Economics and Consumer Behaviour*, Cambridge University Press, Cambridge, UK.

De Grauwe, P. (1987), 'International Trade and Economic Growth in the European Monetary System', *European Economic Review*, Vol. 31, pp. 389-398.

De Grauwe, P. (1988), 'Exchange Rate Variability and the Slow-down in Growth of International Trade', *IMF Staff Papers*, Vol. 35, pp. 63-84.

De Grauwe, P. (1996), *International Money*, Oxford University Press, Oxford, UK, Second Edition.

Dellas, H. and Zilberfarb, B. (198?), 'Real Exchange Rate Volatility and International Trade', *Southern Economic Journal*, Vol. 59, pp. 641-647.

Dickey, D. A. and Fuller, W. A. (1979), 'Distribution of the estimators for autoregressive time series with a unit root', *Journal of the American Statistical Association*, Vol. 74, pp. 427-431.

Dickey, D. A. and Pantula, S. G. (1987), 'Determining the order of differencing in autoregressive processes', *Journal of Business and Economics Statistics*, Vol. 15, pp. 455-461.

Dickey, D. A. and Rossana, R. J. (1994), 'Cointegration Time Series: A Guide to Estimation and Hypothesis Testing', *Oxford Bulletin of Economics and Statistics*, Vol. 56, No. 3, pp. 325-353.

Diboglu, S. and Enders, W. (1995), 'Multiple Cointegrating Vectors and Structural Economic Models: An Application to the French Franc / US Dollar Exchange Rate', *Southern Economic Journal*, Vol. 61, No. 4, pp. 1098 - 1116.

Domowitz, I. and Hakkio, C. S. (1985), 'Conditional variance and the risk premium in the foreign exchange market', *Journal of International Economics*, Vol. 19, pp. 47-66.

Doornik, J. A. and Hendry, D. F. (1995), *PcFIML 8.0: Interactive Econometric Modelling of Dynamic Systems*, Chapman and Hall, London, UK.

Durbin, J. and Watson, G. S. (1950), 'Testing for Serial Correlation in Least Squares Regression II', *Biometrika*, Vol. 38, pp, 159-178.

Durbin, J. and Watson, G. S. (1951), 'Testing for Serial Correlation in Least Squares Regression I', *Biometrika*, Vol. 37, pp, 409-428.

Edison H. J. and Melvin, M. (1990), 'The Determinants and Implications of the Choice of an Exchange Rate System' in W. S. Haraf and T. D. Willett (eds.), *Monetary Policy for a Volatile Global Economy*, AEI Press, Washington DC, USA.

Enders, W. (1995), *Applied Econometric Time Series*, John Wiley & Sons, New York, USA.

Engel, C. and Hakkio, C. S. (1993), 'Exchange Rate Regimes and Volatility', *Federal Reserve Bank of Kansas City Economic Review*, 3rd Quarter, pp. 43-58.

Engle, R. F. and Granger, C. W. J. (1987), 'Cointegration, Error Correction: Representation, Estimation and Testing', *Econometrica*, Vol. 55, pp. 251 - 276.

Ethier, W. (1973), 'International Trade and the Forward Exchange Market', *American Economic Review*, Vol. 63, No. 3, pp. 393-503.

Fama, E. F. (1970), 'Efficient Capital Markets: a review of theory and empirical work', *Journal of Finance*, Vol. 25, pp. 383-417.

Fama, E. F. (1991), 'Efficient Capital Markets II', *Journal of Finance*, Vol. 66, No. 5, pp. 1575-1617.

Fama, E. F. and Roll, R. (1971), 'Parameter estimates for symmetric stable distributions', *Journal of American Statistical Association*, Vol. 66, pp. 331-338.

Farrell, V. S., De Rosa, D. A. and McCown, T. A. (1983), 'Effects of Exchange Rate Variability on International Trade and other economic variables: a review of the literature', *Staff Studies No. 130, Board of Governors of the Federal Reserve System.*

Feenstra, R. C. and Kendall, J. D. (1991), 'Exchange Rate Volatility and International Prices', *National Bureau of Economic Research*, Working Paper, No. 3644.

Feldstein, M. (1969), 'Mean-Variance Analysis in the theory of liquidity preference and portfolio selection', *Review of Economic Studies*, Vol. 36, pp. 5-12.

Fountas, S. and Bredin, D. (1998), Exchange Rate Volatility and Exports: the case of Ireland', *Applied Economics Letters*, Vol. 5, pp. 301-304.

Franke, G. (1991), 'Exchange Rate Volatility and International Trading Strategy', *Journal of International Money and Finance*, Vol. 10, pp. 292-307.

Friedman, 1953, M. (1953), 'The Case for Flexible Exchange Rates' in M. Friedman *Essays in Positive Economics*, University of Chicago Press, Chicago, USA.

Friedman, M. (1976), *Price Theory: A Provisional Text*, Aldine Press, Chicago, USA.

Gagnon, J. E. (1993), 'Exchange Rate Variability and the Level of International Trade', *Journal of International Economics*, Vol. 34, pp. 269-287.

Garratt, A., Lee, K., Pesaran, M. H. and Shin, Y. (1998), 'A Long Run Structural Macroeconometric Model of the UK', *University of Cambridge, Department of Applied Economics Working Paper No. 9812, August, 1998.*

Giovannini, A. (1988), 'Exchange Rates and Traded Goods Prices, *Journal of International Economics*, Vol. 24, pp. 45-68.

Godfrey, L. G. (1978), 'Testing Against General Autoregressive and Moving Average Error Models when the Regressors Include Lagged Dependent Variables', *Econometrica*, Vol. 46, pp. 1303-1310.

Gosling, S. (1987), 'Effects of Exchange Rate Volatility on UK Exports', *National Economic Development Organisation, Economics Working Paper*, No. 24.

Gotur, P. (1985), 'Effects of Exchange Rate Volatility on Trade: Some further Evidence', *IMF Staff Papers*, Vol. 33, pp. 475-512.

Granger, C. W. J. (1981), 'Some properties of time series data and their use in econometric model specification', *Journal of Econometrics*, Vol. 16, pp. 121 -130.

Granger, C. W. J. (1997), 'On Modelling the Long Run in Applied Economics, *Economic Journal*, Vol. 107, No. 440, pp. 169 - 177.

Granger, C. W. J. and Newbold, P. (1974), 'Spurious Regressions in Econometrics', *Journal of Economics*, Vol. 2, pp. 111-120.

Granger, C. W. J. and Swanson, N. (1996), 'Future Developments in the Study of Cointegrated Variables', *Oxford Bulletin of Economics and Statistics*, Vol. 58, pp. 537 - 553.

Grassman, S. (1976), 'Currency Distribution and Forward Cover in Foreign Trade: Sweden Revisited', *Journal of International Economics*, Vol. 6, pp. 215-221.

Greenslade, J. V., Henry, S. G. B. and Jackman, R. (1998), 'A Dynamic Wage-Price Model for the UK', *Centre for Economic Forecasting, Discussion Paper No. 10-98, London Business School, London, UK.*

Hall, S. G. (1989), 'Maximum Likelihood Estimation of Cointegrating Vectors: An Example of the Johansen Procedure', *PRACTITIONERS CORNER, Oxford Bulletin of Economics and Statistics*, Vol. 51, No. 2, pp. 213-218.

Hall, S. G. (1991), 'The Effect of Varying Length VAR models on the Maximum Likelihood Estimates of Cointegrating Vectors', *Scottish Journal of Political Economy*, Vol. 38, pp. 317-323.

Hall, S. G. and Henry, S. G. B. (1989), *Macroeconomic Modelling*, North-Holland, Amsterdam.

Hansen, B. E. (1992), 'Efficient estimation and testing of cointegrating vectors in the presence of deterministic trends', *Journal of Econometrics*, Vol. 53, pp. 87 - 121.

Hansen, J. D. and Nielsen, J. U. M. (1997), *An Economic Analysis of the EU*, Mc-Graw - Hill, London, UK, Second Edition.

Harris, R. I. D. (1992), 'Testing for unit roots using the Augmented Dickey - Fuller test: Some issues relating to the size, power and lag structure of the test', *Economics Letters*, Vol. 38, pp. 381-396.

Harris, R. I. D. (1995), *Using Cointegration Analysis in Econometric Modelling*, Harvester Wheatsheaf, London, UK.

Harvey, A. (1997), 'Trends, Cycles and Autoregressions', *Economic Journal*, Vol. 107, No. 440, pp. 192-201.

Hassan, M. K. and Tufte, D. R. (1998), 'Exchange Rate Volatility and aggregate export growth in Bangladesh', *Applied Economics*, Vol. 30, pp. 189-201.

Hassapis, C. (1995), 'Exchange Risk in the EMS: Some Evidence based on a GARCH model', *Bulletin on Economic Research*, Vol. 47, No. 4, pp. 295-303.

Hataiseree, R. and Phipps, A. (1996), 'The degree of capital mobility in Thailand', *Applied Economics Letters*, Vol. 3, No. 1, pp. 9-13.

Hendry, D. F., Neale, A. and Srba, F. (1988), 'Econometric Analysis of small linear systems using PC - FIML', *Journal of Econometrics*, Vol. 38, pp. 1-18.

Hicks, J. (1962), 'Liquidity', *Economic Journal*, Vol. 72, pp. 787-802.

Holden, D. and Perman, D. (1994), 'Unit Roots and Cointegration for the Economist' in B. B. Rao (ed.), *Cointegration for the Applied Economist*, St. Martin's Press, New York.

Holly, S. (1995), 'Exchange Rate Uncertainty and Export Performance: Supply and Demand Effects', *Scottish Journal of Political Economy*, Vol. 42, No. 4, pp. 381-391.

Hooper, P. and Kohlhagen, S. W. (1978), 'The Effect of Exchange Rate Uncertainty on the Prices and Volume of International Trade', *Journal of International Economics*, Vol. 8, pp. 483-511.

Hsieh, D. A. (1988), 'The Statistical Properties of Daily Foreign Exchange Rates: 1974-1983', *Journal of International Economics*, Vol. 24, pp. 129-145.

International Monetary Fund (1984), 'Exchange Rate Volatility and World Trade', *IMF Occasional Paper*, No. 28, July.

International Monetary Fund (1988), *International Financial Statistics: Supplement on Trade Statistics*, IMF, Washington, USA.

Johansen, S. (1988), 'Statistical Analysis of Cointegrating Vectors', *Journal of Economic Dynamics and Control*, Vol. 12, pp. 231-254.

Johansen, S. (1994), 'A Statistical Analysis of Cointegration for I(2) variables', *Econometric Theory*, Vol. 11, No. 1, pp. 25-29.

Johansen, S. (1995), 'Identifying restrictions of Linear Equations with Applications to Simultaneous Equations and Cointegration', *Journal of Econometrics*, Vol. 59, pp. 1551-1180.

Johansen, S. and Juselius, K. (1990), 'Maximum Likelihood Estimation and Inference on Cointegration - With Applications to the Demand for Money', *Oxford Bulletin of Economics and Statistics*, Vol. 52, No. 2, pp. 169-210.

Johansen, S. and Juselius, K. (1992), 'Testing structural hypotheses in a multivariate cointegration analysis of the PPP. and UIP for UK', *Journal of Econometrics*, pp. 211 - 244.

Justice, G. (1983), 'The Impact of Exchange Rate Variability on International Trade Flows', *Bank of England, Discussion Paper*, No. 4.

Kenen, P. B. (1980), 'Exchange Rate Variability', *Princeton University*, (unpublished).

Kenen, P. B. and Rodrik, D. (1984), 'Measuring and Analyzing the Effects of Short Term Volatility in Real Exchange Rates', *Working Papers in International Economics, G-84-01, Department of Economics, Princeton University*, Princeton, USA.

Kenen, P. B. and Rodrik, D. (1986), 'Measuring and Analyzing the Effects of Short Term Volatility in Real Exchange Rates', *Review of Economics and Statistics*, pp. 311-315.

King, A. (1997), 'From Demand Equations to Two Regimes: The Theoretical Development of Export Models', *Bulletin of Economic Research*, Vol. 49, No. 2, pp. 81-125.

Klein, M. W. (1990), 'Sectoral Effects of Exchange Rate Volatility on United States Exports', *Journal of International Money and Finance*, Vol. 9, pp. 299-308.

Knight, F. K. (1921), *Risk, Uncertainty and Profit*, University of Chicago Press, Chicago, USA.

Koenker, R. (1981) 'A note on studentizing a test for heteroskedasticity', *Journal of Econometrics*, Vol. 17, pp 107-112.

Koop, G., Pesaran, M. H., and Porter, S. (1996), 'Impulse Response Analysis in nonlinear multivariate models', *Journal of Econometrics*, Vol. 74, pp. 119-147.

Koray, F. and Lastrapes, W. D. (1989), 'Real Exchange Rate Volatility and US Bi-lateral Trade: A VAR approach', *The Review of Economics and Statistics*, Vol. 68, pp. 311-315.

Kroner, K. F. and Lastrapes, W. D. (1993), 'The Impact of Exchange Rate Volatility on International Trade: Reduced Form Estimates using GARCH-in-Mean model', *Journal of International Money and Finance*, Vol. 12, pp. 298-318.

Krugman, P. (1995), 'Growing World Trade: Causes and Consequences', *Brooking Papers on Economic Activity*, Vol. 1, pp. 327-377.

Kumar, R. and Dhawan, R. (1991), 'Exchange Rate Volatility and Pakistan Exports to the Developed World, 1974-1985', *World Development*, Vol. 19, No. 9, pp. 1225-1240.

Kumar, V. and Whitt, J. A. (1992), 'Exchange Rate Volatility and International Trade', *Federal Reserve Bank of Atlanta, Economic Review.*

Langlois, R. N. and Cosgel, M. M. (1993), 'Frank Knight on Risk, Uncertainty and the Firm: a new interpretation', *Economic Inquiry*, Vol. 31, pp. 456-465.

Lanyi, A. and Suss, E. C. (1982), 'Exchange Rate Variability: Alternative Measures and Interpretation', *IMF Staff Papers*, Vol. 30, pp. 527-560.

Lao, D. (1994), *Exchange Rate Variability and International Trade Flows: A New Approach*, Arizona State University, Phd Dissertation.

Lastrapes, W. D. and Koray, F. (1990), 'Exchange Rate Volatility and US Multi-lateral trade flows', *Journal of Macroeconomics*, Summer, Vol. 12, No. 3, pp. 341-362.

Lee, K. C. and Pesaran, M. H. (1993), 'Persistence profiles and business cycle fluctuations in a disaggregated model of UK output growth', *Riecherche Economiche*, Vol. 47, pp. 293-322.

LeRoy, S. F. and Singell, L. D. (Jr.), (1987), 'Knight on Risk and Uncertainty', *Journal of Political Economy*, Vol. 95, No. 2, pp. 394-406.

Luce, R. D. and Raiffa, H. (1968), *Games and Decisions: introduction and critical survey*, John Wiley, New York.

Lütkepohl, H. and Reimers, H. E. (1992), 'Impulse Response Analysis of Cointegrated Systems', *Journal of Economic Dynamics and Control*, Vol. 16, pp. 53-78.

Lumsdaine, R. L. And Papell, D. H. (1997), 'Multiple Trend Breaks and the Unit Root Hypothesis', *Review of Economics and Statistics*, Vol. 78, pp. 212-218.

Macdonald, R. (1988), *Floating Exchange Rates: Theories and Evidence*, Unwin Hyman, London.

Machina, M. J. And Rothschild, M. (1987), 'Risk' in *Palgrave Dictionary of Economics*, (eds.), J. Eatwell, M. Milgate and P. Newman, Macmillan, London, UK.

Machlup, F. (1970), 'The Forward Exchange Market: Misunderstandings Between Practitioners and Economists' in *Approaches to Greater Flexibility of Exchanges*, C. F. Bergsten *et al*, eds., Princeton University Press, Princeton.

Mackinnon, J. (1991), 'Critical Values for co-integration tests', in R. F. Engle and C. W. J. Granger (eds.), *Long Run Relationships: Readings in Cointegration*, Oxford University Press, Oxford.

Makin, J. H. (1976), 'Eurocurrencies and the Evolution of the International Monetary System', in C. H. Stern, J. H. Makin and D. E. Logue (eds.), *Eurocurrencies and the International Monetary System* (Washington DC: American Enterprise Institute, USA).

Mann, C. L. (1989), 'The Effects of Exchange Rate Trends and Volatility on Export Prices: Industry Examples from Japan, Germany and the United States', *Weltwirtschaftles Archiv*, Vol. 125, pp. 588-618.

Markowitz, H. (1959), 'Portfolio Selection', *Journal of Finance*, Vol. 7, pp. 77-91.

Maskus, K. E. (1986), 'Exchange Rate Risk and US Trade: A Sectoral Analysis', *Federal Reserve Bank of Kansas City, Economic Review*, March, pp. 16-28.

McFarland, J. W., Pettit, R. R. and Sung, S. K. (1982), 'The Distribution of Foreign Exchange Price Changes: Trading Day Effects and Risk Measurement', *Journal of Finance*, Vol. XXXVII, No. 3, pp. 693-715.

Mckinnon, R. I. (1986), 'Comments on Willett', *Journal of International Money and Finance*, Vol. 5, Supplement, S113-115.

Mckenzie, M. D. (1999), 'The Impact of Exchange Rate Volatility on International Trade Flows', *Journal of Economic Surveys*, Vol. 13, No. 1, pp. 71-106.

Medhora, R. (1989), 'Effect of Exchange Rate Variability on Trade: A Survey', *Economic and Political Weekly*, March, Vol. 24, No. 11, pp. 579-586.

Medhora, R. (1990), 'The Effect of Exchange Rate Variability on Trade: The Case of West African Monetary Union's Imports', *World Development*, Vol. 18, No. 2, pp. 313-324.

Muscatelli, V. and Hurn, S. (1992), 'Cointegration and Dynamic Time Series Models', *Journal of Economic Surveys*, Vol. 6, No. 1, pp. 1-43.

Muscatelli, V. A., Srinivason, T. G. and Vines, D. (1992), 'Demand and Supply Factors in the Determination of NIE Exports: A Simultaneous Error Correction Model for Hong Kong', *Economic Journal*, Vol. 102, pp. 1467-1477.

Nunes, C. L., Newbold, P. and Kuan, C-M. (1997), 'Testing for Unit Roots With Breaks: Evidence on the Great Crash And The Unit Root Hypothesis Reconsidered', *Oxford Bulletin of Economics and Statistics*, Vol. 59, No. 4, pp. 435-448.

Organisation for Economic Development (1996), *World Economic Outlook*, Vol. 4, OECD, Paris, France.

Organisation for Economic Development (1996), *Flows and Stocks of Fixed Capital*, OECD, Paris, France.

Osborn, D. R. (1990), 'A Survey of seasonality in UK macroeconomic variables', *International Journal of Forecasting*, Vol. 6, pp. 327-336.

Osterwald - Lenum, M. (1992), 'A note with quantiles of the asymptotic distributions of the ML cointegrating rank test statistics', *Oxford Bulletin of Economics and Statistics*, Vol. 50, pp. 361 - 377.

Pagan, A. and Ullah, A. (1986), 'The Econometric Analysis of Models with Risk Terms', *Centre for Economic Policy Research, Discussion Paper*, No. 127, July.

Page, S. A. B. (1981), 'The Choice of Invoicing Currency in Merchandise Trade', *National Institute Economic Review*, Vol. 98, pp. 60-72.

Park, J. Y. (1992), 'Canonical Cointegrating Regressions', *Econometrica*, Vol. 60, pp. 119-143.

Perẽe and Steinherr, A. (1989), 'Exchange Rate Uncertainty and Foreign Trade', *European Economic Review*, Vol. 33, pp. 1241-1264.

Perman, R. (1991), Cointegration: An Introduction to the Literature', *Journal of Economic Studies*, Vol. 18, No. 3, pp. 1 - 30.

Perron, P. (1988), 'Trends and random walks in macroeconomic time series: further evidence from a new approach', *Journal of Economic Dynamics and Control*, Vol. 12, pp. 297-332.

Perron, P. (1989), 'The Great Crash, the oil shock and the unit root hypothesis', *Econometrica*, Vol. 57, pp. 1361-1402.

Pesaran, M. H. (1997), 'The Role of Economic Theory in Modelling the Long Run', *Economic Journal*, Vol. 107, No. 440, pp. 178-191.

Pesaran, M. H. and Pesaran, B. (1997), *Working with Microfit 4.0: Interactive Econometric Analysis*, Oxford University Press, Oxford, UK.

Pesaran, B. and Robinson, G. (1993) 'The European Exchange Rate Mechanism and the volatility of the sterling - deutschemark exchange rate', *Economic Journal*, Vol. 103, pp. 1418-1431.

Pesaran, M. H. and Shin, Y. (1996) 'Cointegration and Speed of Convergence to Equilibrium', *Journal of Econometrics*, Vol. 71, pp. 117-143.

Pesaran, M. H. and Shin, Y. (1997a), 'An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis', *Department of Applied Economics, University of Cambridge, Discussion Paper*, Cambridge, UK. Also in S. Strom, A. Holly and P. Diamond, *Centennial Volume of Ragnar Frisch*, Cambridge University Press (forthcoming), Cambridge, UK.

Pesaran, M. H. and Shin, Y. (1997b), 'Long-Run Structural Modelling', *Department of Applied Economics, University of Cambridge, Discussion Paper*, Cambridge, UK.

Pesaran. M. H., Shin, Y. and Smith, R. J. (1996), 'Testing for the Existence of a Long - Run Relationship', *Department of Applied Economics, University of Cambridge, Discussion Paper*, Cambridge.

Pesaran. M. H., Shin, Y. and Smith, R. J. (1997), 'Structural Analysis of Vector Error Correction models with Exogenous I(1) Variables', *Department of Applied Economics Working Papers Amalgamated Series, No. 9706, University of Cambridge.*

Pesaran, M. H. and Smith, R. P. (1998), 'Structural Analysis of Cointegrating VARs', *Journal of Economic Surveys*, Vol. 12, pp. 471-506. Also in (eds.) L. Oxley and M. McAleer *Practical Issues in Cointegration Analysis*, Basil Blackwell, Oxford (forthcoming 1998).

Phillips, P. C. B. (1986), 'Understanding Spurious Regressions in Econometrics', *Journal of Econometrics*, Vol. 33, pp. 311-340.

Phillips, P. C. B. (1987), 'Time series regression with a unit root', *Econometrica*, Vol. 55, pp. 277-301.

Phillips, P. C. B. and Hansen, B. E. (1990), 'Statistical Influence in Instrumental Regression with I(1), processes', *Review of Economics Studies*, Vol. 57, pp. 119 - 125.

Phillips, P. C. B. and Perron, P. (1988), 'Testing for a unit root in time series regression', *Biometrika*, Vol. 75, pp. 335-346.

Pozo, S. (1991), 'Exchange Risk and the Invoicing of Trade: Evidence from Seven European Countries' in K. Fatemi (ed.), *Selected Readings in International Trade*, Taylor & Francis, New York, USA.

Pozo, S. (1992), 'Are Flexible Exchange Rates really more volatile? Evidence from the early 1990s', *Applied Economics*, Vol. 24, pp. 1213-1218.

Pozo, S. (1992), 'Conditional Exchange Rate Volatility and the Volume of International Trade: Evidence from the Early 1990s', *The Review of Economics and Statistics*, Vol. 72, pp. 325-329.

Pratt, J. W. (1964), 'Risk Aversion in the Small and the Large', *Econometrica*, Vol. 32, No. 1-2, pp. 122-136.

Pugh, G. T., Tyrall, D., Rodecki, P. and Tarnawa, L. (1998), 'Exchange rate variability, international trade and monetary co-operation in Europe: some quantitative evidence for the single currency debate', *Staffordshire University Business School, Division of Economics Working Paper*, No. 98.9, August, Staffordshire, UK.

Qian, Y. and Varangis, P. (1994), 'Does Exchange Rate Variability Hinder Export Growth? Additional Evidence', *Empirical Economics*, Vol. 19, pp. 371-386.

Ramsey, J. B. (1969) 'Tests for specification errors in classical linear least squares regression analysis', *Journal of the Royal Statistical Society*, Vol. 31, pp. 350-371.

Rana, P. B. (1981), 'Exchange Rate Risk under Generalized Floating: Eight Asian Countries', *Journal of International Economics*, Vol. 11, pp. 459-466.

Rao, B. B. (1994), *Cointegration for the Applied Economist*, St. Martin's Press, London, UK.

Reimers, H. E. (1992), 'Comparisons of tests for multivariate cointegration', *Statistical Papers*, Vol. 33, pp. 335-359.

Reinsel, G. C. and Ahn, S. K. (1988), 'Asymptotic Properties of the Likelihood Ratio Test for Cointegration in the Nonstationary Vector AR Model', *Technical Report, Department of Statistics, University of Wisconsin*, Madison, USA.

Rothschild, M. and Stiglitz, J. E. (1970), 'Increasing Risk I: A definition, *Journal of Economic Theory*, Vol. 2, pp. 225-243.

Sapir, A. and Sekkat, K. (1990), Exchange Rate Volatility and International Trade: The Effect of the European Monetary System in P. De Grauwe and L. Papademos, eds., *The European Monetary System in the 1990's.*

Sapir, A. and Sekkat, K. (1995), Exchange Rate Regimes and Trade prices: Does the EMS Matter?, *Journal of International Economics*, Vol. 38, pp. 75-94.

Sapir, A., Sekkat, K. and Weber, A. (1994), 'The Impact of Exchange Rate Fluctuations on European Union Trade', *Centre for Economic Policy Research, Discussion Paper No. 1041*, London.

Sargan, J. D. and Bhargava, A. (1983), 'Testing residuals from least squares regression of being generated by the Gaussian Random Walk', *Econometrica*, Vol. 51, pp. 153-174.

Savvides, A. (1992), 'Unanticipated Exchange Rate Variability and the Growth of International Trade', *Weltwirtschaftles Archiv*, Vol. 128, No. 3, pp. 446-463.

Schwarz, G. (1978), 'Estimating the Dimension of a Model' *Annals of Statistics*, Vol. 6, pp. 461-464.

Seabra, F. (1995), 'Short run exchange rate uncertainty in Latin America', *Applied Economics*, Vol. 27, pp. 441-450.

Sercu, P. and Vanhulle, C. (1992), 'Exchange rate volatility, international trade and the value of exporting firms', *Journal of Banking and Finance*, Vol. 16, pp. 155-182.

Shoesmith, G. L. (1995), 'Multiple Cointegrating Vectors. Error Correction and Forecasting with Litterman's Model', *International Journal of Forecasting*, pp. 557 - 567.

Shone, R. (1989) *Open Economy Macroeconomics: Theory, Policy and Evidence*, Harverster Wheatsheaf.

Sims, C. A. (1980), 'Macroeconomics and Reality', *Econometrica*, Vol. 48, No. 1, pp. 1-48.

Söderlind, P. and Vredin, A. (1995), 'Applied Cointegration Analysis in the Mirror of Macroeconomic Theory', *Journal of Applied Econometrics*, Vol. 11, pp. 363 - 381.

Sohmen, E. (1961), *Flexible Exchange Rates*, University of Chicago Press, Chicago, USA.

Spanos, A. (1986), *Statistical Foundations of Econometric Modelling*, Cambridge University Press, Cambridge, UK.

Stock, J. H. (1987), 'Asymptotic Properties of least-squares estimates of co-integrating vectors', *Econometrica*, Vol. 55, pp. 1035-1056.

Stock, J. H. and Watson, M. (1988), 'Testing for Common Trends', *Journal of the American Statistical Association*, Vol. 83, pp. 1097-1107.

Stokman, A. C. J. (1995), 'Effects of Exchange Risk on Exports', *De Economist*, Vol. 143, No. 1, pp. 41-54.

Tavlas, G. S. (1997) 'The International Use of the US Dollar: An Optimum Currency Area Perspective', *World Economy*, Vol.??, .

Thursby, M. C. (1980), 'The Resource Reallocation Costs of Fixed and Flexible Exchange Rates: a counter example', *Journal of International Economics*, Vol. 10, pp. 79-90.

Thursby, M. C. (1981), 'The Resource Reallocation Costs of Fixed and Flexible Exchange Rates: a multicountry extension', *Journal of International Economics*, Vol. 11, pp. 487-493.

Thursby, J. C. and Thursby, M. C. (1987), 'Bi-lateral trade flows, the Linder Hypothesis and Exchange Risk', *The Review of Economics and Statistics*, pp. 488-495.

Tobin, J. (1958), 'Liquidity Preference as Behavior Towards Risk', *Review of Economic Studies*, Vol. 25, pp. 65-86.

Viaene, J. M. and de Vries, C. G. (1992), 'International Trade and Exchange Rate Volatility', *European Economic Review*, Vol. 30, pp. 1311-1321.

Vlaar, P. J. G. and Palm, F. C. (1993), 'The Message in Weekly Exchange Rates in the European Monetary System: Mean Reversion, Conditional Heteroscedasticity, and Jumps', *Journal of Business and Economic Statistics*, Vol. 11, No. 3, pp. 351-360.

Westerfield, J. M. (1977), 'An Examination of foreign Exchange Risk under Fixed and Floating Rate Systems', *Journal of International Economics*, Vol. 7, pp. 181-200.

Wickens, M. R. (1996), 'Interpreting Cointegrating Vectors and Common Stochastic Trends', *Journal of Econometrics*, Vol. 74, pp. 255 - 271.

Willett, T. D. (1986), 'Exchange Rate Volatility, International Trade and Resource Allocation: A Perspective on Recent Research', *Journal of International Money and Finance, Supplement*, pp. S101-112.

Zivot, E. and Andrews, D. K. W. (1992), 'Further Evidence of the Great Crash, the Oil Price Shock and the Unit Root Hypothesis', *Journal of Business and Economic Statistics*, Vol. 10, pp. 251-270.