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Abstract

We analyse the impact of volatility *per se* on exports for a a small open economy concentrating on Irish trade with the UK and the US. An important element is that we take account of the time lag between the trade decision and the actual trade or payments taking place by using a flexible lag approach. Rather than adopt a single measure of risk we also adopt a spectrum of risk measures and detail varied size characteristics and statistical properties. We find that the ambiguous results found to date may well be due to not taking account of the timing effect which varies substantially depending on which volatility measure is used. However, the foreign exchange volatility effect is consistently positive, indicating the dominance of exporters expectations of possible profitable opportunities from future cash flows. The potential negative aspects of trade, the entry and exit costs, are accounted for by a negative influence of income volatility on trade.

Keywords: Exports, risk measurement, distributed lags
JEL Classification: C32, C51, F14, F31

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1 Introduction

The international trade performance of a small open economy (SOE) plays a pivotal role in the performance of the economy and especially over the last number of years, in the case of Ireland. The share of Irish merchandise exports in Gross Domestic Product (GDP) has grown dramatically in recent years (from 43% in 1979 to 94% in 2002), thus rendering the economy more open than before and more dependent on foreign markets.[1] Hence, policies designed to enhance export performance are of increasing importance to national economic welfare. Good policy decisions are assisted by having relevant information on the factors that determine the level of exports and imports. In this paper, we examine the impact of volatility *per se* on Irish exports to the UK and the US using a two country imperfect substitutes model.[2] As well as including real income and real foreign exchange, volatility of these underlying variables is also analysed. The analysis of a small open economy's export function is in contrast to the vast majority of the previous studies which focus on large and predominantly closed economies. The issue of the sensitivity to volatility considers both foreign exchange volatility as well as foreign income volatility. Moreover, in excess of 40% of Irish exports goes to the UK and US and these transactions dominate those of its trading partners within the auspices of the Euro currency union. Also the case of the Irish economy can provide unique insights into the effects of currency unions given it was part a currency union with UK Sterling up until 1979.

There are a number of important advances in the current study focusing on a small open economy economy. Firstly, the data set studied is representative of a small open economy facing a high degree of uncertainty from external factors. Although a member of the European single currency, Euro, the majority of Irish exports are to non Euro zones with the US and the UK representing the most important markets. At the start of our sample 1979 Irish exports to the US represented just under 5% of total exports, while at the end of the sample it was close to 20%. The traditional economic and monetary links between the Irish and the UK economy have diminished in recent years. [3] In terms of trade, Irish exports to the UK have fallen from

[1] Ireland's status as a SOE is clearly evident and especially its reliance on Non-Euro trade of over 60% of total trade dominated by its activities with the UK and US. In contrast, other economies in the European Union are not nearly as reliant on Non-Euro dominated trade.

[2] Exports only are analysed as they represent a much higher proportion of our trade with the UK and US relative to imports and also are open to differing degrees of volatility.

[3] The Irish pound was established in the late 1920's and maintained a one for one link with UK Sterling until 1979 when Ireland joined the European Monetary System (EMS). During the 1970's the UK inflation rate was both high and extremely volatile and the potential to link to the more stable core EU economies was the main motivation for joining the EMS.

about 40% in 1979 to 20% in 2002. While the trend, in terms of the share of total Irish exports to the US and the UK, is moving in opposite directions, the combined importance remains extremely strong, i.e. over 40% of total Irish exports go to the US and the UK at both the beginning and the end of the sample. In this study we focus on the impact of volatility, exchange rate and business cycle, on Irish exports to the UK and the US.

Secondly, we adopt a comprehensive set of volatility measures. These include recent advances in the time varying autoregressive heterosecasticity literature, APARCH, absolute volatility underpinned by the theory of power variation, and the model free log range estimate. This paper outlines alternative models for foreign exchange and income volatility and details their statistical properties in conjunction with their impact on the export function. The vast majority of previous studies give mixed evidence on the influence of volatility on trade by focusing only on a particular measure of foreign exchange volatility and have not accounted for the recent developments in time varying risk measurement. As well as exchange rate volatility, the impact of foreign income uncertainty may well be crucial to a small open economy such as Ireland. The importance of foreign income volatility in terms of trade was first highlighted by Franke (1991) and was adopted by Baum et al (2004). Franke (1991) views trade as an option to be exercised by a firm and will be exercised if doing so is profitable. Thus as well as including income and foreign exchange in our exports model we include volatility of these underlying variables. This is consistent with Franke (1991), where we now view foreign income volatility (rather than foreign exchange volatility) as signalling greater profit opportunities. As well as addressing the impact of foreign exchange rate volatility and foreign income volatility, we also look at the interaction between the two and hence take account of any possible non-linear influences on exports that they may have.

Finally, rather than looking at the long-run relationship between Irish exports and a set of variables, we analyse the impact of volatility *per se* adopting a flexible lag approach. Using a Poisson distributed lag structure the model takes account of the lag between trade decisions and the time of the actual trade flow/payment. Thus our empirical results show the total effect of volatility as well as the distribution of the effect over time. A similar flexible lag approach has been adopted by both Baum et al (2004) and Klassens (2002) for fully developed economies.

The paper finds very strong evidence on the influence of volatility on a small open economy. We find that the foreign exchange volatility effect is consistently positive, indicating the dominance of exporters expectations of possible profitable opportunities from future cash flows associated with the export function. In contrast, the potential negative aspects of trade, the entry and exit costs, appear to be accounted for by negative effect of

income volatility on trade. Moreover, positive non-linear effects for the interaction between foreign exchange and income volatility influence export modelling for a small open economy. Importantly these findings occur in the face of volatility measures that differentiate considerably in their statistical properties according to the modelling process used. Overall we find that the ambiguous results found to date in the literature may well be due to not taking account of the timing effect which varies substantially depending on the volatility measure.

The remainder of the paper is organized as follows: Section 2 provides a survey of the theoretical and empirical literature. The methodological approach with the operations of the adopted export model and the alternative volatility measures are discussed in detail in section 3. Section 4 includes a description of the data used and an analysis of the alternative volatility measures. Section 5 reports details of the model specification and the findings from our empirical model concentrating on the influence of volatility. Finally, section 6 concludes.

2 Literature Review

2.1 Theoretical models

Theoretically the modelling of exports allows for different impacts of volatility with no unanimity on direction and magnitude. To illustrate, Demers (1991) assumed that exchange rate risk leads to lower production and trade due to price uncertainty implications for foreign demand. This rational is generally supported by policy makers (see EU Commission (1990)). Here, the effect of higher exchange rate volatility depends on the expected marginal utility of the export income. Higher exchange rate risk reduces the expected marginal utility of export revenues, and thus, risk averse producers reduce their output.

An alternative model consistent with a positive association between exchange rate volatility and exports implies that exchange rate movements are not just a source of risk but also create opportunities to make profits, because they affect the real opportunities of the firm (De Grauwe, 1994). Assuming that firms make their production and export decisions once they have observed the exchange rate, higher exchange rate uncertainty may increase the average profit of the firm. For a profit-taking firm, a higher price due to an exchange rate change results in the firm enjoying higher profits per unit of output and so expands its output. Equivalently, in this analysis, exporting represents an option. At a favourable exchange rate the firm exercises its option to export. The opposite happens for unfavourable movements. Since the value of options increase with the variability of the

underlying asset, the firm is better off when exchange rate variability increases. Even assuming risk aversion, it remains possible that exchange rate volatility increases exports, provided that the increase in utility of the firm from the increase in the average profit, offsets the decline in utility of the risk averse firm due to the greater uncertainty of profits.

More specifically, Franke (1991) follows a real options approach and views trade as an option to be exercised by a firm. The author examines the decision making process of exporters under uncertainty in an intertemporal multiperiod setting. The real options approach extends the possible factors included in modelling exports. In particular, any underlying variable has associated volatility giving rise to adding income and foreign exchange volatility to our export function. Here for example, the exchange rate is assumed to be mean reverting and there are costs to entering and exiting markets. Firms will exercise the option to enter a market if doing so is profitable. The profitability of the option depends on the present value of expected cash flows from exporting and on the present value of expected entry and exist costs. A weaker (stronger) exchange rate increases (decreases) both the cash flow from exporting and entry and exit costs. The latter are assumed to be a concave function of the exchange rate. If volatility causes expected cash flows from exporting to grow faster than expected entry and exit costs, then the value of the option to export has increased and volatility and trade are positively related. This will be the case if cash flow are convex in the exchange rate. According to this scenario, increased volatility will result in firms entering the market sooner and exiting later and the number of trading firms will increase.

Furthermore, ambiguity on the relationship between exchange rate uncertainty and trade has also been outlined (Viaene and de Vries, 1992). If you allow for the existence of forward markets then exchange rate volatility can impact trade either positively or negatively through its impact on the determination of forward rates. The outcome is then determined through the empirical analysis. Thus, overall the theoretical predictions regarding volatility and trade are inconclusive.

2.2 Empirical Evidence

The vast empirical evidence of the influence of exchange rate volatility on exports is also mixed. [4] Findings are dependent on models employed, sample period analysed and countries examined (Bacchetta and van Wincoop, 2000). Furthermore there is no consistency in the measures of volatility used ranging from unconditional estimates such as standard deviation in the early literature to conditional ones such as GARCH estimates in more

[4] See McKenzie (1999) for a review.

recent times (McKenzie, 1999). For instance, Koray and Lastrapes (1988) find evidence of a negative relationship between exchange rate volatility and trade using cointegration techniques involving US pairs. In contrast, Baum et al (2003)show evidence of a positive relationship between exchange rate volatility and trade using a poisson flexible lag structure, while Klaessen (2002), did not find evidence of any significant effect of exchange rate volatility on trade for G7 economies. Hedging through derivative products usually explains the lack of significance, although Wei (1999) finds a negative and statistically significant effect of foreign exchange rate volatility on exports even after taking account of futures and options instruments to hedge risk. There is some evidence that views increased exchange rate volatility as a result of greater integration of world markets (see Rose, 2000). In contrast, Glick and Rose (2002) find conflicting evidence on the same issue for panel data covering 217 countries. Measuring exchange rate uncertainty using unconditional standard deviation, the authors find that an increase (decrease) in exchange rate volatility resulting from leaving (joining) a currency union has a negative (positive) impact on trade statistics.

The majority of empirical studies estimate an export functions based on the following (see Arize, 1997):

$$x_t = \beta_0 + \beta_1 y_t^* + \beta_2 p_t + \beta_3 \sigma_{st} \tag{1}$$

where x_t, y_t^*, and p_t, stand for real exports, foreign real income, and relative prices, respectively (in logs), and σ_{st} stands for exchange rate volatility that captures exchange rate uncertainty. Economic theory suggests that real income levels of the trading partners for the domestic country and competitiveness measures affect the volume of exports positively and negatively respectively. This paper concentrates on the effect of exchange rate volatility on exports and as stated is ambiguous from a theoretical point of view.

In addition to the mixed empirical results many alternative modelling approaches have been applied. Early empirical studies disregarded the issue of nonstationarity of macroeconomic time series and used classical regression analysis and are subject to the to the "spurious regression" criticism (Granger and Newbold, 1974). Studies also test for stationarity of the relevant time series and employ cointegration techniques, e.g., Koray and Lastrapes (1989). Two recent studies take a different approach, Klassens (2002) and Baum et al (2004). Rather than looking at the long-run relationship between the variables both papers analyse the impact of exchange rate volatility adopting a flexible lag approach. In other words the model takes account of the lag between a trade decision and the time of the actual trade flow/payment. In both cases the empirical part of the studies use a Poisson lag structure in order to account for the possible extended effect.

Klassens focuses on US exports to other G7 countries for the period 1978 to 1996. The author finds that exchange rate volatility has an insignificant effect on US exports in all cases.

Baum et al (2004) focuses on bilateral aggregate real exports between 1980 and 1998 for the following countries, US, Canada, Germany, UK, France, Italy, Japan, Finland, Netherlands, Norway, Spain, Sweden, and Switzerland. Baum et al (2004) also include foreign income volatility and is consistent with Franke (1991). We now view foreign income volatility as a signal for greater profit opportunities. As well as addressing the impact of foreign exchange rate volatility and foreign income volatility, they also look at the interaction between the two and hence take account of any possible non-linear relationship. Overall they find a significant impact of real income volatility on trade that varies in direction for the countries analysed.

Evidence on the impact of volatility on Irish trade statistics is relatively sparse.[5] Thom and Walsh (2002), modelling overall Irish trade find no evidence that exchange rate regime changes impact Anglo-Irish trade from analysing time series and panel regressions in a case-study approach. Using the unconditional standard deviation to measure exchange rate volatility the study argues that the unilateral move by Ireland to join the EMS and their rational is unique in that the devolvement did not disrupt trade due to their joint membership of the EEC. Also, Lothian and McCarthy (2000) find that foreign exchange volatility changes according to exchange rate systems and decrease on joining a currency union vis-a-vis other systems.

3 Methodology

3.1 Modelling Exports

As in Klassens (2002) and Baum et al (2004) we adopt the flexible lag version of the Goldstein and Khan (1985) two country imperfect substitutes model for bilateral trade between Ireland and the US and the UK in real terms. This allows for examining the decision making process of exporters under uncertainty for intertemporal multiperiod horizons. The variable of interest is real Irish exports, using Irish unit export value as our deflator.[6] Irish exports to the UK and US are invoiced in UK Sterling and US Dollars respectively and we examine the logarithm of real Irish exports. The determinants of exports relate to the assumptions concerning export supply

[5]Studies concentrate on examining the movements in real exchange rate levels and overlook the impact the impact of the second moment.

[6]The Irish export sector is considered to be dualistic, with relatively smaller indigenous firms dominating the more low technology production sectors, while larger subsidiaries of foreign owned multinationals tend to dominate the more high technology sectors.

and demand. The determinants of demand are foreign income and relative prices, $p^*_{xt} = log(P_{xt}/P^*)$, and both are stated in foreign currency.

$$q^d_t = q^d(y^*_{t-k}, p^*_{xt}) \tag{2}$$

The determinants of the exports supply function only includes the relative price of exports converted to domestic prices;

$$q^s_t = q^s(p^*_{xt} + s_t) \tag{3}$$

where s_t is the real exchange rate, $(S_t \times P^*)/P_t$, and is measured as foreign per unit of domestic currency. Given that decisions will be made based on the forecast of relative prices, both the conditional mean and the standard deviation of $p^*_{xt} + s_t$ are both included in the supply equation.

$$q^s_t = q^s(E_{t-k}[p^*_{xt} + s_t], \sigma_{s,t-k}[p^*_{xt} + s_t]) \tag{4}$$

Goldstein and Khan (1985) assume that the export decision and physical actual exports and payments are not contemporaneous introducing a degree of uncertainty into the trade model. To incorporate this uncertainty, the model is estimated with a flexible poisson lag structure. This allows for uncertainty between trading decisions and actual completion of trade and we examine how it impacts our variables in the trade modle. In addition, the process is extended following an options based approach by including volatility of the underlying variables. Franke (1991) details the options based approach in terms of the entry and exit costs of the traders export decision. The exporters decision making process is impacted upon by variables that affect not only their immediate supply but also their medium term supply. Both foreign income and the exchange rate can fluctuate over this time period and this may improve or disimprove the traders profit opportunities. For example, greater volatility in foreign demand may lead to greater sales opportunities in the foreign market. The response to the uncertainty in the underlying variables only occurs over the medium term suggesting the use of lags in the exporters decision making behaviour. Furthermore there may be non-linear effects arising from a combination of income and foreign exchange volatility effects not directly measured in the variables alone (Baum et al, 2004). To incorporate this an interaction term of income and foreign exchange volatility is introduced into the exporter's supply function.Taking account of these extensions we can now re-write exports supply as:

$$q^s_t = q^s(E_{t-k}[p^*_{xt} + s_t], \sigma_{s,t-k}[p^*_{xt} + s_t], \sigma_{s,t-k}, \sigma_{y,t-k}, \sigma_{s\times y,t-k}) \tag{5}$$

where $\sigma_{s,t-k}$ is foreign exchange volatility, $\sigma_{y,t-k}$ is income volatility both outlining direct effects, and $\sigma_{s\times y,t-k}$ is the interaction term incorporating non-linear indirect responses of income and foreign exchange volatility on the supply function.

Equating supply and demand leads to a function for real exports;

$$x_{it} = x(y^*_{t-k}, E_{t-k}[s_t], \sigma_{s,t-k}, \sigma_{y,t-k}, \sigma_{s\times y,t-k}) \tag{6}$$

3.2 The Poisson Lag Approach

An important element is that we take account of the time lag between the trade decision and the actual trade taking place or payment taking place (Goldstein & Khan, 1985). Hence it is clearly not sufficient to account for only contemporaneous relationships between exports and our explanatory variables.

In order to model the impact using a flexible lag approach, we adopt a Poisson lag structure (see Baum et al (2004) and Klassens (2002)). Alternative, but more restrictive, approach's include the geometric and the polynomial lag specification. The Poisson lag approach is derived from the Poisson probability distribution;

$$\beta_{kl} = \beta_k . \frac{(\lambda_k - 1)^{l-1}}{(l-1)} exp[-(\lambda_k - 1)] \tag{7}$$

for $\lambda_k \geq 1$ & $k = y^*, s, \sigma_s, \sigma_y$, & $\sigma_{s\times y}$ and λ is the lag at which the maximum effect occurs. One important advantage of the Poisson lag approach is the number of parameters to be estimated is minimized, $2k + 1$, where k is the number of independent variables. As can be seen the parameters $\lambda_1, ...\lambda_k$ enter into the equation in a non-linear fashion. In order to calculate the parameters $\lambda_1, ...\lambda_k$, we use the simulated annealing optimization technique (see, Goffe et al. 1994).[7] Once the parameters, $\lambda_1, ...\lambda_k$, have been obtained from the non-linear optimization technique, the estimated coefficients, $\beta_1, ...\beta_k$, are calculated using OLS.

3.3 The Appropriate Volatility Measure

Our export model follows an options based approach (see Franke, 1991). Here participation in export markets is based on evaluation of entry and exit

[7] An important advantage of the simulated annealing optimization routine is that it escapes from local maxima and local minima and can maximise or minimise functions that are difficult to optimize. We use the GAUSS code by E.G. Tsionas to run the procedure.

costs using a real options approach to the decision making process. This real options approach suggests additional volatility variables affect medium term exports. The real options approach incorporates volatility of the economic variables under consideration thus including volatility of exchange rates and of income. So as well as examining the impact of real exchange rates and real income, the approach suggests determining the impact of the volatility of these factors. The approach determines the optimal strategy facing a firm that incurs entry and exit costs for a foreign market. To illustrate Franke (1991) finds a significant positive relationship between exports and exchange rate volatility. The rational is that firms increase exports in response to increased volatility if the present value of expected cash flows from exports exceeds the sum of entry and exit costs. For instance, changes in the volatility of foreign income changes an exporting firm's entry/exit cost ratio and therefore their export opportunities to that economy. Thus higher foreign income volatility may signal higher profit opportunities resulting in a change in exporters decision-making leading to increased exports.

Given the importance of volatility in our modelling process it is interesting to note that the literature relies on many different types of volatility estimates (McKenzie, 1999). So for example, unlike exchange rates that are available contemporaneously exchange rate volatility is modelled ex-post. This has led to a major research agenda in trying to model financial volatility through analysis of its distributional and dynamic characteristics. Major developments have been made in modelling the time-variation of volatility through autoregressive conditional heteroskedasticity (ARCH) related models and more recently with model-free aggregated based procedures underpinned by the theory of power variation. In contrast, models that assume constant volatility are now generally ignored. Regardless of what approach is used, the key issue is to recognize that volatility is latently unobservable thereby requiring proxies. This gives rise to a modelling approach that could involve a spectrum of procedures and we estimate the export specification with a number of alternative risk measures to determine if volatility determination impacts on inferences from the export model. Specifically we address the issue as to whether alternative volatility estimates are responsible for the inconclusive empirical evidence? By looking at a number of estimates we can ascertain the influence of volatility per se rather than be swayed by the conclusions from a single estimate. The paper focuses on four separate measures for foreign exchange and income respectively and when combined give rise to sixteen interaction terms. The foreign exchange and income measures necessarily diverge due to data availability, e.g. the foreign exchange rates are available at relatively high frequencies such as daily intervals, while the income estimates are only available at monthly frequencies.

The volatility measures come from different strands of the literature such as conditional measures where we apply a time-varying APARCH pro-

cess that nests seven different parametric ARCH models (for a review see Bollerslev et al, 1994). Also, estimates underpinned by the theory of power variation such as realized volatility that requires aggregation from high to low frequency observations has been advocated with many illustrations for volatility modelling (see references in Andersen et al, 2003). Moreover, we examine the impact of other model free estimates using squared, absolute and range based estimates (see Ding and Granger, 1996; and Alizadeh et al, 2002).

First concentrating on the aggregated measures that are applied to the daily exchange rates, the most common approach suggests the use of aggregated squared exchange rate changes over a period, say for example, aggregating daily realisations to obtain monthly estimates instead of using a single estimate from the monthly exchange rate changes (see Baum et al, 2004; Klaessens, 2002). This estimate is closely associated with the variance. Merton (1980) illustrates the advantages in using relatively high frequency observations to obtain more precise low frequency risk measures and early applications with monthly estimation cumulating daily observations are given in French et al. (1987). This paper also analyses aggregated absolute realistions that evolves from the same theoretical framework of realized power variation (see Barndorff-Nielsen and Shephard, 2003) as exchange rate changes have the stylized property of exhibiting fat-tails due to excessive large-scale movements and modelling with absolute realisations is more robust in the presence of this property (Davidian and Carroll, 1987). Also, more attractive time-series properties are documented for absolute realised volatility measures than their squared counterparts (Barndorff-Nielsen and Shephard, 2003).

Turning to the theoretical framework we begin by defining the price process that is underpinned by realised power variation. This incorporates the popularly used quadratic variation that details the use of aggregated squared realisations and absolute power variation using aggregated absolute realisations. Barndorff-Nielsen and Shephard (2003) extend the framework for different power variations, $0.5 > n < 3$. We analyse the price process that has $r_{m,t} = p_t - p_{t-/m}$ as the compounded returns with m evenly spaced observations per month. Volatility of this price process as measured by integrated volatility is unobservable. However, realised power variation that incorporates realised absolute variation, namely the sum of absolute realisations, $\Sigma|r_m|$, equate with integrated volatility.

We present power variations for both squared and absolute measures for the monthly foreign exchange volatility. The practical implementation of the theory simplifies into constructing volatility estimators using aggregated absolute exchange rate changes and their variants for any month t with m daily intervals:

$$|r_t^2|^n = \sum_{j=1}^{m} |r_{m,t+j/m}|^n \tag{8}$$

allowing for fat-tails in exchange rate changes. Also, in terms of the commonly applied principle of quadratic variation using aggregated squared realisations exchange rate volatility is given as:

$$[r_t^2]^n = \sum_{j=1}^{m} [r_{m,t+j/m}^2]^n \tag{9}$$

where different power transformations are underpinned by the theoretical framework.

Moving to the standard modelling of time variation GARCH type processes have traditionally been applied (Kroner and Lastrapes, 1993; and Klaessens, 2002). A large number of specifications are available with for example, Kroner and Lastrapes (1993) using a GARCH-M process whereas Klaessens (2002) using a GARCH (1, 1) model. All these models have a common feature in modelling clustering of second moments. We use the Asymmetric Power ARCH (APARCH) to provide end of month income and foreign exchange rate volatility estimates. The model developed by Ding et al (1993) advantageously nests many extensions of the GARCH process. As well as encompassing three ARCH specifications (ARCH, Non-linear ARCH and Log-ARCH), two specifications of the GARCH model (using standard deviation and variance of returns), it also details two asymmetric models (both ARCH and GARCH versions). It is given by:

$$\sigma_t^d = \alpha_0 + \sum_{i=1}^{p} \alpha_i (|\epsilon_{t-i}| + \gamma_i \epsilon_{t-i})^d + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^d \tag{10}$$

for $\alpha_0, \alpha_i, \beta_j \geq 0$, $\alpha_i + \beta_j \leq 1$, $-1 \leq \gamma_i \leq 1$. Detailing the model, the process presents volatility in the form of a Box-Cox transformation whose flexibility allows for different specifications of the residuals process allowing for different GARCH models. As well as describing the time-variation in exchange rate changes, it also allows for the possibility of leverage effects, γ_i, by letting the autoregressive term of the conditional volatility process be represented as asymmetric absolute residuals. Non-linear GARCH models are derived from different power coefficients, d. The model is fitted with a conditional student-t distribution thereby allowing for fat tails. The model adequately deals with second moment persistence documented for the underlying variables.

In addition, the use of the log range defined as the first difference of the log of maximum and minimum prices is applied to foreign exchange data at monthly intervals. This simple estimate has been used widely in an ad hoc fashion in the literature and its time series properties are formally examined in Alizadeh et al (2002). They find that it is an efficient estimator with small measurement error and further attractive time series properties by being approximately gaussian.

The aggregation procedure and range based measure are not applied in measuring income uncertainty due to a lack of intra-monthly observations. Notwithstanding this there are many different types of volatility estimates that could model income dynamics ex-post. Here we overcome the problem of proxying for unobservable volatility by using the observed absolute income changes and observed squared income changes as measures of income uncertainty. Ding and Granger (1996) show that these model free volatility proxies adequately model the long term persistence property associated with financial data. The final income measure is the moving window approach advocated by Thursby and Thursby (1987) to obtain adaptive risk measures. Here the moving window technique estimates income volatility for the US and the UK where the logarithm of real income is regressed on a quadratic trend for a six-month moving window. The root mean squared error of the regression represents the time-varying process for our volatility measure using relatively low frequency income data.

Taking income volatility and exchange rate volatility we produce an interaction term as a product of these variables. This allows us to not only examine the direct impact of the respective volatility estimates, but also assess whether there is an indirect influence of these volatilities through their interaction with each other. Following the real options approach both exchange rate and income volatility would both have a direct concurrent impact on exporters decision-making but there may also be an indirect influence. To examine any combined effects of these separate dynamics, the interaction term between exchange rate and income volatility is included to help describe the exporters behaviour. This allows for the processing of information that is different from each volatility measure but combines both income and exchange rate volatility. Any indirect impact of the respective volatility measure is captured by this interaction variable and it may remove omitted variable bias by examining respective volatility measures only. Thus exchange rate volatility could impact income volatility and vice versa. For each volatility measure we create an interaction term giving sixteen separate measures each labelled as a combination of the respective volatility measures, for example APARCH exchange rate volatility combined with Squared income changes. These combinations imply that the impact of the interaction term will not be constant, but will depend on the respective measures of volatility.

4 Data Considerations

4.1 Data

We use monthly data for the period May 1979 to December 2002. The starting point of our sample is dictated by data availability and that the Sterling link was abandoned in 1979. Irish exports to the UK and US are taken from the Trade Statistics Series of the CSO publication and were divided by Ireland's unit export value to obtain the real exports figure.[8] Given real national income is only available at quarterly frequencies, monthly UK and US industrial production (constant prices) is used. Irish, UK and US export unit values are obtained at monthly intervals. The exchange rate data used in the study is daily UK Sterling per unit of euro and US Dollar per unit of euro adjusted from Irish Pounds in the pre-Euro period.

As shown in figure 1, Irish exports to the UK and US make up a sizable proportion of Irish Exports. Although traditionally the UK was the important market for Irish exports, this has diminished in recent years. At the same time, exports to the US have grown steadily over the last number of years. Although moving in different directions, exports to both countries is sizable and is exposed to exchange rate movement pressures. Furthermore, Ireland has an unique relationship with the UK that has driven many of its economic policies. For example, in terms of foreign exchange, Ireland and the UK was part of a currency union between 1800 and 1979.[9] The Irish pound - introduced in 1927 - was held in a $1:1$ no-margins peg with Sterling until 1979 using an adhoc currency commission to maintain the arrangement. Prior to this there was no independent Irish pound since the Act of Union in 1800. The break from parity was due to Ireland's decision to be a member of the European Monetary System (EMS) and the UK's non-participation. The most important influences on the Irish decision to join the EMS decision were the perceived political benefits, the promise of additional EEC subsidies, and a desire to shift the currency's nominal anchor from Sterling, then considered to be inflation prone, to the new 'zone of monetary stability' based on the German mark. (Economic and Social Research Institute, 1996). Overall foreign exchange volatility for the Irish economy has increased in real terms since 1979 than it was under the Sterling link (Lothian and McCarthy, 2000).

[8] All remaining data is from Datastream.

[9] Since then the currencies have been part of separate currency arrangements such as the Euro and the EMS with the exception of the period between October 1990 and September 1992 where the UK joined the EMS and subsequently departed around its currency crises.

4.2 Volatility Measures

Using the respective volatility measures outlined we describe their statistical properties and analyse similarities and divergences. We find a large divergence for the respective volatility estimates in terms of size, pattern and statistical properties. There also appears to be a high degree of persistence. For foreign exchange volatility the measures all exhibit a different scale as can be seen in figure 2, with a common large spike around the ERM crises in 1992/93. [10] Although time variation is captured by all measures, the APARCH measure is smoothest whereas the RANGE is noisiest. Irish exporters faced considerable variation in exchange rate volatility for both currencies across the sample period with a major increase evident during the 1992/93 currency crises that enveloped the EMS currencies. This was followed by a relatively tranquil period but volatility tended to increase in the early years of the Euro.

The summary statistics in table 1 outline the first four moments and the Jarque-Bera test for normality. The magnitude of moments varies considerably, with for example the mean spanning from 1.84 to 5.07 for the US whereas its standard deviation, the volatility of volatility measure exhibits a scale between 0.36 and 1.25. Non-gaussian features of excess skewness and kurtosis are documented for all except for the aggregated squared and absolute measures in the case of the US and the aggregated squared measure for the UK. The Range is more prone to fat-tails with positive skewness. Whilst generally strong persistence is shown for all foreign exchange volatility measures it is particularly pronounced for the APARCH estimates but disappears after six months for both US and UK squared volatility.

Similar departures are indicated for the respective income volatility measures. Notwithstanding the divergences, the result of the US expansionary policy increases all volatility measures in the early 80's and there has also been a common increase in income volatility for the UK in 2002. Furthermore, all the measures exhibit excess skewness and kurtosis in table 2 and are non-normal. The excess skewness and kurtosis is strongest for the squared measure whereas APARCH has a platykurtotic bunching of realisations. Diverging patterns of the respective measures also occurs with the squared and absolute measures noisy relative to APARCH and moving window volatility. This noise (or lack of) results in moments that vary considerably with for example the standard deviation ranging between 0.25 and 2.66 across measures. The shape of plots in figure 3 indicate that all the volatility measures are non-normal with excess positive skewness.[11] Also all

[10] Only a subset of the plots are presented for conciseness. However the inferences of diverging volatility measures hold across foreign exchange volatility, income volatility, and the interaction term. The full set of plots are available on request.

[11] The shape of plots for the UK plus foreign exchange volatility and interaction are

measures exhibit very fat upper tails and UK APARCH is bimodal. In addition, both APARCH and Moving window volatility exhibit strong memory for the UK that declines exponentially but nevertheless remains significant over long lags in figure 4.[12] In contrast, the persistence of the squared and absolute measures is similar by declining rapidly and disappearing after lag 6. Again the income volatility estimates have varying relationships with each other with the APARCH estimate involving the lowest linkages and a strong relationship between squared and absolute measures for both UK and US.

The extent of the relationships between respective foreign exchange rate volatility measures is shown in the scatter plots of figure 5 and clearly indicates divergences.[13] For instance, linkages between the squared and aggregated measures is high, but in contrast the range is not strongly related to the other measures with correlations of less than 0.4 in both US and UK cases.

Given the respective divergences for income and foreign exchange volatility measures, and the interaction term being defined as a combination of these, it is no surprise to see similar conclusions for the respective interactions.[14] For instance, the standard deviation extends between 0.95 and 8.38 with very different patterns emerging for those estimates involving Squared and Absolute measures vis--vis the other measures of volatility. The latter measures are much smoother for both US and UK. However, all measures exhibit excess skewness and kurtosis and deviate from normality especially interactions involving Squared measures. Furthermore, combining the respective foreign exchange and income volatility estimates result in some common distributional properties especially fat-tails. Finally the varying strength of the relationships of the respective interaction terms incorporating the APARCH foreign exchange volatility measures with patterns reasonably similar. Thus for both US and UK exhibit strong linkages between Absolute and Squared measures with correlations in excess of 0.88 in comparison to the other relatively weak relationships. Overall the respective volatility measures diverge strongly in terms of size, pattern and statistical properties. These findings are consistent for both UK and US volatility measures. Given these discrepencies these inputs are now used to model Ireland's export function with it largest trading partners to determine their respective influence on the economy's exports.

available on request.

[12]Persistence plots for foreign exchange volatility and interaction are available on request.

[13]Divergences in the relationships also occur for the income volatility and interaction terms with plots available on request.

[14]Only estimates involving APARCH are presented for conciseness but the conclusions remain for the other measures and are available upon request.

5 Empirical Results

5.1 Model Specification

The export model is run using the poisson lag structure for 16 combinations for each country pair.[15] As has been discussed an important element is that we take account of the time lag between the trade decision and the actual trade taking place or payment taking place.[16] The stochastic optimization process of simulating annealing is run twice for the same function in all cases. The algorithm is re-run with different starting values and a different seed for the random number generator and in all cases the optima were found to be identical. Consistent with Baum et al (2004) we allow for a maximum of 30 lags, however we do not restrict the final four variables to have the same lag; real foreign exchange, real foreign exchange volatility, real foreign income volatility, and the interaction term. Our unrestricted approach is taken to fully capture the exposure of exports from a small open economy from foreign exchange and income volatility.

The lag structure and the parameter coefficients of the models are of interest. The former details the optimal lag of exporters with respect to variables impacting their export decision whereas the latter shows the impact of economic variables such as income volatility on the export decision. Given that the volatility measures exhibit considerable deviations it is interesting to determine their respective impacts on the estimation of the lag structures for the export model. This would possibly help to explain the diverging results in the literature for volatility and trade.

Summary statistics of the different lag structures affecting the variables in the export model in terms of mean and variance are given in table 4 for each country. Also a plot of the lag distribution for income and real exchange rates and associated volatility for exports to the UK and US is given in Figure 6. Unlike previous studies we do not assume an identical lag structure for each of our volatility terms. Both US and UK average

[15]The estimated models were adjusted for the exchange rate crisis 1992/1993 and the regime switch to the Euro in 1999. The dummy for the exchange rate crisis was not statistically significant for either exports to the UK or US. The dummy for the change over to the Euro (taking value one from January 1999 to the end of the sample and zero elsewhere) was statistically significant in the case of exports to the UK only, with a mean value of 0.29. A tentative interpretation is that the single currency has had a positive effect on Irish exports to the UK. The significance of this dummy may also be taking account of the ending of the fraudulent activity of 'carousel trade' with the UK in goods such as electrical parts and machinery. Although there was no effect on the net Irish trade statistics, there was a significant fall in Irish exports and imports to and from the UK, see Central Bank of Ireland (2004).

[16]Consistent with previous studies, we find that Irish exports are cointegrated with real foreign income and real exchange rates. Results are available on request.

real foreign exchange volatility measures have their maximal impact after a large number of lags of just under a year for the US and just over a year for the UK. Different maximal lags are evident across the explanatory variables including foreign exchange and associated volatility. For instance the strongest lag effect occurs for real exchange rates having a mean of 0.44 compared to 9.99 for real exchange rate volatility for the US. However consistency in the lag structures for specific variables is generally evident, with the US generally having lower mean lags than the UK. In particular, exports to the US is generally affected quicker by economic wealth and foreign exchange activity compared to the impact of those variables for the UK. Also for the specific lag structures, the mean of the maximal lag for real income is much higher for the UK (11.15) than the US (1.94) but with a reasonably similar dispersion. The latter is in line with the fast decline predicted by Goldstein & Khan (1985). The relatively large income lag for the case of exports to the UK is similar to Klassens (2002) analysing developed economies although the study assumed the mean and variance of the lag structure to be equivalent.

Turning to the volatility lag structures, both US and UK average real foreign exchange volatility measures have their maximal impact after a large number of lags of just less (more) than a year for the US (UK). Also, the 95% interval estimate for real forex volatility is between 13.18 and 19.47 with a median of 15 months. However, there is a fair degree of dispersion according to each model with a range of lags of over a year for both countries indicating that the largest effects vary according to different foreign exchange volatility measures. This can be seen in figure 7, which plots the distribution associated with the highest and lowest lag effect. The pattern of lag weights suggest a hump shape in line with Klaessens (2002) and Baum et al (2004). The maximal effect for income volatility (figure 8) is even longer with a median of 13.71 for the US and 26.16 for the UK with standard errors around 2 suggesting that exports respond slowly to economic activity. Again there is a large dispersion between minimum and maximum lags that present the strongest effects for income volatility measures on Irish exports. Finally the average lag of the interaction term is around a year but shows a large level of dispersion across the different models. Overall, the different volatility measures result in large variations in the export model's lag structure and emphasise the importance of accounting for the respective lag structures.

5.2 Volatility and Exports

Estimated parameters for the export models are given in table 5 summarising the results for the 16 models for each country pair. Very strong positive real income effects are reported with all t-statistics significant. These large positive coefficients are associated with a low dispersion of estimates

with a minimum of 4.93 for the US and a maximum of 5.22. The point estimates for the US are only slightly stronger than the UK. The negative effects of real foreign exchange are consistent with theory and in line with previous studies that measure their variables in foreign currency. The impact of foreign exchange is reasonably constant with very little dispersion indicated for the country pair parameters. Again the parameters are consistent across the country pairs with coefficients of similar magnitude.

The main empirical issue of the paper examines the impact of volatility on exports using the small open Irish economy as a case study and is now discussed. As discussed, many studies have investigated the influence of real exchange rate volatility with very contradictory findings. For Ireland, real exchange rate volatility has a positive impact on trade and statistically significant regardless of the foreign exchange volatility measure applied. This implies that exporters treat an increase in real foreign exchange volatility to the US and UK as a positive situation to exploit profit opportunities associated with the positive expected cash flow dominating the entry and exit costs of exporting. Exporters then decide to exercise their option to trade resulting in increased trade flows being determined by increased foreign exchange volatility. The consistency of the finding occurs given the backdrop of diverging magnitude and statistical properties documented across the volatility measures.

The positive effect of real foreign exchange volatility supports the findings of Franke (1991) and Baum et al (2004). Given the diverse statistical nature reported for the volatility measures used it is reassuring to find that foreign exchange volatility is an important determinant on Irish trade flows. Dispersion of the impact of foreign exchange volatility measures does occur however indicating that the choice of volatility proxies matter. For instance, the smallest effect occurs for the Range volatility measure in the US equation but is still statistically positive with a t-statistic of 2.82. In contrast, the largest effect occurs for the APARCH measure for the UK with a t-statistic of 9.36. Between these estimates there is a reasonable spread of estimates with the lowest influence being associated with the Range measure and the highest with Absolute volatility in the case of the US and the APARCH measure for the UK.

International evidence regarding the impact of income volatility on export flows is sparse. Following the approach adopted by Franke (1991) volatility of the underlying model variables including income are of interest in the real options approach with mixed empirical evidence being given by Baum et al (2003). They find that income volatility is significant in only a quarter of their cases and claim that the sign of the statistically important parameters is ambiguous with nearly as many negative influences as positive influences being recorded. We find stronger results in adopting the

real options approach and the respective influence of income volatility with significant influences being found in all but three of the thirty two cases, one being positive and two being negative. Overall foreign income volatility is primarily a negative determinant of Irish exports to the US in 10 models and to the UK in 12 models. The finding suggests that the negative impact of exit and entry costs driven by the export decision dominates the cash flow benefits associated with greater levels of income volatility and results in reduced trade as exporters do not exercise their option to trade in these circumstances. Furthermore, the negative coefficients recorded in the remaining models dominate the positive findings as evidenced by the mean statistic and their associated confidence interval in table 5. The average impacts are reasonably similar for the US and UK. However the range is large for the different models applied with estimates of 2.50 for the UK and 2.21 for the US.

Finally, the effect of the combination of the respective income and foreign exchange volatility measures is examined. The coefficients represent the indirect influence of foreign exchange and income volatility on the export decision. The findings strongly suggest that the interaction terms have a positive impact on Irish exports, with fourteen of the sixteen cases for the UK and in all cases for the US being statistically significant.[17] The influence of the indirect term is stronger for the US (median 0.25) than the UK (median 0.03) although there is a reasonable spread of values with the US having a range of 0.40 compared to 0.83 for the UK. Thus, exporters not only have to take account of the direct influences of foreign exchange and income volatility, but the combination of these factors also affect the export function, albeit in an indirect fashion.

6 Conclusions

The paper analyses the impact of real foreign exchange and income volatility on Irish exports to the UK and the US. The majority of the literature in this area has focused on exports from fully developed economies and may well have led to the inconclusive empirical evidence to date. This issue has been highlighted by Bacchetta and Wincoop (2000) and Baum et al (2004) who suggest that data selection issues may be driving the mixed results. This study reverses the analysis by focusing on a small open economy with a very high dependency on trade and potentially high levels of volatility affecting the factors driving exports.

Of interest is the effect of foreign exchange and income volatility on Irish exports to the UK and the US over the period studied, 1979-2002. Although

[17] In two of sixteen cases for the UK the interaction term is not statistically significant and hence the mean values reported in the table 5 appears as not statistically significant.

Ireland is a member of the Euro, the remaining foreign exchange volatility effects may be substantial as a large percentage of Irish exports are to the UK and the US, over 40%. This was especially the case for the Sterling rate, which previously had a currency union with the Irish currency pre 1979, and also was part of the EMS between 1990 and 1992. In terms of the effect of foreign exchange volatility, we find that there is a consistently positive effect on Irish exports to the UK and the US. We also address the issue of exporting being viewed as an option, suggested by Franke (1991), and the impact of income volatility. Here we find a negative impact of income volatility on exports and so indicating that costs of entry dominate the decision to export. Finally, we also test the impact of the interaction between foreign exchange rate and income volatility, and find a positive effect in the majority of cases. This illustrates an indirect effect of foreign exchange and income volatility on the export function.

The paper is underpinned by the use of alternative volatility measures with diverging magnitude and statistical properties but yet results in the consistent set of findings. This consistency is welcome given that volatility is inherently unobservable and previous studies have utilised measures from a spectrum of modelling procedures. Moreover, there is considerable variation in the timing effect of volatility *per se* on Irish exports uncovered by analysing the lag structure of the export model. The lack of decomposition of volatility effects into timing and causality and the limited choice of volatility measures applied may well have supported the historically mixed evidence in previous empirical studies. An interesting extension to this study is to examine disaggregated trade flows focusing on the specific relationships of individual industry sectors with their non-Euro trading partners.

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Figure 1:Exports to the UK and the US (% of Total Irish Exports)

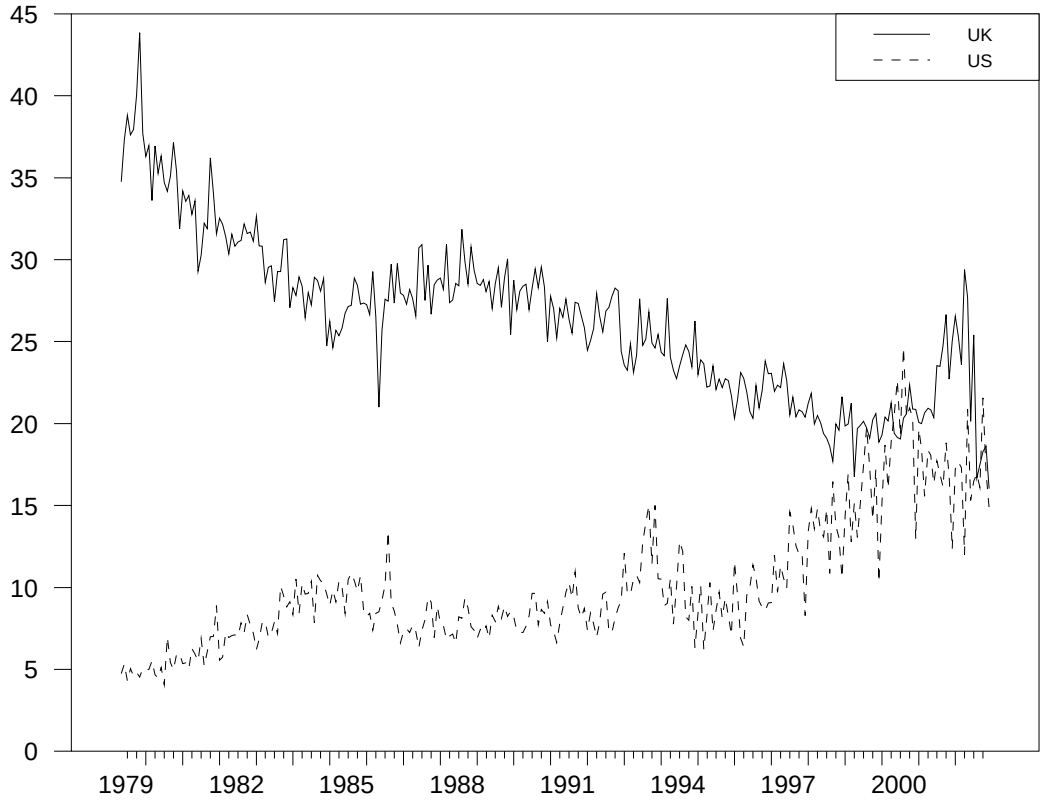

Figure 2: Monthly Foreign Exchange Volatility Plots for US Dollar

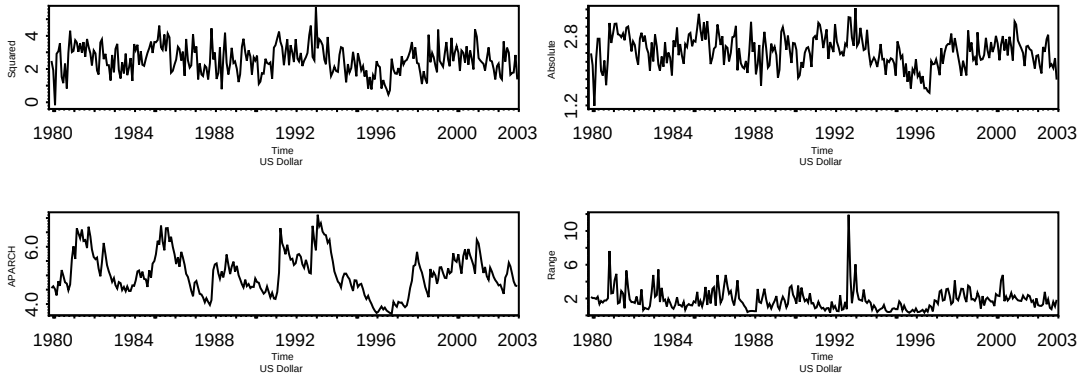

Figure 2: Monthly Foreign Exchange Volatility Plots for UK Sterling

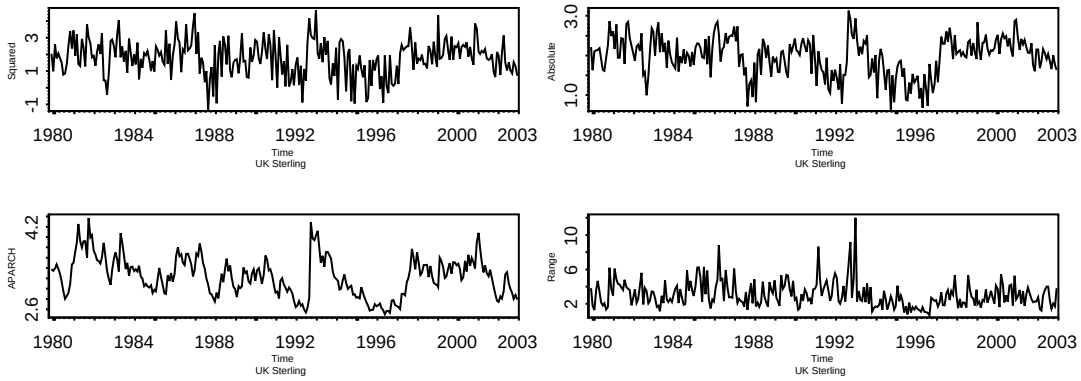

Figure 3

ure 3: Monthly Income Volatility Distribution Plots for US

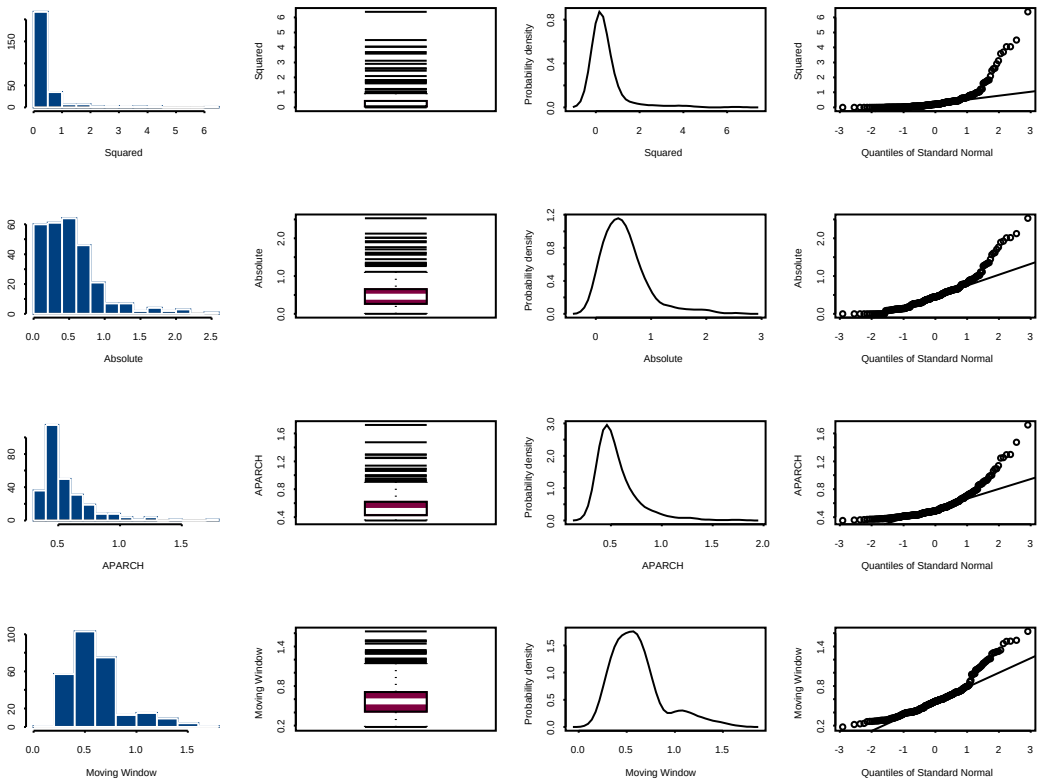

Figure 4: Persistence of Monthly Income Volatility for US

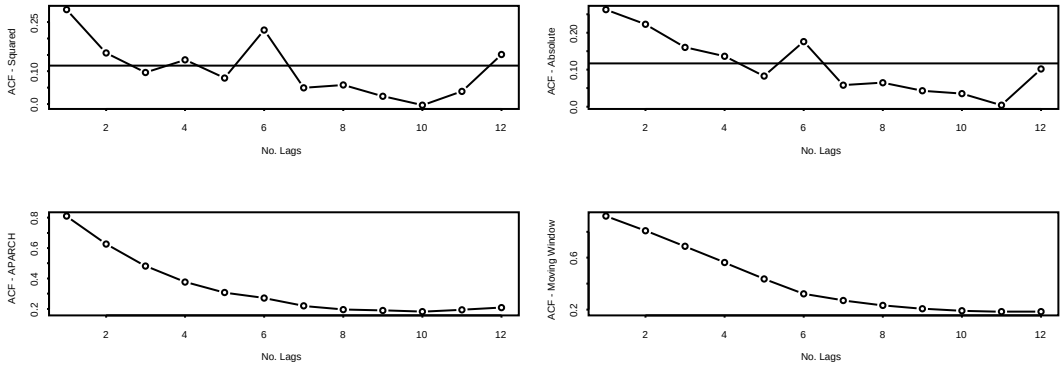

Figure 4: Persistence of Monthly Income Volatility for UK

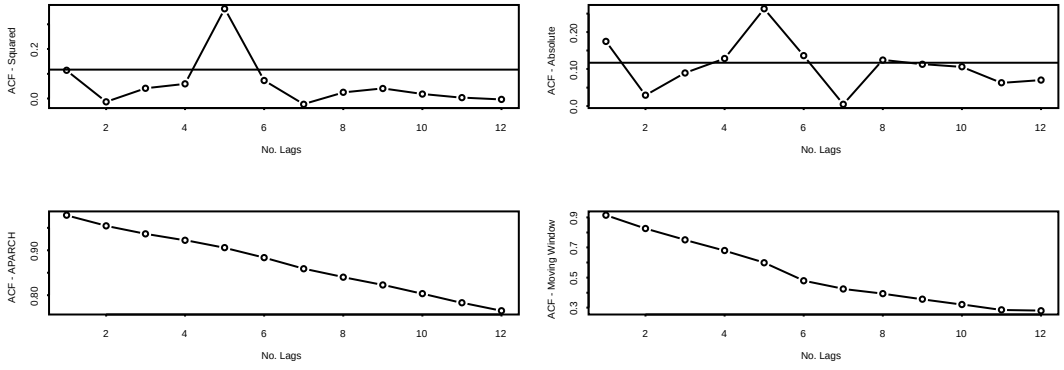

Figure 5: Scatter Plots for Monthly Foreign Exchange Volatility

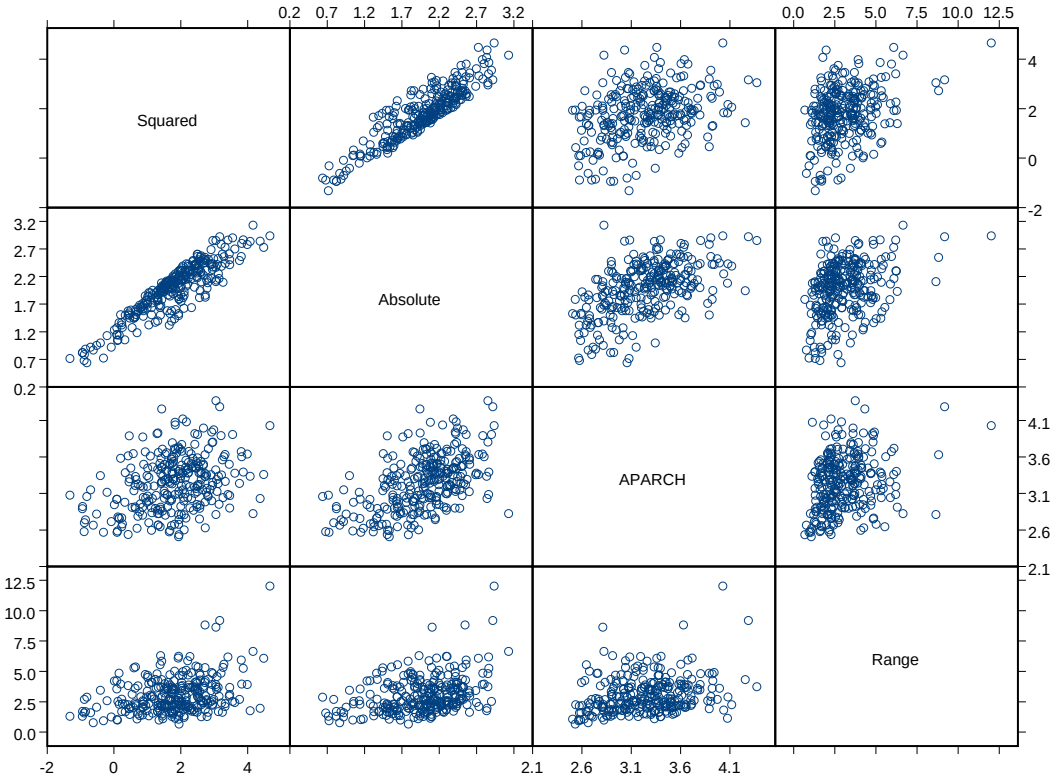

Figure 6

Poisson Lag Distribution on Real Foreign Income & Foreign Exchange

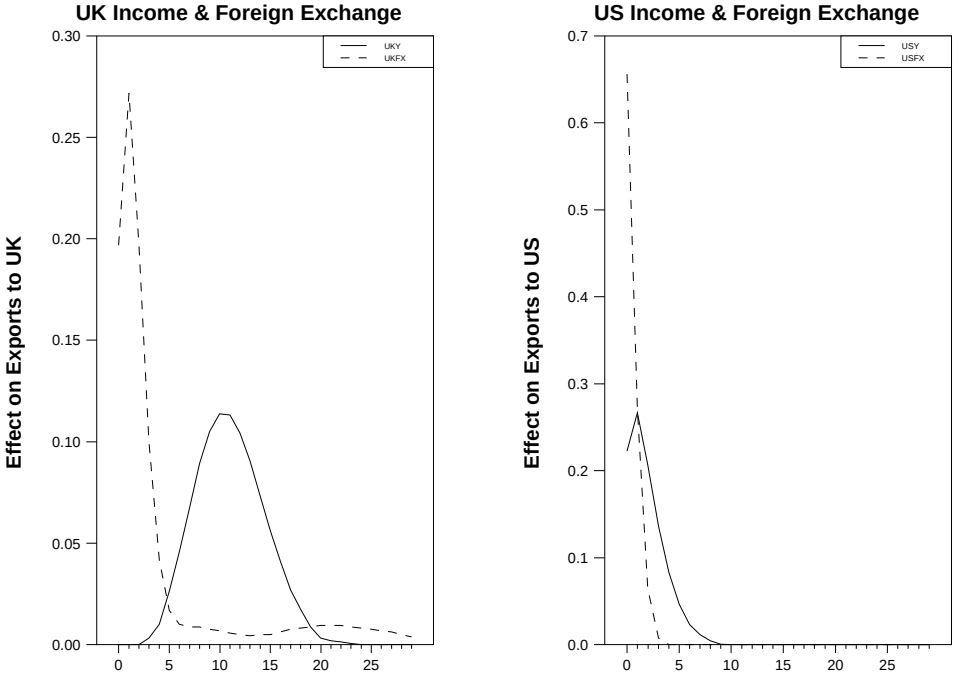

Figure 7

Poisson Lag Distribution on Real Foreign Income & Exchange Rate Volatility

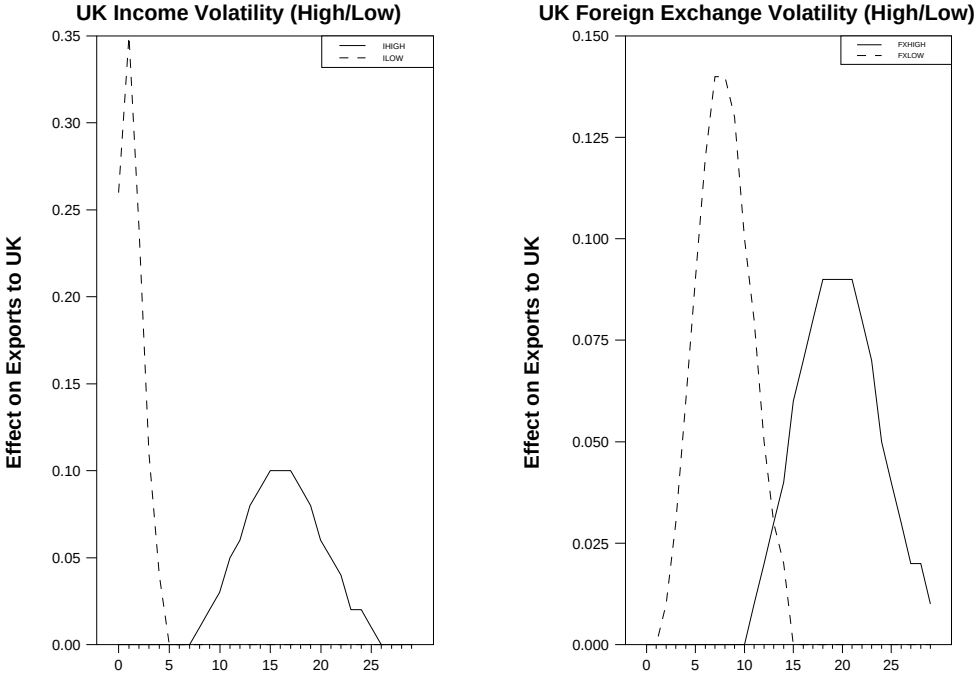

Figure 8

Poisson Lag Distribution on Real Foreign Income & Exchange Rate Volatility

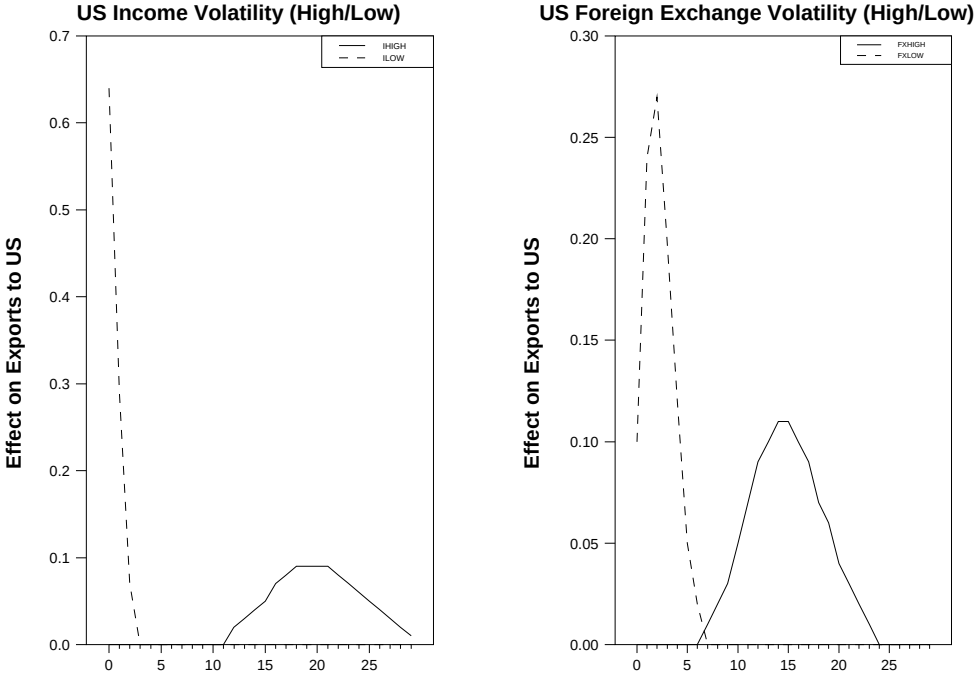

Table 1: Summary Statistics of Foreign Exchange Volatility

US Dollar	Squared	Absolute	APARCH	Range
Mean	2.56	2.44	5.07	1.85
Standard Deviation	0.88	0.37	0.72	1.25
Skewness	0.10	-0.19	0.38	2.85
Kurtosis	0.12	0.02	-0.24	16.34
Normality	0.76	0.43	0.03	0.00
UK Sterling	Squared	Absolute	APARCH	Range
Mean	1.79	1.98	3.25	3.07
Standard Deviation	1.07	0.48	0.38	1.50
Skewness	-0.27	-0.47	0.25	1.65
Kurtosis	0.25	0.08	-0.27	5.45
Normality	0.13	0.01	0.14	0.00

Notes: The volatility estimates are defined in the text. The figures for normality refer to p-values for the Bera-Jarque test of normality.

Table 2: Summary Statistics of Income Volatility

US Income	Squared	Absolute	APARCH	Moving Window
Mean	0.44	0.52	0.56	0.61
Standard Deviation	0.77	0.41	0.20	0.27
Skewness	4.00	1.68	2.29	1.29
Kurtosis	19.86	4.02	7.08	1.65
Normality	0.00	0.00	0.00	0.00
UK Income	Squared	Absolute	APARCH	Moving Window
Mean	1.22	0.80	0.84	1.00
Standard Deviation	2.66	0.76	0.26	0.50
Skewness	5.88	2.01	0.05	0.91
Kurtosis	44.58	6.53	-0.98	0.86
Normality	0.00	0.00	0.00	0.00

Notes: The volatility estimates are defined in the text. The figures for normality refer to p-values for the Bera-Jarque test for normality.

Table 3: Summary Statistics of the Interaction Term (APARCH)

US	Squared	Absolute	APARCH	Moving Window
Mean	2.20	2.63	2.83	3.06
Standard Deviation	1.01	2.27	2.55	2.72
Skewness	4.22	1.73	2.02	1.45
Kurtosis	22.45	4.65	5.40	1.97
Normality	0.00	0.00	0.00	0.00
UK	Squared	Absolute	APARCH	Moving Window
Mean	3.96	2.61	2.74	3.24
Standard Deviation	8.38	2.49	0.95	1.67
Skewness	5.56	1.84	0.29	0.73
Kurtosis	41.38	5.09	-0.83	0.22
Normality	0.00	0.00	0.00	0.00

Notes: The volatility estimates are defined in the text. The figures for normality refer to p-values for the Bera-Jarque test of normality. The interaction estimates here are a combination involving APARCH foreign exchange volatility with the respective income volatility measures.

Table 4: Summary Statistics of the Poisson Lag Structure

US	Y	Fx	Fx_{vol}	Y_{vol}	$Inter$
Mean	1.94	0.44	9.99	14.45	12.01
St. Err.	0.27	0.04	1.12	2.22	2.03
95 % CI	1.37	0.35	7.60	9.71	7.68
	2.51	0.52	12.38	19.19	16.35
Median	1.58	0.41	11.54	13.71	12.17
St. Dev.	1.07	0.16	4.49	8.89	8.14
Range	3.25	0.59	12.67	29.54	24.52
Min	0.54	0.15	2.28	0.46	3.60
Max	3.79	0.74	14.95	30.00	28.12
UK	Y	Fx	Fx_{vol}	Y_{vol}	$Inter$
Mean	11.15	3.31	16.33	22.94	15.40
St. Err.	0.37	1.50	1.48	2.34	3.09
95 % CI	10.35	0.11	13.18	17.94	8.80
	11.94	6.50	19.47	27.93	21.99
Median	11.38	1.36	15.00	26.16	21.44
St. Dev.	1.49	6.00	5.90	9.37	12.38
Range	6.43	23.91	18.07	29.99	29.68
Min	8.60	1.06	8.09	0.01	0.01
Max	15.03	24.97	26.16	30.00	29.69

Note: Y refers to real income, Fx is real foreign exchange rate, Fx_{vol} is real foreign exchange volatility, Y_{vol} is real income volatility, and $Inter$ is the interaction term.

Table 5: Summary Statistics of the Estimates of the Model

US	Y	Fx	Fx_{vol}	Y_{vol}	$Inter$
Mean	5.06	-0.99	0.20	-0.53	0.24
St. Err.	0.02	0.02	0.04	0.18	0.03
95 % CI	5.01	-1.02	0.12	-0.92	0.18
	5.12	-0.95	0.27	-0.15	0.29
Median	5.05	-0.98	0.16	-0.64	0.25
St. Dev.	0.09	0.07	0.15	0.72	0.11
Range	0.29	0.23	0.43	2.21	0.40
Min	4.93	-1.07	0.05	-1.67	0.08
Max	5.22	-0.85	0.48	0.54	0.48

$R^2 = 0.97$, Standard Error = 0.16

UK	Y	Fx	Fx_{vol}	Y_{vol}	$Inter$
Mean	3.34	-1.04	0.12	-0.46	0.04
St. Err.	0.19	0.13	0.04	0.10	0.03
95 % CI	3.42	-0.99	0.14	-0.41	0.05
	3.27	-1.09	0.11	-0.50	0.02
Median	3.38	-1.03	0.09	-0.43	0.03
St. Dev.	0.31	0.14	0.10	0.56	0.20
Range	1.25	0.51	0.38	2.50	0.83
Min	2.82	-1.26	0.01	-1.54	-0.37
Max	4.07	-0.75	0.39	0.95	0.46

$R^2 = 0.92$, Standard Error = 0.16

Note: Y refers to real income, Fx is real foreign exchange rate, Fx_{vol} is real foreign exchange volatility, Y_{vol} is real income volatility, and $Inter$ is the interaction term.