Technical Paper

01/RT/02 **March 2002**

An Empirical Analysis of Short-Run and Long-Run Irish Export Functions: Does Exchange Rate Volatility Matter ?

By

Don Bredin*

Central Bank of Ireland

Stilianos Fountas

and

Eithne Murphy

National University of Ireland, Galway

* Corresponding Author: Don Bredin, Economic Analysis, Research and Publications Department, Central Bank of Ireland, PO Box 559, Dublin 2. Tel.(353-1) 6716666. Fax: (353-1) 6706871. Email: erp@centralbank.ie

Abstract

We analysis the long-run and short-run relationship between merchandise export volume and its determinants, foreign income, relative prices and exchange rate volatility, using the techniques of cointegration and error correction. The model was estimated for Irish exports and sectoral exports SITC 0-4 and SITC 5-8 to the EU using quarterly data for the period 1979-1992. The sectoral classification corresponds to the exports of mainly indigenous Irish firms and multinationals, respectively. We find that the exchange rate volatility has no effect on the volume of trade in the short-run but a significant positive effect in the long run. This is true in the aggregate and for our sectoral classifications. We can tentatively conclude that the decline in intra-EU exchange rate volatility associated with the single currency will lead to a long-run fall in Irish exports to the EU.

1. Introduction

The international trade performance of a small open economy (SOE), such as Ireland, plays a central role in the economic health of the country. The share of Irish merchandise exports in Gross Domestic Product (GDP) has grown dramatically in recent years (from 43% in 1979 to a forecast level of 86.8% in 1999), thus rendering the economy more open than before and more dependent on foreign markets. 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 long-run and short-run Irish export demand by the country's most important trading partners; that is to say, by the principal member states of the European Union (EU).

This paper restricts itself to examining the effect of exchange rate variability on exports, notwithstanding the fact that an examination of overall trade would permit an analysis of the welfare effects of variability. The rationale for this decision is the greater importance of the EU as a destination for Irish exports as opposed to a source of Irish imports. Exports to the EU as a percentage of total exports were consistently and appreciably higher than imports from the EU as a percentage of total imports, over the period under examination[1]. Moreover, Irish-EU trade in this period was always in surplus, again reflecting the asymmetry of Irish trade in terms of destination of exports and source of imports. Given that our exports and imports are subject to different degrees of exchange rate volatility, it seems reasonable to focus our analysis along one dimension, in this instance exports.

[1] This differential is even greater for continental trade; that is to say, trade that excludes the UK.

There have been different empirical studies of the determinants of Irish exports. A common feature of most of these studies is their use of traditional estimation methods; in other words, classical regression techniques (see, for example, O'Connell, 1978; Browne, 1982; Lynch, 1983; and Flynn, 1984). More recent studies by Caporale and Chui (1995) and McGettigan and Nugent (1995) adopted more advanced estimation techniques that recognise the non-stationarity of economic variables. The present paper continues in the recent tradition by treating exports and their determinants as potentially non-stationary variables. In contrast to all previous studies, the effect of exchange rate volatility on exports is explicitly considered. This is of immense contemporary policy significance following the launch of the Economic and Monetary Union (EMU). Theory is not unambiguous about the effect of exchange rate volatility on trade. Traditional trade models assumed that increasing uncertainty had a dampening effect on trade flows, especially if producers were risk averse. It has been shown theoretically by De Grauwe (1988) that extreme risk aversion could result in volatility having an expansionary impact on trade. More intuitively plausible, are the models that emphasise the effect of exchange rate variability on expected profits. If mean profits are an increasing function of the degree of exchange rate variability, then, unless firms are very risk averse, increased volatility could lead to increased trade. In this paper we develop a simple model to illustrate the effect of exchange rate variability on expected profits and exports. The Irish export sector is dualistic, with relatively smaller indigenous firms dominating the more low technology production sectors (SITC 0-4), while larger subsidiaries of foreign owned multinationals tend to dominate the more high technology sectors (SITC 5-9). Given the dualistic nature of the Irish export sector, it was considered appropriate to estimate, in addition to a

general export function, a separate function for sectors (SITC 0-4) and (SITC 5-9). This allows to draw conclusions about the effect of volatility on different types of enterprises. The determinants of exports often have a lagged effect. We take this possibility into account by estimating both long-run and short-run export functions using the techniques of cointegration and error-correction models (ECMs), respectively.

The paper is organised as follows: Section 2 provides a survey of the theoretical literature and includes a simple model that illustrates how volatility affects expected profits. Section 3 presents our empirical approach and surveys the empirical literature and section 4 presents our econometric methodology. Section 5 summarises and interprets our results and section 6 concludes.

2. Theory

Theory does not give us unambiguous answers as to the effect of exchange rate variability on trade. All analyses focus on producer theory under uncertainty, with exchange rate changes representing the only source of risk to the firm. The focus of traditional models was on risk aversion (Clark, 1973, Baron, 1976 and Hooper and Kohlhagen, 1978). Exchange rate volatility increases the variance of profit. If firms are risk averse, this will lead to a decline in volume of exports, as firms wish to reduce their risk exposure. Lowering exports reduces the variance in profit caused by exchange rate volatility.

DeGrauwe (1988) showed how, contrary to the accepted wisdom, high risk aversion could actually lead to increased exports. Exchange rate volatility unambiguously reduces the total utility to be derived from exporting, but would result in increased exports if the marginal utility of exporting increased. (The firm is assumed to be engaged in the

domestic market and the export market and allocating output optimally between both markets). Crucial to this result is the idea that the degree of risk aversion is not constant. If it were constant, then exchange rate volatility would unambiguously reduce the level of exports, as exporting has become a relatively less attractive activity (substitution effect). There would be no income effects. Alternatively, if the degree of risk aversion increases with shrinking income, then the income effect will lead them to export even more in response to increased exchange rate volatility, in order to avoid the utility depressing effect of a large reduction in their export earnings.

Another approach is to focus on the effect of exchange volatility on expected profits (see Giovannini, 1988, Franke, 1991, Sercu and Vanhulle, 1992 and De Grauwe, 1994). If profits are a convex function of the exchange rate, then increased exchange rate variability will lead to increased expected profits. This could account for a positive relationship between exports and exchange rate variability, especially if producers are risk neutral, since exporting has now become a more profitable activity. Only Sercu and Vanhulle (1992) assume risk aversion but allow for perfect hedging. A common feature of this research, with the exception of De Grauwe (1994), is its inter-temporal context. Giovannini (1988) assumed that firms must commit to prices at the beginning of every period and that production changes to meet demand. The main focus of this work is the choice of currency in which to invoice exports. If profits are a convex (concave) function of the exchange rate then expected profits will be higher if prices are set in domestic (foreign) currency. He concludes that increased exchange rate variability does not necessarily lead firms to restrict export supply.

Franke (1991) views trade as an option to be exercised by a firm. 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 flow 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 flow from exporting to grow faster than expected entry and exit costs, then the value of the option to export has increased. This will be the case if cash flow is 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.

Sercu and Vanhulle (1992) analyse the behaviour of an existing exporter who has incurred sunk costs to enter the market. Exchange rates are assumed to follow a random walk. When the exchange rate drops, firms can either exit the market without any prospect of re-entry or they can suspend trade temporarily (incurring costs if they invoke this option). Their results show that an increase in exchange risk raises the value of the exporting firm and lowers the exchange rate at which they abandon the market.

De Grauwe (1994) presents a very simple static model of a firm that is a price taker in its export market. There are no adjustment costs and the firm is assumed to optimally respond to changing producer prices. A weaker (stronger) exchange rate increases (decreases) the export price in domestic currency that the producer faces and induces her to expand (contract) output. De Grauwe (1994) shows diagramatically, that exercising the option to adjust output optimally increases average profits. In other words, the value of the option increases when the variability of the underlying asset increases. The

greater the degree of exchange rate variability, the higher average profits.

The following model is in the spirit of De Grauwe (1994), although it is a more general version of same. It serves to illustrate the conditions under which increased exchange rate variability would lead to increased exports. It also shows explicitly the role played by demand and costs in the relationship between exports and the exchange rate.

Let all production be for export and assume that costs have a domestic and foreign component and that these two components are separable. The latter assumption is important as it means that costs are linear in the exchange rate. We will return to this point again.

$$\Pi = eR^*(X) - eC^*(X) - C(X) \qquad (1)$$

where Π equals profit denominated in domestic currency, R* is revenue denominated in foreign currency terms, C*(X) and C(X) are foreign and domestic costs, respectively.

First-order conditions for profit maximisation are:

$$\frac{d\pi}{dX} = eR_X^*(X) - eC_X^*(X) - C_X(X) = 0 \qquad (2)$$

where $R_x^*(X)$ is marginal revenue expressed in foreign currency, and $eC_x^*(X) + C_x(X)$ is marginal cost in domestic currency terms.

The effect on profit of a change in value in the domestic currency is:

$$\frac{d\pi}{de} = R^*(X) - C^*(X) + (eR^*_x(X) - eC^*_x(X) - C_x(X))\frac{dX}{de} \quad (3)$$

where,

$$\frac{dX}{de} = \frac{-(R^*_x(X) - C^*_x(X))}{eR^*_{xx}(X) - eC^*_{xx}(X) - C_{xx}(X)} \quad (4)$$

When firms are already producing the optimal level of output, expression (3) reduces to:

$$\frac{d\pi}{de} = R^*(X) - C^*(X) \quad (3)'$$

From (3)', the convexity or concavity of profits in e is as follows:

$$\frac{d^2\pi}{de^2} = \frac{-(R^*_x(X) - C^*_x(X))^2}{eR^*_{xx}(X) - eC^*_{xx}(X) - C_{xx}(X)} \quad (5)$$

From (3)' we can see that profits in domestic currency terms are increasing in the exchange rate as long as foreign revenue exceeds foreign input costs.

If marginal revenue is non-increasing in output, $R^*_{xx}(X) \leq 0$ and costs are an increasing convex function of output, $C^*_{xx}(X) + C_{xx}(X) > 0$ and if some domestic inputs exist such that $(R^*_x(X) - C^*_x(X) > 0)$, then, expressions (4) and (5) are positive. Higher e leads to higher export volumes and profit is an increasing convex function of e.

Marginal revenue can also be expressed in terms of foreign prices (P*) and the elasticity of foreign demand (ε_d):

$$\frac{dX}{de} = \frac{-\left(P^*\left(1-\frac{1}{|\varepsilon_d|}\right) - C^*_x(X)\right)}{eR^*_{xx}(X) - eC^*_{xx}(X) - C_{xx}(X)} \qquad (4)'$$

Marginal foreign revenue will only exceed marginal foreign costs if demand is sufficiently elastic. With elastic demand $\varepsilon_d > 1$, a fall in foreign prices will increase total foreign revenue. It therefore makes sense that if output is an increasing function of e, and profits are an increasing convex function of e, then exports will be priced in domestic currency and exchange rate changes will be passed through to foreign export prices, thus influencing total foreign demand. Given that exchange rate variability increases expected earnings, then risk neutral firms will expand exports as a response to increased variability. If firms are risk averse, the positive relationship between variability and exports may still hold, provided that the increase in firm utility from increased average profits more than offsets the decline in utility from greater uncertainty of profits.

If all inputs were imported such that marginal foreign revenue equals marginal foreign costs, then we can see from (4) and (5), that output would not change and profits would be a linear function of the exchange rate. In this case, all exports would be priced in foreign currency terms. When profits are linear in the exchange rate, then $E\Pi(e) = \Pi(\bar{e})$, hence volatility would have no effect on expected earnings. If firms are risk neutral, the extent of exchange rate variability will have no effect on the level of exports. If firms are risk averse, then utility from expected profits would be lower when volatility is higher and one would expect exports to fall as a result.

If: (i) demand was sufficiently convex ($R^{*}_{XX}(X) = 2P^{*}_{x} + X P^{*}_{xx} > 0$), where P^{*}_{x} and P^{*}_{xx} are the first and second derivatives of the demand curve, respectively, and $P^{*}_{xx} > 0$; (ii) marginal cost was constant ($C^{*}_{XX}(X) + C_{XX}(X) = 0$) and, (iii) there is a domestic cost component to production ($R^{*}_{X}(X) - C^{*}_{X}(X) > 0$), then profits would be a concave function and exports would be a negative function of the exchange rate. When profits are concave in the exchange rate, expected earnings would be lower when volatility is higher. Risk neutral and risk averse firms would respond to increased earnings volatility by lowering the level of their exports.

In the above simple model, the convexity of profits in e depends on exports being an increasing function of e. The features of demand and cost that would ensure convexity of profits in e are quite reasonable. If substitution were possible between domestic and foreign inputs, then costs would be an increasing but concave function of the exchange rate. This would give rise to convexity of profits in e, even if output and exports did not change. However, exports would still rise when the exchange rate depreciates (assuming substitutability of domestic and foreign inputs), since an increase in e will have a bigger positive impact on marginal revenue than on marginal costs, due to the domestic cost component[2].

[2] The above analysis assumes agents' expectations are based on the assumption that the real exchange rate follows a random walk. However, the analysis also holds if the exchange rate is mean reverting provided most of the sample period the exchange rate was below its mean value which is true as the Irish pound was overvalued. However, this analysis would not necessarily carry through in other time periods.

3. Empirical Approach

The modern empirical literature on the estimation of export functions is based on the following long-run export function (see, for example, Asseery and Peel, 1991; Pozo, 1992; Chowdhury, 1993; Arize, 1995, 1997):

$$\ln X_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln P_t + \beta_3 V_t \qquad (6)$$

where X_t, Y_t, and P_t, stand for real exports, foreign real income, and relative prices, respectively, and V_t stands for exchange rate volatility that captures exchange rate uncertainty.

Economic theory suggests that the real income level of the trading partners of the domestic country and a measure of competitiveness between the domestic country and its major trading partners would affect positively and negatively the volume of exports, respectively. As discussed in the previous section, the effect of exchange rate volatility on exports is ambiguous from a theoretical point of view.

The international empirical evidence on the influence of volatility on exports is also mixed. IMF (1984), Cote (1994) and McKenzie (1999) provide comprehensive reviews of the empirical literature. Early empirical studies disregarded the issue of nonstationarity of macroeconomic time series and used classical regression analysis. These studies, therefore, are subject to the "spurious regression" criticism (Granger and Newbold, 1974). They include Gotur (1985), Kenen and Rodrik (1986), Koray and Lastrapes (1989), Peree and Steinherr (1989) and Pozo (1992). A number of recent studies test for stationarity of the relevant time series and, in some cases, employ

cointegration techniques, e.g., Lastrapes and Koray (1990), Asseery and Peel (1991), Chowdhury (1993), Arize (1995, 1997), Holly (1995) and Fountas and Aristotelous (1999). Kenen and Rodrik (1986), Koray and Lastrapes (1989), Peree and Steinherr (1989), Pozo (1992), Chowdhury (1993), Holly (1995), Arize (1995, 1997), and Fountas and Aristotelous (1999), among others, find evidence of a negative relationship between exchange rate volatility and trade. Asseery and Peel (1991) show evidence of a positive relationship between exchange rate volatility and trade, while Gotur (1985), Bailey, Tavlas and Ulan (1986), Peree and Steinherr (1989), and Gagnon (1993) were unable to find evidence of any significant effect of exchange rate volatility on trade[3]. As far as estimates of relative price and income effects is concerned, Kenen and Rodrik (1986), Chowdhury (1993), Caporale and Chui (1995) and Arize (1995) support the predictions of the theory concerning income and relative prices presented earlier. Exceptions are de Grauwe (1988), Pozo (1992) and Chowdhury (1993) who found mixed signs for relative price effects on export volumes.

Most of the studies that focus on the determinants of Irish exports were produced in the 1970s and 1980s and are subject to the "spurious regression" criticism. They include O'Connell (1978), Browne (1982), Lynch (1983), and Flynn (1984). O'Connell's (1978) study is one of the first attempts to provide econometric evidence on the determinants of Irish exports. O'Connell (1978) estimates the equilibrium and disequilibrium versions of a two-equation model and derives price elasticities of export demand and supply equal to -1.44 and 2.33, respectively[4]. The author finds the price elasticity of demand estimate is

[3] There is some recent evidence that views increased exchange rate volatility as a result of greater integration of world markets (see Rose, 2000).

[4] The author also estimates a single-equation export model for the Irish economy. However his model assumes infinitely elastic supply, which would not be consistent with a small open economy.

small for a SOE, when compared to the Goldstein and Kahn (1978) results for Belgium and Netherlands. Browne (1982) estimates the SOE version of the Goldstein-Kahn model. He obtains estimates of the price elasticity of supply that are lower and demand that are higher than in O'Connell (1978) and, hence, more consistent with the SOE assumption. Lynch (1983) estimates a single-equation model for Irish manufacturing exports using quarterly data from 1963 to 1981. He includes both supply and demand side determinants in order to get a more complete picture of export demand and uses a 2SLS procedure to account for simultaneity between prices and quantities. He obtains estimates of the income elasticity of exports in the range 1.10 to 2.69 and estimates of the price elasticity of exports in the range -1.23 to -0.26. Flynn (1984) analyses the determinants of both manufacturing and industrial exports. His approach differs from Lynch (1983) in his variable choice and the choice of a dynamic set up. Since exports of foreign multinationals (MNEs) in Ireland accounted for 70% of total exports in 1980, Flynn (1984) drops the relative price variable from the estimated equation because of the way in which these firms make their decisions. Flynn's (1984) estimates for the income elasticity are 0.59 and 0.49 for manufacturing and industrial exports, respectively, and are much smaller than those obtained by O'Connell (1978) and Browne (1982). Flynn (1984) speculates that this is due to transfer pricing.

A few recent studies employ modern nonstationary time-series techniques using Irish data[5]. Caporale and Chui (1995) pursue a multicountry time series study that includes Ireland. Using annual data for the period 1960-1992 the authors estimate income and price elasticities of exports using cointegration techniques. Employing the

[5] Morgenroth (2000) looks at the effect of exchange rates on Irish exports to the UK. The principle aim in our study is to focus on the effect of exchange rate *volatility* on Irish exports to the EU.

Dynamic OLS (DOLS) procedure, the authors derive estimates of the income and relative price elasticities equal to 2.97 and -0.34, respectively. Quite similar elasticities are obtained for Belgium, another SOE. McGettigan and Nugent (1995) attempt to estimate short-run and long-run export functions using ECMs and cointegration techniques, respectively.[6] Using quarterly data for the period 1975 to 1994, the authors obtain long-run income elasticities in the range 1.78 (for merchandise exports) to 2.04 (for manufacturing exports). The estimates of the relative price elasticity are -4.33 and -7.58, respectively. The latter value appears to be very large.

4. Econometric Methodology

The mixed results obtained by most of the previous studies using classical regresssion analysis may be due to the non-stationarity of real exports and its determinants. Variables such as real exports and real income are by their nature potentially nonstationary. In this paper cointegration analysis is used to test for a long-run export function of Irish exports to the EU. Tests for cointegration require nonstationary time series of the same order of integration. Therefore, we first test for the presence of a unit root in both the level and the first difference of the four variables in equation (6), using the Dickey-Fuller (DF) and the Augmented Dickey-Fuller (ADF) tests (Fuller, 1976 and Dickey and Fuller, 1979). We have decided to use the Johansen multivariate cointegration approach (Johansen, 1988, Johansen and Juselius, 1990). Our choice is justified by Phillips (1991) who finds that the Johansen approach is optimal in terms of symmetry, unbiasedness and efficiency. A Monte Carlo study by Gonzalo (1994) supports the superior properties

[6] A number of studies have also looked at import demand functions for Ireland (see O' Reilly,

of the Johansen technique relative to several other single and multivariate techniques. In the Johansen framework, all variables, including exchange rate volatility, are treated as endogenous. The treatment of volatility as an endogenous variable is particularly important in the context of the EU where Central Banks have tried systematically to stabilize the nominal exchange rates against the DM and hence against the currencies of the other ERM-member countries. Provided that cointegration exists among our variables, the cointegrating vector is normalised on exports to give the long-run income and relative price elasticities for export demand.

We also estimate the short-run export equation using the ECM:

$$\Delta \ln X_t = \alpha_0 + \alpha_1 R_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta \ln X_{t-i} + \sum_{i=1}^{n} \delta_i \Delta \ln Y_{t-i} + \sum_{i=1}^{n} \varepsilon_i \Delta \ln P_{t-i} + \sum_{i=1}^{n} \zeta_i \Delta V_{t-i} + e_t \qquad (7)$$

If our variables are cointegrated, then the ECM will be of the above form, where R_{t-1} is the error-correction term (ECT), i.e., the one-period lagged residual in the cointegrating regression. The rest of the equations in the ECM (not reported) are analogous to equation (7) with the only difference being in the left-hand side variable of the equation. This ECM allows us to estimate the short-run relationship between exports and its determinants. It includes both the short-run dynamics and the long-run relation between the series captured by the ECT.

1985).

5. Data and Empirical Results

(i) Data and the exchange rate volatility proxy

We use quarterly data for the period 1978Q3-1995Q4. As mentioned earlier, our aim is to estimate the short-run and long-run function for Ireland's exports to the EU. The starting point of our sample are dictated by data availability considerations. Data on Irish exports to EU-member states at the one-digit classification level became available in 1978. As shown in figure 1, Irish exports to the EU make up the majority of Irish exports.

The export variable is taken from the Trade Statistics Series of the CSO publication, and was divided by Ireland's unit export value to obtain the real exports figure. The aggregate figure of Ireland's exports to the EU is split up into SITC divisions 0-4 and 5-8. Division 5-8 is the standard definition of manufacturing exports. However, 5-8 is also the division where MNEs are very prominent. Murphy (1994) and Walsh (1996) argue that a large percentage of Irish output and export growth may be traced to the activities of MNEs in three specific areas; computer and related areas, chemicals (including pharmaceuticals) and cola concentrates. We can, therefore, distinguish between exports of SITC 0-4 (dominated by indigenous industries) and exports of SITC 5-8 (dominated by the MNEs). We also employ the total figure SITC 0-8 in our empirical analysis.

Our first explanatory variable in the export function is foreign income. This series is constructed by taking the weighted average of the GDP series of Ireland's five most important EU trading partners[7](EU-5). The EU-5 are in order of importance, UK, Germany, France, the

Netherlands and Italy. The trade weights are calculated by aggregating the export and import figure for each particular country and then dividing by the aggregate figure for exports and imports for all countries. These weights are given in figure 2. The quarterly GDP data were obtained from the International Financial Statistics (IFS) tape, and was then converted to a common currency (Irish pound). The exchange rate was obtained from the Central Bank Bulletin.

The second right-hand side variable in equation (6) is a measure of competitiveness. It is defined as the ratio of the exchange rate-adjusted price of Irish exports to the price of exports of Ireland's major trading partners, as defined above. Hence, it is the ratio of the Irish unit export value[8] to the weighted average of the unit export values of the EU-5, denominated in Irish pounds. The weights are identical to those used in the construction of the income variable. Data for the export unit value were again obtained from the IFS tape[9].

Finally, as a measure of time-varying exchange rate volatility, we use the moving standard deviation of the growth rate of the real effective exchange rate[10]:

$$V_t = [\ (1/m) \sum_{i=1}^{m} (\ln Z_{t+i-1} - \ln Z_{t+i-2})^2]^{1/2} \qquad (8)$$

---

[7] Choosing the weighted average of the income levels of the most important trading partners is standard procedure in the literature (see Lynch, 1983 and Chowdhury, 1993).

[8] The unit export value for Ireland is constructed using a basket of commodities at the 6-digit level classified according to various geographical partner areas. The criteria for including a 6-digit HS by area heading in the basket are that the exports in that heading/area have an acceptable degree of stability (in terms of unit value) and a meaningful measure of quantity exists for the heading. Therefore, even though most of the value of trade is included in the basket, a significant amount is not, including a share of the output of the computer and pharmaceutical sectors.

[9] Unit export value data were not available in disaggregated form and, therefore, the same aggregate figure was used for both divisions 0-4 and 5-8.

[10] Recently, several authors model exchange rate volatility using an ARCH approach. We have not taken this route since we use low-frequency data (quarterly) that are less appropriate in ARCH modelling.

where Z is the real effective exchange rate and m, the order of the moving average, is set equal to 8[11]. The real effective exchange rate is calculated by the weighted average of the exchange rate-adjusted relative prices (unit export values) where the trade weights are the ones used in creating foreign income and relative prices[12]. This measure of exchange rate volatility is adopted by Kenen and Rodrik (1986), Koray and Lastrapes (1989) and Chowdhury (1993).

(ii) Results

The first step in our analysis is to establish the order of integration of the variables in equation (6). This is done using the DF and ADF(4) unit root tests. The unit root test results (not shown, but available upon request from the authors) imply that all variables are integrated of order one, I(1). Therefore, we can now proceed to the cointegration tests. The results of these tests are shown in Table 1. The appropriate lag length in the VAR was chosen on the basis of the AIC (Akaike information criterion) and the Hannan and Quinn (1979) test. As shown in Table 1, both maximum eigenvalue and trace tests imply one cointegrating vector in each of the three export divisions.

The cointegration vectors (normalised on exports) and likelihood ratio (LR) test statistics are given in Table 2. The cointegration coefficients of the real foreign income and relative price variables can be interpreted as long-run export elasticities. We obtain three main results. First, the long-run relationship between Irish exports and foreign economic activity is positive, large and statistically significant,

[11] Our main results are robust to alternative choices of the lag length.

[12] Although we use real exchange rates to calculate our volatility measure, Thursby and Thursby (1987) and Lastrapes and Koray (1990) obtain similar results when using nominal exchange rates instead.

especially in those sectors (SITC 5-8) dominated by MNEs. The latter is to be expected, as exports of foreign corporations located in Ireland are generally high-technology products, which tend to be highly income elastic. The figures for income elasticity also serve to highlight the extent to which the economic health of a small open economy, such as Ireland, is positively dependent on economic growth in our main EU partner countries. The size of the estimated income elasticity for overall exports exceeds previous estimates based on less recent data, reflecting the increasing income sensitivity of Irish exports to the EU and the increasing importance of MNEs in Irish exports. Of course, part of the difference is accounted for by our exclusive focus, in constrast to other studies, on exports to the EU alone. Second, the competitiveness variable is negatively related to real exports and is significant for each of the three export divisions. Our estimates of the relative price elasticity are also higher than those obtained by some previous studies (e.g. Caporale and Chui, 1995), but in broad agreement with Lynch (1983). As said earlier, though, our results are not directly comparable as, in contrast with these studies that looked at overall Irish exports, we focus our attention on Irish exports to the EU.

Finally, and perhaps most importantly, exports are positively related to volatility for export divisions SITC (0-4), SITC (5-8) and overall exports. This would seem to indicate that export firms based in Ireland, regardless of size and origin, have responded to exchange rate volatility by increasing exports. The cointegration coefficient of volatility is of similar magnitude for the sectors dominated by indigenous firms and those dominated by MNEs. This would lead us to conclude that higher expected profit associated with volatility is the reason for this positive long-run relationship. If we think back to expressions (4) and (5), we can get some idea as to why the relationship

between exports and volatility is as strong as it is for the smaller indigenous firms and the larger multinational-dominated sectors. The high domestic cost component in the output of indigenous firms, plus the fact that they are probably price takers in their destination markets would explain the sensitivity of output to volatility. The absence of foreign input costs combined with price taking would reduce expression (4) to:

$$\frac{dX}{de} = \frac{-(P^*(X))}{-C_{XX}(X)} > 0.$$

On the other hand, MNEs are more likely to have quite a high level of foreign inputs, be dominant in their export markets and probably exhibit economies of scale in production (especially given the sectors in which they operate). If we assume constant returns to scale, then expression (4) reduces to:

$$\frac{dX}{de} = \frac{-(R^*_X(X) - C^*_X(X))}{eR^*_{XX}(X)} > 0,$$ as long as foreign marginal revenue exceed foreign marginal cost. Larger firms are also less likely to exhibit risk aversion, which would reinforce the relationship between exports and exchange rate variability.

Therefore, for different reasons associated principally with production costs, one can think of reasons why sectors dominated by small and large firms may respond positively to increased exchange rate variability.

Using the cointegrating vectors normalised on exports, we estimated the ECMs that provide us information on the short-run export functions. The results are shown in Table 3. To decide on the final form of the ECM, we initially started with three lagged differences of

each variable and then deleted the insignificant lagged variables. Variables were not deleted if this introduced autocorrelation in the error term of the regression. This allowed us to derive a parsimonious model. Before we discuss the results, we need to determine the adequacy of the ECMs. For this reason, we performed a number of tests reported in the last column of Table 3. These tests indicate that the ECMs are adequate for further analysis. The adjusted R^2 ranges from 0.65 to 0.72. Such values compare well with those reported in other studies for regressions based on first differences in variables. The Breusch-Godfrey serial correlation LM test indicates the absence of serial correlation in the residuals of the estimated equations at the 5% level. Moreover, autoregressive conditional heteroskedasticity (ARCH) does not seem to be a problem according to the ARCH LM test[13].

Given the evidence supporting the adequacy of the estimated ECMs, we can make a number of observations regarding the estimates presented in Table 3. First, the ECM results show that, as expected, changes in foreign income have positive and statistically significant short-run effects on real exports. Second, changes in relative prices have a negative, but statistically insignificant (except for overall exports), impact on exports. Third, in contrast with the long-run results, the short-run volatility measure is statistically insignificant for the three export divisions. Fourth, the ECT that shows the adjustment speed towards the elimination of disequilibrium is negative but statistically significant only for exports in SITC (0-4)[14]. The insignificance of the ECT in the equations for MNE's exports and aggregate exports implies that exports do not restore the long-run equilibrium. A possible

[13] Using a step-response function, we have also determined that parameter stability applies in the ECM regressions. This is shown by smooth and monotonic step responses of exports to a 1% shock to independent variables.

[14] Note that in our ECM that includes three equations, at least one of the ECTs must be negative and significant in order to restore the long-run cointegrating equilibrium.

explanation for the insignificant coefficient is that MNEs, which make up a large part of exports in SITC 5-8 (and, therefore, SITC (0-8)), are price setters and so the adjustment towards the long-run equilibrium takes place through the competitiveness measure and not export volumes.

Based on the ECM results we can make the following observations. First, as anticipated, the short-run income elasticities are smaller than the long-run elasticities. Moreover, the short-run income elasticity of export demand is higher for the output of MNEs than for the output of indigenous firms. Apart from the differing nature of the products in both classifications (which also explains the differences in long-run income elasticities), a larger short-run income elasticity for the MNE sector, compared to the indigenous sector, indicates a greater ability to respond to changes in demand. This would be consistent with the existence of horizontally integrated plants in different countries operating at undercapacity. Second, in contrast with the long-run results, the coefficient of the short-run volatility measure is statistically insignificant for the categories tested. The existence of contracts reduces the sensitivity of exports to exchange rate changes in the short-run. Moreover, the positive relationship between volatility and exports requires exports to increase (decrease) as the exchange rate depreciates (appreciates). Only then will expected profits increase with increased volatility. However, exports will only respond to changes in the exchange rate if the new rate is expected to persist at least for the time it takes to adjust production or change inventories. Hence, it is unsurprising that volatility has an insigificant effect on the level of exports in the short run.

6. Conclusions

The paper analyses the long-run and short-run relationship between export volume and its determinants, namely, relative prices, foreign income and exchange rate variability, using the techniques of cointegration and error-correction methods. The model was estimated for Irish exports and sectoral exports SITC 0-4 and SITC 5-8 to the EU. The sectoral classification corresponds to exports of smaller indigenous firms and larger mainly foreign owned enterprises, respectively. Our results show that exchange rate volatility has no effect on the volume of trade in the short-run but a significant positive effect in the long run. This is true in the aggregate and for our sectoral classifications. A very plausible explanation of this result is the positive effect of increased exchange rate volatility on expected profits, if firms are free to exercise the option to adjust output optimally in response to exchange rate changes. Despite the differing characteristics of small indigenous firms and large foreign owned firms, our model can explain, in both instances, why exchange rate volatility could have a positive effect on the volume of exports.

Our results have important policy implications arising from Ireland's participation in the EMU since the launch of the single European currency on 1 January, 1999. They allow us to tentatively conclude that the decline in intra-EU exchange rate volatility associated with the single currency may lead to a long-run fall in Irish exports to the EU. This conclusion is subject to a caveat: recent international evidence (Rose, 2000) shows that increasing exchange rate volatility is due to increasing integration into the world markets. Hence, the finding of higher exports could be due to increased integration, meaning that the declining exchange rate volatility from Ireland's participation in the Euro zone might have no effect on intra-EU exports. Second, as

mentioned in section 2, the theoretical interpretation of our result is valid under certain assumptions about the time series properties of real exchange rates, which might not always apply under various exchange rate regimes.

References

Arize, A.C. 1995. "The Effects of Exchange Rate Volatility on U.S. Exports: An Empirical Investigation", *Southern Economic Journal*, Vol. 62, pp. 34-43.

Arize, A.C., 1997, Conditional Exchange Rate Volatility and the Volume of Foreign Trade: Evidence from Seven Industrialized Countries, *Southern Economic Journal* 64, 235-254.

Asseery, A. and D.A. Peel, 1991. "The Effects of Exchange Rate Volatility on Exports-Some New Estimates", *Economics Letters*, Vol. 37, pp. 173-177.

Bailey, M.I., G.S. Tavlas and M. Ulan, 1986. "Exchange Rate Variability and Trade Performance: Evidence for the Big Seven Industrial Countries", *Weltwirtschaftliches Archiv*, Vol. 122, pp. 466-477.

Baron, D., 1976. “Fluctuating exchange rates and the pricing of exports”, *Economic Inquiry*, Vol. 14, pp. 425-438.

Browne, F.X., 1982. "Modelling Export Prices and Quantities in a Small Open Economy", *The Review of Economics and Statistics*, Vol. 64, pp. 346-347.

Caporale, G.M. and M. Chui, 1995. "Estimating Income and Price Elasticities of Trade in a Cointegration Framework", Discussion Paper No. 34-95, London Business School, Centre for Economic Forecasting.

Chowdhury, A.R. 1993. "Does Exchange Rate Volatility Depress Trade Flows ? Evidence from Error-Correction Models", *The Review of Economics and Statistics*, Vol. 75, pp. 700-706.

Clark, P., 1973. “Uncertainty, exchange risk, and the level of international trade”, *Western Economic Journal*, Vol. 11, pp. 302-313.

Cote, A., 1994. "Exchange Rate Volatility and Trade", Bank of Canada Working Paper 5.

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 Slowdown in Growth of International Trade", *IMF Staff Papers*, Vol. 35, pp. 63-84.

De Grauwe, P. 1994. *The Economics of Monetary Integration*, Oxford: Oxford University Press.

Dickey, D.A. and W.A. Fuller, 1979. "Distribution of Estimates of Autoregressive Time Series with a Unit Root", *Journal of the American Statistical Association*, Vol. 74, pp. 427-431.

Flynn, J., 1984. "Forecasting Manufactured and Industrial Exports", Central Bank of Ireland Technical Paper 9/RT/84.

Fountas, S., and K. Aristotelous, 1999. "Has the European Monetary System Led to More Exports? Evidence from Four European Union Countries", *Economics Letters*, Vol. 62, pp. 357-363.

Franke, G., 1991. "Exchange Rate Volatility and International Trading Strategy", *Journal of International Money and Finance*, Vol. 10, pp. 292-307.

Fuller, W.A. *Introduction to Statistical Time Series*, New York: Wiley, 1976.

Gagnon, J., 1993. "Exchange Rate Variability and the Level of International Trade", *Journal of International Economics*, Vol. 34, pp. 269-287.

Giovannini, A., 1988. "Exchange Rates and Traded Goods Prices", *Journal of International Economics*, Vol. 24, pp. 45-68.

Goldstein, M. and M.S. Khan, 1978. "The Supply and Demand for Exports: A Simultaneous Equation Approach", *The Review of Economics and Statistics*, Vol. 60, pp. 275-286.

Gonzalo, J., 1994. "Five Alternative Methods of Estimating Long-Run Equilibrium Relationships", *Journal of Econometrics*, Vol. 60, pp. 203-233.

Gotur, P., 1985. "Effects of Exchange Rate Volatility on Trade: Some Further Evidence", *IMF Staff Papers*, Vol. 32, pp. 475-512.

Hannan, E. and B.G. Quinn, 1979. “The determination of the order of an autoregression”, *Journal of the Royal Statistical Society*, Vol. 41, pp. 190-195.

Holly, S., 1995. “Exchange Rate Uncertainty and Export Performance: Supply and Demand Effects” *Scottish Journal of Political Economy*, Vol. 42, pp. 381-391.

Hooper, P., and S. Kohlhagen, 1978. “The effect of exchange rate uncertainty on the prices and volume of international trade”, *Journal of International Economics*, vol. 8, pp. 483-511.

International Monetary Fund, 1984. "Exchange Rate Volatility and World Trade", Occasional Paper No. 28.

Johansen, S., 1988. "Statistical Analysis of Cointegration Vectors", *Journal of Economic Dynamics and Control*, Vol. 12, pp. 231-254.

Johansen, S., and K. Juselius, 1990. "Maximum Likelihood Estimation and Inference on Cointegration - With Applications to the Demand for Money", *Oxford Bulletin of Economics and Statistics*, Vol. 52, pp. 169-210.

Kenen, P. and D. Rodrik, 1986. "Measuring and Analyzing the Effects of Short-term Volatility in Real Exchange Rates", *The Review of Economics and Statistics*, Vol. 68, pp. 311-315.

Koray, F. and W. Lastrapes, 1989. “Real Exchange Rate Volatility and US Bilateral Trade: A VAR Approach, *The Review of Economics and Statistics*, Vol. 71, pp. 708-712.

Lastrapes, W.D. and F. Koray, 1990. "Real Exchange Rate Volatility and US Multilateral Trade Flows", *The Journal of Macroeconomics*, Vol. 12, pp. 341-362.

Lynch, D, 1983. "Modelling Irish Manufacturing Exports", Central Bank of Ireland Technical Paper 1/RT/83.

McGettigan, D, and J. Nugent, 1995. "Competitiveness Measures for Ireland: An Assessment", Central Bank of Ireland Technical Paper 6/RT/95.

McKenzie, M. D., 1999, “The Impact of Exchange Rate Volatility on International Trade Flows”, *Journal of Economic Surveys* 13, 71-106.

Morgenroth, E.L.W. 2000, “Exchange Rates and Trade: The Case of Irish Exports to Britain”, Applied Economics, Vol. 13, pp. 107-110.

Murphy, A., 1994. "The Irish Economy: Celtic Tiger or Tortoise?", Money Markets International.

O'Connell, T. 1978. "Demand and Supply Functions for Irish Exports of Manufactures", *The Economic and Social Review*, Vol. 8, pp. 257-278.

O’Reilly, L. 1985. “Determining Irish Merchandise Imports”, *Central Bank of Ireland Technical Paper*, 4/RT/85.

Peree, F. and A. Steinherr, 1989. "Exchange Rate Uncertainty and Foreign Trade", *European Economic Review*, Vol. 33, pp. 1241-1264.

Phillips, P. C. B., 1991. “Optimal Inference in Cointegrated Systems”, *Econometrica*, Vol. 59, pp. 283-306.

Pozo, S. 1992. "Conditional Exchange Rate Volatility and the Volume of International Trade: Evidence from the Early 1900s", *The Review of Economics and Statistics*, Vol. 74, pp. 325-329.

Rose, A. (2000). “One money, one market: the effect of common currencies on trade”, *Economic Policy*, 30, pp. 7-45.

Sereu, P. and C. Vanhulle, 1992. "Exchange Rate Volatility, Exposure and the Value of Exporting Firms", *Journal of Banking and Finance*, Vol. 16, pp. 155-182.

Thursby, J, and M. Thursby, 1987. “Bilateral Trade Flows, the Linder Hypothesis, and Exchange Risk”, *The Review of Economics and Statistics*, Vol. 69, pp. 488-495.

Walsh, B., 1996. "The Real Exchange Rate, Fiscal Policy and the Current Account: Interpreting Recent Irish Experience", Centre for Economic Research WP96/10.

Table 1

Johansen Cointegration Test Results

	Maximum	**Eigenvalue**	**Test**	
H_0:	**r = 0**	**r ≤ 1**	**r ≤ 2**	**r ≤ 3**
SITC 0-4	37.90**	12.93	9.24	1.06
SITC 5-8	48.49**	13.70	7.33	0.17
SITC 0-8	46.04**	13.11	7.98	0.13
		Trace Test		
H_0:	**r = 0**	**r ≤ 1**	**r ≤ 2**	**r ≤ 3**
SITC 0-4	61.13**	23.23	10.31	1.06
SITC 5-8	69.69**	21.20	7.50	0.17
SITC 0-8	67.25**	21.22	8.11	0.13

Note: ** Denotes significance at 5 %.

Table 2

Cointegration Vectors and Likelihood Ratio Tests

Export Divisions	Normalised Cointegration Vectors	H_0: $\beta_1=0$	H_0: $\beta_2=0$	H_0: $\beta_3=0$
SITC 0-4	$\ln X_t = 2.77\ln Y_t - 0.88\ln P_t + 8.15V_t$	23.15**	5.10**	5.79**
SITC 5-8	$\ln X_t = 3.98\ln Y_t - 0.77\ln P_t + 8.12V_t$	31.38**	6.33**	8.14**
SITC 0-8	$\ln X_t = 3.61\ln Y_t - 0.84\ln P_t + 7.85V_t$	29.92**	8.26**	8.56**

Note: The test statistic for H_0: $\beta_i = 0$, i=1, 2, 3, for the equation $\ln X_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln P_t + \beta_3 V_t$ has a $\chi^2(1)$ distribution under the null hypothesis. ** denotes significance at the 5% level.

Table 3

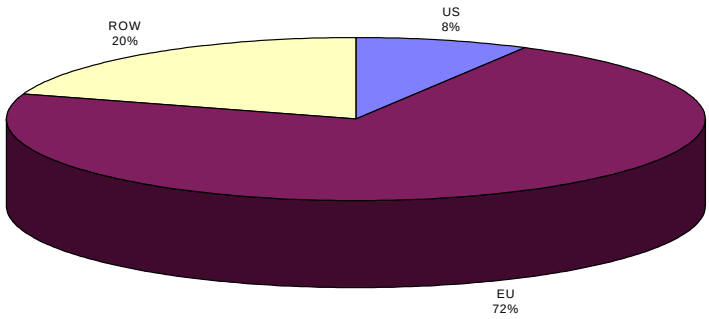
Regression Results for Error-Correction Models

Dependent variable: ΔlnX

Export Divisions	lag	R(-1)	ΔlnX	ΔlnY	ΔlnP	ΔV	Summary Statistics
SITC 0-4	1	-0.47 (2.42**)	-0.78 (4.46**)		-0.98 (1.38)	-5.44 (0.94)	$\overline{R}^2$ = 0.72 BG=3.05(0.55) ARCH=6.58(0.16)
	2		-0.58 (3.26**)				
	3		-0.32 (2.67**)	1.64 (1.69*)			
SITC 5-8	1	-0.03 (0.30)	-0.87 (6.98**)		-0.51 (1.36)	2.69 (0.83)	$\overline{R}^2$=0.65 BG = 1.65 (0.80)
	2		-0.73 (6.00**)				ARCH= 1.34(0.85)
	3		-0.52 (5.07**)	2.17 (3.80**)			
SITC 0-8	1	-0.09 (0.75)	-0.98 (7.18**)		-0.84 (1.98*)	1.19 (0.33)	$\overline{R}^2$=0.69 BG=0.60 (0.96)
	2		-0.69 (4.58**)				ARCH=0.93 (0.92)
	3		-0.39 (3.53**)	2.32 (3.77**)			

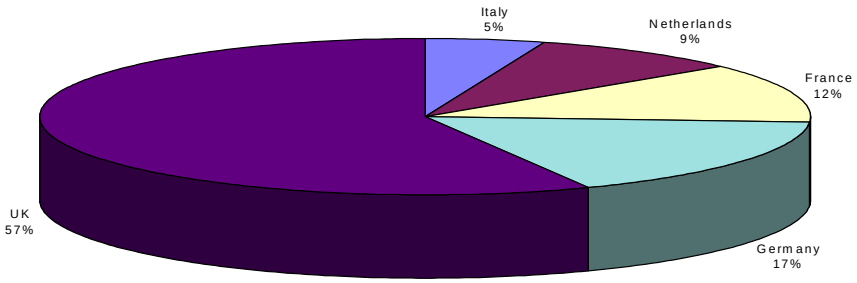
Note: Figures in parentheses underneath the estimated coefficients are the absolute t-statistics. * and ** denote significance at the 10% and 5% levels, respectively. The Breusch-Godfrey LM(4) test statistic for autocorrelation (BG) and the LM(4) test statistic for autoregressive conditional heteroskedasticity (ARCH) are reported. Marginal significance levels are given in parentheses.

Figure 1: Total Irish Exports



Annual Trade Data: 1978-1995
Source:CSO Trade Statistics

Figure 2: Irelands Trade Weights



Annual Trade Data: 1978-1995
Source:CSO Trade Statistics