EUROPEAN CENTRAL BANK

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WORKING PAPER NO. 64

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ISSN 1561-0810

Contents

Abstract:

This paper estimates an import demand function for the euro area vis-à-vis its main extra-area trading partners which takes into account the possible impact of both intra- and extra-euro area exchange rate uncertainty. We derive a theoretical model which captures various mechanisms by which exchange rate volatility may influence the demand for extra-euro area imports. If importers are risk averse, the model predicts not only a negative effect of exchange rate volatility, but also substitution possibilities between extra- and intra-area imports due to differences in the degree of extra- and intra-area exchange rate volatility. The magnitude of these impacts also depends on the share of trade invoiced in foreign currency (and not hedged) as well as the degree of substitutability between the imports of different suppliers. Using quarterly data for the past eleven years, panel estimates suggest that extra-area exchange rate volatility may have decreased extra-euro area imports by around 10 per cent. Although such quantitative estimates should be treated with caution, the magnitude of our estimate is similar to other studies which find a statistically significant impact of exchange rate volatility on trade flows. Finally, we also provide some limited evidence that differences in extra- and intra-area exchange rate volatility may have resulted in substitution between extra- and intra-area imports.

1. Introduction

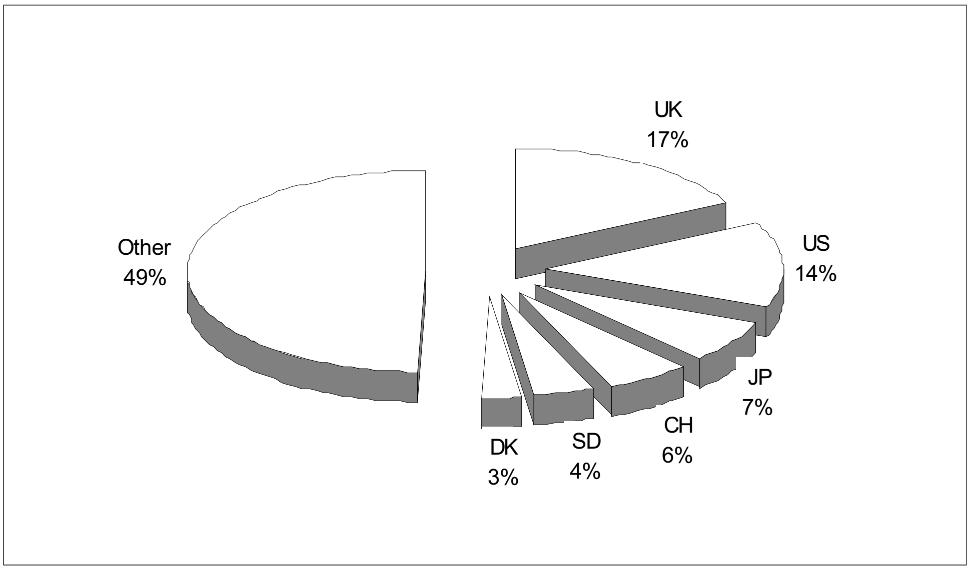
Many studies have investigated whether exchange rate volatility has a significant impact on trade flows. The main intuition behind these studies is that an increase in exchange rate volatility leads to uncertainty which might have a negative impact on trade flows.

In contrast to previous work, which is primarily concerned with exports, we provide estimates of the impact of exchange rate volatility on the demand for imports. Furthermore, we provide some initial estimates of an import demand function for the euro area using data for bilateral trade flows between the euro area and its major external trading partners. We begin by developing a theoretical model which captures the various mechanisms by which exchange rate volatility may influence the demand for imports. The model represents a significant step forward in that it allows us to distinguish between import suppliers in terms of their degree of exchange rate volatility. In the case of the euro area, this model allows us to investigate whether extra-euro area exchange rate volatility has a negative effect on extra-area imports, but also captures the possibility of substitution between intra- and extra-area imports due to differences in the degree of intra- and extra-area exchange rate volatility. Our empirical work uses quarterly data for the past eleven years and pools the data across different import suppliers, and additionally across the individual euro area countries, in order to obtain panel estimates for an extra-area import demand function for the euro area. Moreover, we experiment with different measures of exchange rate volatility and test for their significance within our estimated import demand function.

Our data cover the period 1989Q1 to 1999Q2. We analyse bilateral imports of all euro area member states originating from the following major import suppliers: the US, Japan (JP), Denmark (DK), Sweden (SD), the United Kingdom (UK), and Switzerland (CH). Chart 1 shows the share of each of these trading partners in the total extra-area imports of the euro area.[1] In total, these major import suppliers account for just over fifty per cent of the external imports of the euro area for the period 1995-99.

[1] This study uses data for the original eleven euro area countries (ie, the database excludes Greece).

Chart 1 Import shares of major import suppliers to the euro area (average 95-99)



Source: ECB calculations

The outline of the paper is as follows. Section two gives a brief survey of the literature regarding import demand and exchange rate volatility. Section three develops a theoretical model which describes how extra and intra-euro area exchange rate volatility might influence extra-euro area imports, while section four describes the empirical specification of our import function. The estimation results are given in section five.

2. Review of the empirical literature

We first describe those studies concerned with import demand functions and exchange rate volatility[2] and then extend the analysis to other trade models. For a broader review of the literature, including studies on the theoretical foundations, see McKenzie (1999) or Skudelny (2000).

There are only a few studies which investigate the impact of exchange rate volatility on import demand as most studies in this area focus on exports. The majority of studies use time series analysis, based on bilateral or aggregate trade flows. Gotur (1985), for example, uses aggregate

[2] Some authors have argued that under the existence of forward exchange markets, exchange rate uncertainty can be completely covered so that there is no impact of exchange rate uncertainty on trade (Ethier, 1973 and Baron, 1976). However, even under the existence of forward exchange markets there may be an indirect effect of exchange rate volatility on trade if hedging is costly (see Viaene and de Vries, 1992).

data for the US, Germany, France, Japan and the UK and finds mixed evidence regarding the effect of exchange rate volatility on import demand. Cushman (1986) finds similarly mixed results regarding the impact of exchange rate volatility on US import demand using bilateral time series for the major trading partners of the USA.

Caporale and Doroodian (1994) use a GARCH technique to measure the volatility of exchange rates. Using monthly data for the period 1974-92, they find that exchange rate volatility has a significant negative impact on US imports from Canada. McKenzie and Brooks (1997 and 1998) introduce an exchange rate volatility term into an import demand function for both Australian and German-US trade flows. For the Australian estimates, they find evidence of a significant, but weak, impact of volatility on trade.

Arize (1998a, b) uses co-integration tests and finds a significant and negative effect of exchange rate volatility on import demand. More recently, studies have used panel data in order to analyse the effect of exchange rate volatility on import demand. For example, Pugh *et al* (1999) estimate an import demand equation for sixteen OECD countries over the period 1980-92 and find a significant and negative effect of exchange rate volatility.

Many studies empirically test whether exchange rate uncertainty has an impact on exports, rather than import demand. The main differences between these export studies concerns the estimation technique (ie, whether standard regressions are estimated, or whether a co-integration analysis is used). Most studies use standard regressions, but Arize (1998a, b) and Fountas and Aristotelous (1999) use co-integration techniques and find a significant long run effect of exchange rate uncertainty on trade.

Another difference between studies concerning the estimation technique arises from their use of time series, cross sectional data or panel data econometrics. Most empirical studies use time series techniques, but only a few of them find a significant impact of exchange rate uncertainty on trade, with the effect being very small (eg, Koray and Lastrapes, 1989; Bélanger and Gutierrez, 1988; Bini-Smaghi, 1991; Kenen and Rodrik, 1986; and Sekkat, 1998). Cross sectional studies, such as Hooper and Kohlhagen (1978), De Grauwe (1987), Brada and Méndez (1988), De Grauwe and Verfaille (1988), Savvides (1992), Frankel and Wei (1993), Sapir, Sekkat and Weber (1994) and Eichengreen and Irwin (1995), find more evidence of a negative effect of exchange rate uncertainty, but again this effect is, in most cases, relatively small.

By contrast, studies based on panel estimation techniques have been more fruitful. For example, Abrams (1980), Thursby and Thursby (1987), Dell'Ariccia (1998), Pugh *et al.* (1999) and Rose (1999), all find significant and negative effects for their proxy for exchange rate uncertainty. In the latter three studies, the trade loss through exchange rate uncertainty is quite substantial. When taking the standard deviation of the real exchange rate (or the forward error) as proxies for exchange rate uncertainty, Dell'Ariccia (1998) finds that the trade gains resulting from the elimination of exchange rate volatility would have been 13 percent and 10 percent, respectively.

Pugh *et al* (1999) estimate an import demand model in growth rates, and a gravity type trade model in levels for the period 1980 to 1992 for 16 OECD countries. According to the import demand model, exchange rate volatility (measured as the standard deviation of the nominal exchange rate return) tends to reduce trade growth by around 10 percent. According to the gravity type trade model, exchange rate volatility leads to a once for all decrease in the level of trade by around 8 percent.

Rose (1999, 2000) also estimates a gravity type trade model for 186 countries, territories, and colonies spanning five different years: 1970, 1975, 1980, 1985 and 1990. As the proxy for exchange rate uncertainty, he uses the 5 year moving average of the variance of the nominal exchange rate return and finds that exchange rate volatility has a significant and negative impact on trade (the estimates suggest that zero exchange rate volatility during the observation period would have resulted in a 13 per cent increase in trade). However, Rose also distinguishes between the impact on trade flows of exchange rate volatility and the additional impact of sharing a common currency. He finds that the impact on trade of sharing a common currency is much larger than the additional impact of eliminating exchange rate volatility (also see Frankel and Rose, 2000).[3]

Another point common to the five studies above, beside the use of panel data, is that they all use gravity type trade models. This might also improve their results, as it controls for variables like distance (in the geographical and figurative sense) and for supply, as well as demand, variables.

[3] In contrast to Rose (1999, 2000), the objective of our study is only to assess the impact of exchange rate volatility on trade. We do not attempt to assess the impact of the single currency.

3. Foundations of the exchange rate volatility model

We introduce exchange rate uncertainty into the utility function of a firm which buys goods in order to resell them (after some transformation).[4] Our approach represents a significant extension of the framework developed by Cushman (1986) who investigates the importance of exchange rate uncertainty for an *exporting* firm. We apply a similar framework to an *importing* firm and extend the model so that it captures the potentially different degrees of exchange rate uncertainty associated with different import suppliers (and also takes into account the impact of hedging and the invoicing currency). The inputs used by our importing firm – which is assumed to be based in a euro area country - can be purchased from three different groups of suppliers: (1) home suppliers - which embody zero exchange rate uncertainty; (2) euro area suppliers - which embody some degree of exchange rate uncertainty prior to 1999 (ie, intra-area trade); and (3) non-euro area suppliers - who may be associated with a relatively higher degree of exchange rate uncertainty (ie, extra-euro area trade). The expected utility of our importer can be written as:

$$\begin{aligned} EU_i = {} & P_i^Q Q_i - (1-\gamma_w)P_w M_w - \gamma_w[\delta_w F_w + (1-\delta_w)S_w]P_w^* M_w \\ & -(1-\gamma_{EA})P_{EA}M_{EA} - \gamma_{EA}[\delta_{EA}F_{EA} + (1-\delta_{EA})S_{EA}]P_{EA}^* M_{EA} - P_i M_i \\ & -\theta Var\begin{pmatrix} P_i^Q Q_i - (1-\gamma_w)P_w M_w - \gamma_w[\delta_w F_w + (1-\delta_w)S_w]P_w^* M_w \\ -(1-\gamma_{EA})P_{EA}M_{EA} - \gamma_{EA}[\delta_{EA}F_{EA} + (1-\delta_{EA})S_{EA}]P_{EA}^* M_{EA} - P_i M_i \end{pmatrix} \end{aligned} \tag{1}$$

where EU is the expected utility of the firm, P_i^Q is the sales price of the firm's products, Q_i is the quantity produced, and P_w and P_{EA} are the import prices from the non-euro area and euro area countries respectively, expressed in the importer's currency. P_w^* and P_{EA}^* are the import prices from the non-euro area and euro area countries respectively, expressed in the exporters (foreign) currency. i.e. $P_w = P_w^* S_w$ and $P_{EA} = P_{EA}^* S_{EA}$ with S_w (S_{EA}) the spot exchange rate of the importing country vis-à-vis the exporting country (w or EA respectively). F_w (F_{EA}) is the forward exchange rate of the importing country vis-à-vis the exporting country (w or EA respectively). We assume that the proportion γ_w (γ_{EA}) of imports from non-euro area countries (euro area countries) is invoiced in foreign currency, while the proportion δ_w (δ_{EA}) of the

[4] The transformation might be substantial, ie, the firm imports intermediate goods and uses them to manufacture final goods; or it might be minimal, ie, the firm imports finished goods and merely packages them and then re-sells. Although such transformations would obviously need varying degrees of labour inputs, we do not include labour in our model as the results are unaffected if we assume that labour is exogenous.

imports from the non-euro area countries (euro area countries) invoiced in foreign currency is hedged against exchange rate risk.[5] The last term of equation (1) is equal to the degree of risk aversion, θ, multiplied by the variance of profits (the risk aversion parameter θ is positive when the firm is risk averse). M_w, M_{EA} and M_i are the inputs bought from extra-euro area countries, euro area countries and the home country, respectively. We assume a CES production function based on inputs originating from outside the euro area, inside the euro area as well as from domestic producers:

$$Q_i = \left(M_w^{\frac{\phi-1}{\phi}} + M_{EA}^{\frac{\phi-1}{\phi}} + M_i^{\frac{\phi-1}{\phi}} \right)^{\frac{\phi}{\phi-1}} \tag{2}$$

We further assume that exchange rate volatility is the only uncertainty faced by the importer and that the contract date differs from the payment date. We can therefore write the variance of profits as:

$$\begin{aligned} &Var\begin{pmatrix} P_i^q Q_i - (1-\gamma_w)P_w M_w - \gamma_w[\delta_w F_w + (1-\delta_w)S_w]P_w^* M_w \\ -(1-\gamma_{EA})P_{EA}M_{EA} - \gamma_{EA}[\delta_{EA}F_{EA} + (1-\delta_{EA})S_{EA}]P_{EA}^* M_{EA} - P_i M_i \end{pmatrix} \\ &= [\gamma_w(1-\delta_w)P_w^* M_w]^2 \operatorname{var}(S_w) + [\gamma_{EA}(1-\delta_{EA})P_{EA}^* M_{EA}]^2 \operatorname{var}(S_{EA}) \\ &+ \gamma_w(1-\delta_w)P_w^* M_w \gamma_{EA}(1-\delta_{EA})P_{EA}^* M_{EA} \operatorname{cov}(S_w, S_{EA}) \end{aligned} \tag{3}$$

The firm will maximise expected utility with respect to inputs bought from the domestic market and non-euro area and euro area countries respectively. Dividing the first order conditions of the maximisation with respect to inputs from non-euro area and from euro area countries by each other yields:

[5] Some studies – based on a selection of European countries - suggest that the proportion of imports invoiced in the importer's home currency might range from around one-third to one-half (see, for example, van de Koolwijk, 1994). However, these figures include *intra*-trade and, therefore, may *not* be a good indicator of the invoicing currency characteristics of *extra*-euro area trade. For example, Hartmann (1998) states that 47.6% of world exports were invoiced in US dollars in 1992, whereas for intra-EU trade only 3.9% of exports was invoiced in US dollars, while the corresponding figure for extra-EU trade was 59.4%. Very little information is available regarding the degree of hedging, such that the European Commission (1990) - in their study "One Market, One Money" - *assumed* that the portion of foreign currency transactions hedged goes up with the size of the transaction and might be of the order of 20% for payments inside the ECU 1000 to 5,000 bracket, rising to 50% for payments inside the ECU 50,000 to 100,000 bracket.

$$M_w = M_{EA}\begin{bmatrix}(1-\gamma_{EA}\delta_{EA})P_{EA}^{\;*}S_{EA}+\gamma_{EA}\delta_{EA}F_{EA}P_{EA}^{\;*}+2\theta\left[\gamma_{EA}(1-\delta_{EA})P_{EA}^{\;*}\right]^2 M_{EA}\operatorname{var}(S_{EA})\\ +\theta\gamma_w(1-\delta_w)P_w^{\;*}M_w\gamma_{EA}(1-\delta_{EA})P_{EA}^{\;*}\operatorname{cov}(S_w,S_{EA})\end{bmatrix}^{\phi}$$

$$*\begin{bmatrix}(1-\gamma_w\delta_w)P_w^{\;*}S_w+\gamma_w\delta_wF_wP_w^{\;*}+2\theta\left[\gamma_w(1-\delta_w)P_w^{\;*}\right]^2 M_w\operatorname{var}(S_w)\\ +\theta\gamma_w(1-\delta_w)P_w^{\;*}\gamma_{EA}(1-\delta_{EA})P_{EA}^{\;*}M_{EA}\operatorname{cov}(S_w,S_{EA})\end{bmatrix}^{-\phi} \tag{4}$$

We will use a first order Taylor expansion of this expression (in logarithms) around

$\operatorname{var}(S_{EA})=\operatorname{var}(S_w)=\operatorname{cov}(S_w,S_{EA})=0$ and

$M_w = M_{EA}\left(\frac{(1-\gamma_{EA}\delta_{EA})P_{EA}^{\;*}S_{EA}+\gamma_{EA}\delta_{EA}F_{EA}P_{EA}^{\;*}}{(1-\gamma_w\delta_w)P_w^{\;*}S_w+\gamma_w\delta_wF_wP_w^{\;*}}\right)^{\phi}$. The latter condition is the solution of (4) when all volatility terms are equal to zero. In order to simplify the expression, we will define $Z_{EA}=(1-\gamma_{EA}\delta_{EA})S_{EA}+\gamma_{EA}\delta_{EA}F_{EA}$ and $Z_w=(1-\gamma_w\delta_w)S_w+\gamma_w\delta_wF_w$. These expressions capture the share of imports which is either invoiced in domestic currency or is not hedged multiplied with the spot exchange rate, plus the share of imports which is invoiced in foreign currency and hedged multiplied with the forward exchange rate. Moreover, we define the share of trade invoiced in foreign currency and not hedged as $K_{EA}=\gamma_{EA}(1-\delta_{EA})$ and $K_w=\gamma_w(1-\delta_w)$. Solving the resulting equation for M_w yields:

$$\begin{aligned}M_w = \overline{M}_{EA}\left(\frac{\overline{Z}_{EA}\overline{P}_{EA}^{\;*}}{\overline{Z}_w\overline{P}_w^{\;*}}\right)^{\phi}\Bigg[\,&1-2\phi\theta\left(K_w\overline{P}_w^{\;*}\right)^2\overline{M}_{EA}\frac{\left(\overline{Z}_{EA}\overline{P}_{EA}^{\;*}\right)^{\phi}}{\left(\overline{Z}_w\overline{P}_w^{\;*}\right)^{\phi+1}}\operatorname{var}(S_w)\\ &+2\phi\theta\left(K_{EA}\overline{P}_{EA}^{\;*}\right)^2\overline{M}_{EA}\left(\overline{Z}_{EA}\overline{P}_{EA}^{\;*}\right)^{-1}\operatorname{var}(S_{EA})\\ &+\phi\theta\overline{M}_{EA}K_w\overline{P}_w^{\;*}K_{EA}\overline{P}_{EA}^{\;*}\frac{\left(\overline{Z}_{EA}\overline{P}_{EA}^{\;*}\right)^{\phi-1}-\left(\overline{Z}_w\overline{P}_w^{\;*}\right)^{\phi-1}}{\left(\overline{Z}_w\overline{P}_w^{\;*}\right)^{\phi}}\operatorname{cov}(S_w,S_{EA})\Bigg]\end{aligned} \tag{5}$$

Variables with bars ($\overline{P}_{EA},\overline{P}_w,\overline{S}_{EA},\overline{S}_w,\overline{F}_{EA},\overline{F}_w$ and $\overline{M}_{EA}$) are equal to the original variables (P_{EA}, P_w, S_{EA}, S_w, F_{EA}, F_w and M_{EA}) at the point where $\operatorname{var}(S_{EA})=\operatorname{var}(S_w)=\operatorname{cov}(S_w,S_{EA})=0$ and $M_w = M_{EA}\left(\frac{(1-\gamma_{EA}\delta_{EA})P_{EA}^{\;*}S_{EA}+\gamma_{EA}\delta_{EA}F_{EA}P_{EA}^{\;*}}{(1-\gamma_w\delta_w)P_w^{\;*}S_w+\gamma_w\delta_wF_wP_w^{\;*}}\right)^{\phi}$.

In order to show the impact of exchange rate volatility on M_w , we take the first derivative with respect to the variance of the extra- and intra-euro area exchange rates, respectively:

$$\frac{\partial M_w}{\partial \operatorname{var}(S_w)} = -2\phi\theta\left(K_w \overline{P}_w^{\,*}\right)^2 \overline{M}_{EA}^{\,2} \frac{\left(\overline{Z}_{EA}\overline{P}_{EA}^{\,*}\right)^{2\phi}}{\left(\overline{Z}_w \overline{P}_w^{\,*}\right)^{2\phi+1}} \tag{6}$$

Hence, under the assumption that the importer is risk averse, i.e. $\theta > 0$, the effect of an increase in exchange rate volatility between non-euro area country w and the home country on imports from country w is negative. This effect is stronger, the higher the share of trade invoiced in foreign currency and not hedged (K_W), i.e. the higher the share of imports invoiced in foreign currency (γ_w) and the lower the share of these imports which are hedged (δ_w); and the effect is stronger, the higher the substitutability between the imports of the different suppliers (ϕ).

$$\frac{\partial M_w}{\partial \operatorname{var}(S_{EA})} = 2\phi\theta\left(K_{EA} \overline{P}_{EA}^{\,*}\right)^2 \overline{M}_{EA}^{\,2} \frac{\left(\overline{Z}_{EA}\overline{P}_{EA}^{\,*}\right)^{\phi-1}}{\left(\overline{Z}_w \overline{P}_w^{\,*}\right)^{\phi}} \tag{7}$$

In addition, the effect of an increase in intra-euro area exchange rate volatility on the imports of the euro area from non-euro area country w is positive, if the importer is risk averse (equation 7). Again, the share of imports invoiced in foreign currency (γ_{EA}) and the substitutability between imports of the different regions (ϕ) have an amplifying effect, whereas the share of these imports hedged (δ_{EA}) reduces the impact of exchange rate volatility.

$$\frac{\partial M_w}{\partial \operatorname{cov}(S_w, S_{EA})} = \theta\phi\overline{M}_{EA}^{\,2} K_w \overline{P}_w^{\,*} K_{EA} \overline{P}_{EA}^{\,*} \frac{\left(\overline{Z}_{EA}\overline{P}_{EA}^{\,*}\right)^{\phi-1} - \left(\overline{Z}_w \overline{P}_w^{\,*}\right)^{\phi-1}}{\left(\overline{Z}_w \overline{P}_w^{\,*}\right)^{\phi}} \left(\frac{\overline{Z}_{EA}\overline{P}_{EA}^{\,*}}{\overline{Z}_w \overline{P}_w^{\,*}}\right)^{\phi} \tag{8}$$

Finally, equation (8) shows the effect of an increase in the covariance of extra- and intra-exchange rates on extra-euro area imports.

4. The estimated model

We use a quarterly bilateral trade dataset consisting of the imports of the individual euro area countries originating from six major import suppliers – ie, the USA, Japan, Denmark, Sweden, the UK and Switzerland – for the sample period 1989Q1 to 1999Q2. For each euro area country, we have separate import volume, value and unit values for the imports supplied by each of the above countries (ie, bilateral import data for the individual euro area countries *vis-a-vis* six trading partner countries).[6] We use two different methods of pooling the data in order to obtain panel estimates for specifications based on equation (9) below. First, we pool the data across *both* the individual euro area countries and the six import suppliers to the euro area (we call this the *'double pool'*). Second, instead of pooling across the individual euro area member states, we use the aggregate imports data of the euro area and simply pool across the six trading-partner countries (the *'single pool'*). Using the 'double-pool' as an example, equation (9) represents an unconstrained import demand function specified along the same lines as the bilateral trade models derived by Italianer and d'Alcantara (1986), Marquez and McNeilly (1988) and Anderton (1999a, b):[7]

$$\begin{aligned} \ln M_{ijt} = {} & \alpha_{ij0} + \alpha_{ij1} \ln M_{ij,t-1} + \alpha_{ij2} \ln MP_{ijt} + \alpha_{ij3} \ln PP_{it} + \alpha_{ij4} \ln EAMP_{iEAt} + \\ & \alpha_{ij5} \ln TFE_{it} + \alpha_{ij6} VOL_{ijt} + \alpha_{ij7} VOL_{iEAt} \end{aligned} \tag{9}$$

A priori, we expect:

$$\alpha_{ij1} > 0;\ \alpha_{ij2} < 0;\ \alpha_{ij3} > 0;\ \alpha_{ij4} > 0;\ \alpha_{ij5} > 0;\ \alpha_{ij6} < 0;\ \alpha_{ij7} > 0$$

where: M_{ijt} are the imports of euro area country i from import supplier country j in period t (import volumes in index form, 1995=100); MP_{ij} is the import price for imports of i from j (expected to have a negative sign); PP_{it} is the producer price of euro area country i (positive sign); $EAMP_{iEA}$ is the average price of imports of country i from the rest of the euro area

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[6] One caveat regarding the data is that, as is well known, intra-imports do not equal intra-exports at the EU level. Part of this reason is due to an under-recording of intra-imports which might lead to inaccuracies in the extra-euro area imports data. However, it should be noted that all trade data suffer from inaccuracies in these so-called "mirror" statistics – eg, it is usually the case for any source of trade data that the value of an export transaction is not equal to the corresponding import transaction - hence this problem applies to the majority of empirical trade studies.

[7] By unconstrained, we mean that we allow α_{ij2}, α_{ij3} and α_{ij4} to be 'freely' estimated in order to capture the possible different relationships between the various prices and import volumes, rather than constraining these parameters by expressing prices in relative terms.

(expected to have a positive sign as a rise in intra-area import prices should encourage substitution towards extra-area imports); and TFE_{it} is total final expenditure in constant prices of importer i, which proxies demand (positive sign).[8] We introduce dynamic adjustment into the model by including a lagged dependent variable. VOL_{ijt} is a measure of bilateral *extra-area* exchange rate volatility and is expected to have a negative sign. However, in our model of exchange rate uncertainty the parameter for VOL_{ijt} captures *both* the absolute trade depressing effect of volatility and any substitution away from extra- to intra-area trade due to a rise in VOL_{ijt}. Similarly, the parameter for VOL_{iEAt} – which measures intra-euro area exchange rate volatility - captures any substitution away from intra- to extra-area trade due to a rise in VOL_{iEAt}. All variables are seasonally adjusted. Appendix 1 gives a detailed description of the data and the sources.

We impose the same parameters across the different importing countries and import suppliers, but include 'fixed-effects' in our panel estimates by allowing each 'panel-member' to have a different intercept. Although Nickell (1981) and Baltagi (1995) point out the potential bias of dynamic panel models with fixed effects, we do not instrument the lagged dependent variable as the time dimension of our panel is sufficiently large to avoid serious bias of the estimated coefficients (see Judson and Owen, 1999)[9].

Modelling exchange rate volatility

We define bilateral exchange rate volatility as $BVAR_{ij,t}$ which is the quarterly variance of the weekly nominal exchange rate return between countries i and j in percentage terms:

[8] Given the multicollinearity problems which would arise from including all of the import prices from the other extra-area non-j import suppliers, we constrain the non-j cross-price elasticities to be zero. Other bilateral trade studies - such as Italianer and d'Alcantara (1986), Marquez and McNeilly (1988) and Anderton (1999) – also restrict these cross-price elasticities to be zero.

[9] Judson and Owen (1999) compare the bias of six different estimators of dynamic panel data models: the OLS estimator, a 'standard' least squares dummy variable (LSDV) estimator, a corrected LSDV estimator as proposed by Kiviet (1995), two GMM estimators discussed by Arellano and Bond (1991), and the IV estimator proposed by Anderson and Hsiao (1981). The results of their simulations are that the corrected LSDV estimator of Kiviet (1995) outperforms the other estimators in the case of a balanced panel, and the 'standard' LSDV estimator performs better than the other estimators in the case of an unbalanced panel. However, the LSDV estimator - *which is used in our empirical work* - performs just as well, or better, than the majority of alternatives when the number of time periods is increased to at least 30 (our sample, which consists of 42 time periods, is therefore suitable for the LSDV estimator).

$$BVAR_{ij,t} = \frac{100}{12} \sum_{w=1}^{12} \left(NERR_{ijw} - \overline{NERR_{ijt}} \right)^2$$

where $NERR_{ijw}$ ($\overline{NERR}_{ijt}$) is the weekly (quarterly) nominal exchange rate return:

$$NERR_{ijw} = \frac{NER_{ijw}}{NER_{ij,w-1}} - 1$$

When using euro area aggregate imports as the dependent variable (ie, the 'single pool') we use a weighted average of the bilateral variances:

$$BVAR_{EAj,t} = \sum_i \left[w_{ij} \frac{100}{12} \sum_{w=1}^{12} \left(NERR_{ijw} - \overline{NERR_{ijt}} \right)^2 \right]$$

with $w_{ij} = \dfrac{\overline{X}_{ij} + \overline{M}_{ij}}{\sum_i \left(\overline{X}_{ij} + \overline{M}_{ij} \right)}$

where $\overline{X}_{ij}$ ($\overline{M}_{ij}$) are the average exports (imports) over the whole period between countries i and j, j being a non-euro area country.

In order to test whether the degree of *intra*-euro area exchange rate volatility has an impact on extra-euro area trade flows, we also construct the weighted average of the bilateral volatility terms within the euro area (ie, *intra-area volatility*):

$$VAREA_{it} = \sum_{k \neq i} \left[w_{ik} \frac{100}{12} \sum_{w=1}^{12} \left(NERR_{ikw} - \overline{NERR_{ikt}} \right)^2 \right]$$

with $w_{ik} = \dfrac{\overline{X}_{ik} + \overline{M}_{ik}}{\sum_k \left(\overline{X}_{ik} + \overline{M}_{ik} \right)}$

and k being a euro area country.

When estimating trade volume equations including exchange rate volatility terms, many previous studies use a measure of volatility for the *current period*. However, in our model it is the perception of the importer of the likelihood of being negatively affected by exchange rate volatility that is important. Hence, we assume that the importer uses information from the past as well as the current period for assessing the relative risks associated with exchange rate volatility vis-à-vis different suppliers. Therefore, we experiment with various *moving-average* measures of exchange rate volatility as such a variable not only captures current volatility, along with some 'history' of past volatility, but also eventually 'forgets' episodes of volatility when they become old enough to be irrelevant. In our regressions, we experiment with various moving averages of the quarterly variance ranging from one to nine years and put each of them into a separate regression in order to empirically assess how long importers 'remember' past episodes of significant exchange rate volatility.

5. Empirical results

As mentioned earlier, we estimate specification (9) in various ways using different pooling methods. Our first method, which we call the 'double-pool', pools the import data across all euro area countries, and over all six extra-area trading partners (US, Japan, Denmark, Sweden, the UK, and Switzerland).[10]

We use instrumental variables estimation in order to avoid simultaneity problems[11] and therefore instrument the contemporaneous TFE and price terms. Our instruments comprise four lags for both the TFE and the price variables. We use the White correction, in order to obtain heteroskedastic-consistent standard errors (see White, 1980). In addition, we include a dummy for German unification.[12]

A five year moving average of the volatility term was chosen after experiments with various lags showed that this moving average registered both the highest 't-statistic' and the highest adjusted R^2 for the "double-pool" specification. We show the equation results for three combinations of the *moving average* exchange rate volatility terms: (1) bilateral extra-area volatility ($BVMA_{ijt}$); (2) bilateral extra-area volatility ($BVMA_{ijt}$) and intra-area volatility

[10] Although our sample potentially covers observations for 11 (euro area countries) * 6 (partner countries) * 42 quarters (1989Q1-1999Q2), there are somewhat fewer observations as: (a) we only have observations for Belgium and Luxembourg combined; and (b) there are some missing observations for some countries.

[11] A simultaneity problem arises when one or more of the explanatory variables are jointly determined with the dependent variable.

[12] We add a dummy for re-unification because the imports data are for West Germany before 1991 and West and East Germany combined from 1991 onwards. The dummy is equal to one before 1991 when West Germany is the importer. The parameters for the dummy variables are not reported in the tables.

($EAMA_{ijt}$) included together; and (3) bilateral extra-area volatility relative to intra-area volatility ($RVMA_{ijt}$). The parameters for the model of equation 9 are shown in Table 1 below.

Table 1: Pooling across both euro area countries and extra-area trading partners ("double-pool", "unconstrained" equation 9)

	(1) BVMA			(2) BVMA and EAMA			(3) RVMA		
	Coef.	t-stat.	LR-coef.	Coef.	t-stat.	LR-coef.	Coef.	t-stat.	LR-coef.
$M_{ij,t-1}$	**0.592**	**17.415**		**0.592**	**17.408**		**0.596**	**17.561**	
$M_{ij,t-2}$	**0.179**	**5.667**		**0.179**	**5.661**		**0.183**	**5.743**	
MP_{ijt}	**-0.098**	**-2.0372**	**-0.428**	**-0.097**	**-2.040**	**-0.424**	**-0.103**	**-2.153**	**-0.466**
PP_{it}	0.019	0.397	0.083	0.018	0.371	0.078	0.047	0.999	0.213
$EAMP_{it}$	**0.161**	**2.088**	**0.703**	**0.165**	**2.029**	**0.721**	0.114	1.517	0.516
TFE_{it}	**0.207**	**3.419**	**0.904**	**0.206**	**3.399**	**0.899**	**0.2144**	**3.529**	**0.968**
$BVMA_{ijt}$	**-3.825**	**-5.759**	**-16.703**	**-3.773**	**-4.774**	**-16.475**			
$EAMA_{ijt}$				-0.217	-0.118	-0.947			
$RVMA_{ijt}$							**-4.275**	**-5.445**	**-19.344**
ARSQ	0.790			0.790			0.789		
LM(1)	2.60			2.59			1.65		
LM(4)	4.22			0.02			0.60		

Notes: *Bold numbers represent statistical significance at the 95% significance level.* M_{ij} are the import volumes of euro area country i from import supplier country j; MP_{ij} is the import price for imports of i from j; PP_{it} is the producer price of euro area country i; $EAMP_i$ is the average price of imports of country i from the rest of the euro area; TFE_{it} is total final expenditure (in constant prices) of importer i; $BVMA_{ij}$ is the moving average bilateral extra-area exchange rate volatility; $EAMA_{ij}$ is the moving average intra-area exchange rate volatility; $RVMA_{ij}$ is the moving average bilateral extra-area exchange rate volatility relative to intra-area exchange rate volatility; ARSQ is the adjusted R-squared; LM(1) and LM(4) are the Breusch-Godfrey Lagrange multiplier tests for first and fourth order autocorrelation[13]; LR-coeff is the long-run coefficient (ie, the short-run coefficient divided by one minus the lagged dependent variable parameters). All parameters are obtained using instrumental variables estimation where all current period terms are instrumented by their lagged values for the previous four periods. All variables expressed in logarithms except the volatility terms. Sample period: 1989Q1-1999Q2.

Case (1) in Table 1 shows that the extra-area volatility term ($BVMA_{ijt}$) is both negative and statistically significant thereby implying that extra-area imports are adversely affected by exchange rate uncertainty. Case (2) shows that intra-area volatility is not statistically significant, while case (3) might suggest that an increase in the volatility of extra-area exchange rates relative to intra-area exchange rate volatility results in substitution away from

[13] The Breusch-Godfrey Lagrange multiplier test for first- (fourth) order autocorrelation is based on regressing the residuals on the residuals in period t-1 (to t-4) plus all of the other exogenous regressors. The resulting R^2 is then multiplied by the number of observations to give the test statistic. The test statistic follows a CHISQ distribution with 1 (4) degrees of freedom.

extra-area suppliers. However, most of the negative effect of the relative volatility term is certainly due to the bilateral volatility vis-à-vis the extra-euro area trading partner, rather than movements in euro area volatility. The adjusted R-squared and the standard errors of the equations show a reasonably good fit suggesting that the specification provides a coherent description of the behaviour of bilateral imports. In addition, the Breusch-Godfrey Lagrange multiplier tests indicate that the equations are generally free of first and fourth-order autocorrelation.[14]

Table 1 also shows that the individual price terms all have the expected signs, for example: an increase in the import price of extra-area imports from country j (MP_{ij}) tends to decrease extra-area imports from j; an increase in the domestic producer price of country i (PP_{it}) tends to increase extra-area imports from j; and an increase in the intra-area import price ($EAMP_{iEA}$) also tends to increase extra-area imports from j (ie, substitution away from intra to extra-area imports). Although the extra-area import price is usually statistically significant, the intra-area import price is not always significant, while domestic producer prices are always insignificant. Given that the latter two series move closely together, and that the domestic producer price and intra-area price are each individually statistically significant if the other is excluded, it seems that these two terms are collinear and both tend to act as a proxy for domestic producer prices. Hence, our pragmatic solution is to report results in Table 2 below for the same permutations of the volatility terms in the previous table, but for two separate *constrained* versions of the above model by specifying prices in *relative* terms: one with the import price for j relative to i's producer prices; and another with the import price between i and j relative to the weighted average of import prices between i and the other euro area countries. The resulting estimation equation is therefore:[15]

$$\ln M_{ijt} = \beta_{ij0} + \beta_{ij1} \ln M_{ij,t-1} + \beta_{ij2} \ln RP_{ijt} + \beta_{ij3} \ln TFE_{it} + \beta_{ij4} VOL_{ijt} + \beta_{ij5} VOL_{iEAt} \qquad (10)$$

with RP_{ijt} taking on two different values, $RP1_{ijt} = \frac{MP_{ijt}}{PP_{it}}$ and $RP2_{ijt} = \frac{MP_{ijt}}{EAMP_{iEAt}}$.

[14] The 'testing down' procedure - from a general to a specific equation – indicated that specification (9) only required the addition of a second lag of the dependent variable in order to pass the diagnostic tests.

[15] In other words, $RP1_{ijt}$ imposes: $-\alpha_{ij2} = \alpha_{ij3}$ and $\alpha_{ij4} = 0$; while $RP2_{ijt}$ imposes: $-\alpha_{ij2} = \alpha_{ij4}$ and $\alpha_{ij3} = 0$.

We report the results for equation 10 in Table 2 below (and add a second lag of the dependent variable in order to avoid autocorrelation problems). These *constrained* import demand specifications also seem to provide an adequate explanation of the data-generating process with only a marginally lower adjusted R-squared in comparison to the unconstrained (equation 10) results. Furthermore, the Lagrange multiplier tests show that the equations are free of first and fourth-order autocorrelation and again we avoid some of the potential problems of heteroscedasticity by computing and reporting only heteroscedastic-consistent standard errors (see White, 1980).

Table 2: Pool across both euro area countries and extra-area trading partners ("double-pool", "constrained" equation 10)

	Coef.	t-stat.	LR-coef.	Coef.	t-stat.	LR-coef.
$M_{ij,t-1}$	**0.596**	**17.586**		**0.593**	**17.628**	
$M_{ij,t-2}$	**0.179**	**5.617**		**0.178**	**5.679**	
MP_{ijt}/PP_{it}	*-0.051*	*-1.360*	*-0.225*			
$MP_{ijt}/EAMP_{it}$				*-0.089*	*-1.889*	*-0.388*
TFE_{it}	**0.263**	**5.809**	**1.168**	**0.246**	**7.469**	**1.072**
$BVMA_{ijt}$	**-3.552**	**-5.564**	**-15.767**	**-3.780**	**-6.221**	**-16.507**
ARSQ	0.788	-	-	0.788	-	-
LM(1)	2.37	-	-	2.55	-	-
LM(4)	3.63			2.98		
$M_{ij,t-1}$	**0.596**	**17.588**		**0.594**	**17.614**	
$M_{ij,t-2}$	**0.180**	**5.638**		**0.178**	**5.676**	
MP_{ijt}/PP_{it}	*-0.055*	*-1.451*	*-0.245*			
$MP_{ijt}/EAMP_{it}$				*-0.089*	*-1.905*	*-0.391*
TFE_{it}	**0.261**	**5.709**	**1.162**	**0.244**	**6.898**	**1.067**
$BVMA_{ijt}$	**-3.856**	**-4.838**	**-17.180**	**-3.890**	**-5.007**	**-17.024**
$EAMA_{ijt}$	1.162	0.666	5.176	0.404	0.235	1.768
ARSQ	0.788	-	-	0.788	-	-
LM(1)	2.19	-	-	2.47	-	-
LM(4)	0.91			0.15		
$M_{ij,t-1}$	**0.598**	**17.671**		**0.598**	**17.806**	
$M_{ij,t-2}$	**0.182**	**5.705**		**0.183**	**5.798**	
MP_{ijt}/PP_{it}	*-0.069*	*-1.873*	*-0.312*			
$MP_{ijt}/EAMP_{it}$				*-0.091*	*-1.938*	*-0.415*
TFE_{it}	**0.254**	**5.589**	**1.156**	**0.221**	**6.806**	**1.009**
$RVMA_{ijt}$	**-4.212**	**-5.388**	**-19.145**	**-4.389**	**-5.789**	**-20.021**
ARSQ	0.797	-	-	0.788	-	-
LM(1)	1.20	-	-	1.86	-	-
LM(4)	3.62			8.95		

Bold (italic) numbers represent statistical significance at 95% (90%) level.

Both the long-run parameters for relative prices, varying in magnitude between 0.3 and 0.4, and total final expenditure (around unity) are a bit low when compared with other results for import demand specifications, but both have the expected sign and are usually statistically significant.[16] As in the model of equation 9, the extra-area and relative exchange rate volatility terms are negative and statistically significant in all specifications, while the intra-volatility term is now correctly positively signed, but is not statistically significant. Again, the significant and negative effect of the relative volatility term seems to be due to the bilateral volatility with the extra-euro area trading partner, rather than to intra-euro area volatility.

Our next step is to estimate the model using *aggregate* imports data for the euro area and simply pool across the extra-area import suppliers - ie, the "single-pool" - rather than also pooling across the individual euro area countries. Table 3 gives the results for this specification and shows that the adjusted R-squared is somewhat higher in this specification (around 0.93) although it should be noted that we have a considerably smaller number of observations as we are not pooling across the individual euro area countries.[17] However, the long-run parameters for both the relative price (between -0.9 and -1.2) and total final expenditure (between 2.5 and 2.8) have increased in absolute values and are now more in line with the general results in the literature.[18] As before, all of the volatility terms have the expected signs, but the intra-volatility term is now both positive and *statistically significant*.[19]

Table 3: Aggregate euro area import volumes – pooling across extra-area trading partners ("single-pool", equation 10)

	Coef.	t-stat.	LR-coef.	Coef.	t-stat.	LR-coef.	Coef.	t-stat.	LR-coef.
$M_{ij,t-1}$	**0.830**	**20.944**		**0.839**	**21.459**		**0.834**	**20.976**	
MP_{ijt}/PP_{it}	**-0.156**	**-2.058**	**-0.919**	**-0.198**	**-2.552**	**-1.232**	**-0.174**	**-2.325**	**-1.049**
TFE_{it}	**0.426**	**3.189**	**2.506**	**0.455**	**3.408**	**2.837**	**0.455**	**3.430**	**2.736**
$BVMA_{ijt}$	**-1.713**	**-2.617**	**-10.073**	**-2.036**	**-3.033**	**-12.686**			
$EAMA_{ijt}$				**4.951**	**2.010**	**30.843**			
$RVMA_{ijt}$							**-1.697**	**-2.362**	**-10.219**
ARSQ	0.930			0.931			0.930		
LM(1)	1.614			1.145			1.549		
LM(4)	9.773			4.743			7.549		

Bold numbers represent significant at 95% significance level.

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[16] For example, import demand elasticities greater than two are reported in Anderton and Desai (1988), Anderton (1999a, b). However, other studies do manage to impose a parameter of unity for import demand terms (see Anderton *et al*, 1992).

[17] The "single pool" is based on a sample of 252 observations, ie, 42 (quarters)*6 (partner countries).

[18] In Table 3, we only report import prices relative to producer prices (RP1) as the other version of the relative price term (RP2) provides no additional information.

[19] Again, we choose the most appropriate moving average exchange rate volatility measure. For the "single-pool" estimates we use a three year moving average for the intra-euro area exchange rate volatility term, and a two year moving average for the extra-euro area exchange rate volatility term.

In order to evaluate whether our parameters for the exchange rate volatility terms are realistic and sensible, we also calculate the quantitative impact of volatility on extra-area imports implied by our parameter estimates. Given that our volatility terms are not expressed in logarithms, the parameters for the volatility terms are not elasticities, hence we calculate the impact by multiplying the coefficient of exchange rate volatility by the values of the volatility variable over the sample period.[20] This gives us the percentage of imports lost due to exchange rate volatility. Using an average of the above results, our calculations suggest that extra-euro area import demand may be reduced by about 10% (to a maximum of almost 14%) due to extra-area exchange rate volatility in the long-run.[21] These calculations also show that the corresponding substitution effect associated with changes in intra-area volatility is of the order of around 4% and, as expected, much smaller than the total effect of extra-area exchange rate volatility. The short run effect of extra-area volatility is again much smaller (around 1%) and is comparable to previous findings, as for example in De Grauwe and Skudelny (2000).

Concluding Remarks

The purpose of this study is to discover whether exchange rate volatility affects the demand for extra-euro area imports and whether substitution might take place between intra- and extra-area imports due to differences in extra- and intra-area exchange rate volatility. Therefore, we begin by deriving a theoretical model for an importing firm based in the euro area which has the choice of purchasing its inputs from three different suppliers; domestic (ie, home) suppliers, other euro area suppliers, or extra-euro area suppliers. Given the assumption that the importing firm is risk averse, the expected utility of this firm is negatively affected by exchange rate risk. Maximising the utility of this firm with respect to the purchases from the different suppliers yields a negative impact of extra-area exchange rate volatility vis-à-vis imports from extra-euro area trading partners, and a positive effect on imports from extra-euro area trading partners of an increase in intra-euro area exchange rate volatility. The magnitude of these impacts also depends on the share of trade invoiced in foreign currency (and not hedged) as well as the degree of substitutability between the imports of the different suppliers.

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[20] This is based on the assumption that there is no change in the invoicing behaviour; i.e. the shares γ_w and γ_{EA} of our theoretical model remain constant.

[21] Although one should be cautious in interpreting these results, it should be noted that our estimates are similar to other results concerning the *magnitude* of the impact of exchange rate volatility on trade flows (for example: Pugh *et al*, 1999; Dell'Ariccia, 1998; and Rose, 1999, 2000). Our quantitative results regarding the impact of exchange rate volatility are also consistent with Rose (1999, 2000) – who additionally estimates a large separate impact arising from the actual formation of a currency union – as our study basically covers the euro area when a currency union was <u>not</u> in place.

We then estimate euro area import demand functions for the period 1989Q1 to 1999Q2. We obtain panel estimates for euro area import demand functions by pooling the data across imports of the individual euro area countries from their individual main trading partners (US, Japan, Denmark, Sweden, the UK, and Switzerland). In our model, it is the perception of the importer of the likelihood of being negatively affected by exchange rate volatility that is important. Hence, we assume that the importer uses information from the past as well as the current period for assessing the relative risks associated with exchange rate volatility vis-à-vis different suppliers. Accordingly, we experiment with various moving-average measures of exchange rate volatility as such a variable not only captures current volatility, along with some 'history' of past volatility, but also eventually 'forgets' episodes of volatility when they become old enough to be irrelevant. We find a significant negative effect of extra-area bilateral exchange rate volatility on euro area imports when using a moving average for four to five years.

Our panel estimates suggest that extra-area exchange rate volatility may have decreased extra-euro area imports about 10% (up to a maximum of 14%) in the long run. There is also some limited evidence that differences in extra- and intra-area exchange rate volatility have resulted in substitution between extra- and intra-area imports.

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Appendix I: Data sources

Data for bilateral import values, volumes and unit value indices in ECU's/euros are from Eurostat and relate to trade in goods (source: COMEXT database). These trade data are the main reason for the fairly short sample period of the study as the imports data are only available from 1989Q1 onwards. Import prices are proxied by import unit value indices, while imports data for Belgium and Luxembourg are combined (as in the COMEXT database).

Producer price series are taken from various sources: International Monetary Fund (IMF) International Financial Statistics; Organisation for Economic Cooperation and Development (OECD), Main Economic Indicators; and Eurostat. The raw data in national currency are converted into ECU's/euros in order to be compatible with the trade data and calculated as an index, base year 1995.

Total final expenditure expressed in constant prices is from the OECD, Quarterly National Accounts.

All data are seasonally adjusted using the moving average method.[22]

The *weekly* exchange rate data used to compile the volatility term are taken from the Bank for International Settlements (BIS). The exchange rates vis-à-vis the USD are then converted into bilateral exchange rates between the trading partners.

[22] The series to be adjusted is X, which is indexed by t and is T observations in length. The ratio of the series to its moving average is formed in the following way:

$$MA_{t,q} = \frac{X_t}{\frac{1}{4}\left(\frac{X_{t-2}}{2} + X_{t-1} + X_t + X_{t+1} + \frac{X_{t+2}}{2}\right)}$$

The four adjustment factors are equal to the average of all moving averages for the corresponding quarter:

$$ADJFAC_q = \frac{1}{T-1}\sum_{t=1}^{T} MA_{t,q}$$

where q is the quarter for which the seasonal adjustment factor is calculated, and t are the observations, with T the number of total observations.
The seasonally adjusted series is computed by dividing the old series by the seasonal factors.

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